Political Cleavages and Changing Exposure to Global Warming[*]

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August 18, 2022

Abstract

Why do some countries, cities, firms, and individuals curtail emissions that cause climate change while others continue to pollute? Prevailing explanations focused on collective action and distributive politics assume all actors face costs from global warming; yet this is at odds with research that finds considerable heterogeneity in climate change's economic effects. We amend the standard distributive theory by integrating an information updating model of decision-making with a richer set of preferences derived from a spatial climate change assessment model. We provide evidence that as actors update their beliefs about how locations will be affected by climate change, countries and cities are more likely to enact mitigation policies if they face damages but not if they are uncertain or expect potential net gains. This suggests that rising understanding and salience of global warming's physical effects, not free riding nor incumbent interest groups, will increasingly dominate mitigation decisions.

Word Count: 13,500

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[*] The authors appreciate feedback from Chris Callahan, Jeffrey Frieden, Thomas Hale, Amanda Kennard, Robert Keohane, Devin Judge-Lord, Michael Oppenheimer, Leigh Raymond, Dani Reiter, Dustin Tingley, Erik Voeten, and Noah Zucker, along with audiences at the 2021 International Political Economy Society annual meeting, the 2021 Environmental Politics and Governance online seminar, the 2021 Climate Pipeline Project's Brown University Climate Solutions Lab Convening, and Emory University. The authors extend special thanks to José-Luis Cruz and Esteban Rossi-Hansberg for sharing their data and code.

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Why do some countries, cities, firms, and individuals act to reduce greenhouse gas (GHG) emissions, while others pollute unabated? All actors have a stake, either through the material impacts of climate change or the costs of adjusting to regulations. The physical effects of global warming will have profound redistributive consequences, changing where countries trade, firms invest, and people live. Yet, existing models of climate politics neglect the full range of global warming's distributive effects.

Instead, prominent theories of collective action (Barrett 2003; Keohane and Victor 2016; Nordhaus 2015; Ostrom 1990; Stavins 2011; Stern 2007; Victor 2011) and distributive politics (Aklin and Mildenberger 2020; Breetz, Mildenberger, and Stokes 2018; Colgan, Green, and Hale 2021; Mildenberger 2020) assume universal damages exist; that is, all are hurt by global warming, although some more than others (Gaikwad, Genovese, and Tingley 2022). For collective action, this permits the characterization of carbon abatement as a global public good, since all actors value its provision. For distributive politics, the assumption is necessary to make sense of why actors not invested in fossil fuels or green energy support climate policy due to their vulnerability.

However, this premise is at odds with existing economic models that find considerable variation in global warming's effects. There is a profound geographic inequality: those in the Global North are less exposed, may benefit in the long run from reallocated economic activity, and have preexisting wealth to afford adaptation, whereas those in the Global South are more vulnerable, face economic outflows, and lack the same capacity for adaptation (Cruz and Rossi-Hansberg 2021; Burke, Hsiang, and Miguel 2015b; Diffenbaugh and Burke 2019; Kotz et al. 2021). While the worldwide aggregate losses are negative and warrant a strong governmental response, theory must be guided by the incentives that actors confront.

We hypothesize that this informational dynamic is activating a new political cleavage between the Global North and South. Departing from convention, we define the "Global North" as actors in the northern hemisphere facing potential benefits from higher temperatures or resting on the borderline of gains and losses, while the "Global South" consists of actors in the southern hemisphere confronting certain damages.[1]

We amend the standard distributive politics theory by integrating an information updating model of decision-making with preferences derived from an explicit model of global warming's economic effects. The Cruz and Rossi-Hansberg (2021) spatial integrated climate assessment model, henceforth CR, captures how global warming affects the economy through higher temperatures and changing trade, migration, and innovation as endogenous forms of adaptation. We focus on *location*, rather than *assets* (e.g., Colgan, Green, and Hale 2021), since the preferences of asset owners vary across space and according to mobility.

The CR model suggests what the preferences of political actors would be if they were fully-informed. However, since all projections of climate change's economic effects entail uncertainty, our theory explicitly incorporates how actors process uncertain information. We theorize that climate-related events, like disasters, serve as information shocks that lead actors to update their beliefs about the distribution and immediacy of global warming's effects. In places that experience more frequent and intense climate disturbances political actors should realize they face serious damages. These information shocks induce people and firms facing such losses from the physical effects of climate change to support emissions reductions by altering their cost-benefit calculations, increasingly aligning their preferences with what the CR model implies.

After describing the climate model and our theory, this paper proceeds empirically in two steps. First, we evaluate the extent to which political cleavages over climate policy have formed by examining the actions countries have taken to curtail emissions. We leverage the exogenous variation in climatological disasters to identify the causal effect of information shocks. The results show that as countries experience more disasters – i.e., as understanding and salience of climate change's effects grow – actors facing damages are more likely to respond with mitigation. We account for standard distributive politics explanations by controlling for the strength of polluting interests and carbon footprint of the average citizen.

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[1] Australia and parts of Southern Europe are members of the South. China is in the North.

While fossil fuel endowments have mixed predictive value, countries consistently respond to information shocks. This suggests that global warming's physical impacts increasingly constrain the influence of polluting industries in locations expecting damages. Contrary to expectations that low-income countries are unlikely to reduce emissions due to their desire to prioritize development (e.g., Victor 2011), nations facing damages in the Global South are the most likely to mitigate.

Second, we explore our main argument at the level of cities, which contribute a majority of global emissions (IPCC 2022). Cities provide a useful unit for analyzing the aggregation of preferences, given their control over local policies and homogeneity in climate impacts, whereas countries vary in their political organization of geographic units and may face subnational heterogeneity in damages. Our highly disaggregated data show how the climate cleavages arise and shape political outcomes. Using hierarchical models that nest cities within countries, we find that after cities endure more extreme temperature variation – i.e., information shocks – those facing damages are more likely to react by reporting mitigation activities. In contrast, standard distributive politics explanations, proxied by city-level data on emissions, yield inconclusive results. Inconsistent with collective action, cities that are individually inconsequential to global emissions are willing to bear mitigation costs if they anticipate damages.

We take several steps to assess the validity of the CR climate model and probe the robustness of our results. Benchmarking exercises demonstrate the CR model generates comparable estimates to other economic assessment models. To account for modeling uncertainty, we devise our main measure to focus on the distribution of climate change's physical effects rather than point estimates which would be less precise. We also assess results using different time horizons, since forecasting error grows with time. Further, we conduct robustness exercises that perturb the threshold used to categorize countries as facing potential damages or benefits to show that our findings are not sensitive to changes in the magnitude of CR's estimates. Our results also hold when using alternative model specifications, measures of fossil fuel interests, and a spatial model designed to capture collective action dynamics.

The contributions of this paper are fourfold. First, our theory and empirical approach integrate previously siloed research in climate econometrics and political science to produce a workhorse model of climate preferences that scale across levels of analysis. Second, our decision-making model provides a tractable way to capture how actors update their preferences in response to new information, which advances approaches in political economy that often take preferences as exogenous (e.g., Lake 2009). Third, while work on climate politics has pitted domestic distributive politics and collective action as theoretical alternatives (e.g., Aklin and Mildenberger 2020), we show how within a collective action problem actors may nonetheless contribute to the public good as their cost-benefit calculus shifts in response to information shocks. Lastly, this paper is the first to connect micro-level findings about the effects of climatic changes on public opinion (e.g., Egan and Mullin 2017; Howe et al. 2019) and behavior (e.g., Burke, Hsiang, and Miguel 2015a; Koubi 2019; Hoffmann et al. 2022) with the macro-level policy outputs of nations and cities.

What Explains Climate Mitigation?

Existing explanations for climate mitigation fall into two camps: collective action and distributive politics. Though often framed as competing theories, they are not mutually exclusive. At issue here is their reliance on the assumption that all actors incur damage from the physical effects of climate change. This premise runs counter to research that finds substantial heterogeneity within and across countries in global warming's consequences for various economic outcomes: amenities and productivities (Cruz and Rossi-Hansberg 2021), gross domestic product (Burke, Hsiang, and Miguel 2015b; Burke, Davis, and Diffenbaugh 2018; Callahan and Mankin 2021; Desmet et al. 2021; Kotz et al. 2021; Nordhaus 2006), total factor productivity growth and capital depreciation (Moore and Diaz 2015), agriculture (Conte et al. 2021), manufacturing (Desmet and Rossi-Hansberg 2015), energy consumption

(Rode et al. 2021), crime, coastal storms, labor (Hsiang et al. 2017), and human mortality (Carleton et al. 2022). The remainder of this section explicates how prevailing theories rely on the assumption of damage from climate change's physical effects for all actors and its analytical consequences.

First, collective action theory views carbon mitigation as a global public good and incentives to free ride as the defining strategic problem (Barrett 2003; Keohane and Victor 2016, 2011; Nordhaus 2015; Ostrom 1990; Stavins 2011; Sandler 2004; Stern 2007; Victor 2011). Reducing emissions requires costly actions from all polluters, while the benefits from this are captured by everyone regardless of whether they helped. Since the cost-benefit calculations of national policymakers, firms, and individuals fail to completely capture the beneficial effects of their actions on global welfare, the aggregation of individual actions to mitigate climate change will be less than the ideal from a global viewpoint.

Although there is a debate over what collective action implies and whether it has an empirical foundation (e.g., Aklin and Mildenberger 2020; Kennard and Schnakenberg 2022), our paper takes issue with the theory's implicit assumption about the distribution of climate damages. Crucial to interpreting pollution as free riding is the assumption that all benefit from the public good's provision. The standard assumption is that the individual costs of action are too high compared to the benefits. If, however, some actors face potential benefits or are uncertain of damages, they may continue to pollute or refuse to implement institutional solutions because the benefits of action are too low or are possibly even detrimental.

An alternative to collective action is distributive politics, which views climate politics as a conflict between politicians, voters, and interest groups (Aklin and Mildenberger 2020). Reducing emissions creates winners and losers, and their relative power determines outcomes (Colgan, Green, and Hale 2021; Mildenberger 2020). While distributive politics has a clear explanation for why actors oppose climate policy – concentrated costs to polluters and energy consumers (Aklin and Urpelainen 2018; Bechtel, Genovese, and Scheve 2019; Breetz, Mildenberger, and Stokes 2018; Genovese 2019), or costs relative to competitors (Kennard

2020) – it lacks a cohesive model of why actors support carbon abatement. There are two potential explanations: co-benefits and vulnerability.

First, policies to reduce emissions generate co-benefits such as reduced air pollution and new green jobs (Hale 2020; Kennard and Schnakenberg 2022), which could lead renewable groups and some investors to lobby for mitigation (Aklin and Urpelainen 2013; Hughes and Meckling 2018; Meckling et al. 2015; Stokes 2020). Some go so far as to claim that fossil fuel importers may enjoy economic gains from decarbonizing (Mercure et al. 2021), which would make it especially puzzling as to why greater mitigation is not observed.

However, co-benefits are not a theoretically powerful explanandum. Co-benefits tend to be temporally invariant, such as deaths avoided from air pollution, which makes it difficult to explain change in mitigation policy. Exogenous energy shocks (Aklin and Urpelainen 2018) may help explain instances of climate policy, but do not amount to a general theory. This renders co-benefits, absent further specification, an unstable basis for deriving preferences.

Second, actors might support mitigation if they are ecologically vulnerable (Gaikwad, Genovese, and Tingley 2022; Sprinz and Vaahtoranta 1994). The closest to a unifying model is Colgan, Green, and Hale's (2021) asset revaluation theory, which conceptualizes actors' preferences as a function of their ratio of climate-vulnerable to climate-forcing assets, and the ease with which they can transform their holdings. While this theory is powerful in its parsimony, it does not generate predictions as to which assets and locations are more vulnerable, a necessary step for empirical validation. Though certain answers are intuitive, without a climate model, these assumptions are not definitive enough for testing. For example, Colgan, Green, and Hale (2021) identify "coastal property" as an ideal type vulnerable asset, but sea levels will increase unevenly, and are even forecast to *retreat* in places, such as Juneau, Alaska (Desmet et al. 2021).

Further, like collective action, distributive politics only considers climate damages. The magnitude of harm implied makes it puzzling why governments, even myopic ones captured by fossil fuel interests, have not constrained emissions. However, inaction becomes more understandable if actors face differential damages, including potential benefits.

The other necessary component of a theory of climate politics is a model of decision-making. Collective action and distributive politics often leave this component implicit, either assuming that actors perfectly understand costs and benefits, or that they face uncertainty. Although, Colgan, Green, and Hale (2021) theorize a dynamic process where climate change alters the *value* of assets, which changes the preferences, resources, and power of actors in subsequent periods, this material mechanism leaves under-theorized the *behavioral process* by which actors update their preferences. This microfoundation is necessary to understand why some actors but not others respond to climate disturbances by mitigating emissions.

Modeling Climate Change's Distributive Effects

This section reports the results from CR's spatial integrated assessment model, which contradict the assumption of net damages for all and provides the foundation for deriving actors' preferences. The point of the model is to quantify the economic effects of climate change as a *physical phenomenon*. In our empirical models we employ other measures for the economic effects of climate *policy*, which is the standard focus in distributive politics theories.

CR build upon the established spatial growth framework in Desmet, Nagy, and Rossi-Hansberg (2018). This underlying model of the evolution of the global economy has been validated with backcasting exercises that demonstrate predictive validity for the past 130 years with respect to country population levels and growth rates (Desmet, Nagy, and Rossi-Hansberg 2018). The modeling framework has also been successfully applied to evaluate sectoral responses to global warming (Conte et al. 2021) and the effects of coastal flooding (Desmet et al. 2021).

Here, CR extend this accepted and validated modeling approach by incorporating clean and carbon-based energy as production inputs, a carbon cycle that determines global temperature, and damage functions that define the impact of local temperature changes on fundamental productivities and amenities. Amenities refer to utility an individual receives from the place she lives and productivity is the effectiveness of economic activity.

The model corrects for two limitations that hindered economic assessments of global warming. First, most assessment models employ aggregate loss functions that ignore adaptive responses and differential effects of temperature across locations. Instead, CR endogenize adaptation into the damage functions and quantify the economy at a fine level of geographic resolution.

Second, assessment models often capture interdependence implicitly, if at all, which is relevant in a globalized world where actors may care about damages that affect trading partners. Instead, CR explicitly model interdependence through trade and migration.

CR quantify the model using bidecadal data from 1990 to 2005 on wages, population, land, and energy prices at the $1^\circ \times 1^\circ$ spatial resolution. The procedure captures the direct and indirect effects of long run temperature changes. Temperature is a substantial means by which global warming will impact economic growth through heat's effects on mortality, human physiology, violence, productivity, crop yields, energy demand, and population movements (Carleton and Hsiang 2016). The model captures damages from droughts and wildfires to the extent that these hazards become more frequent due to higher temperatures.

Quantified model in hand, CR simulate the economy from 2001 through 2400. The simulation compares a world where temperature does not affect economic fundamentals to a baseline scenario where temperature influences amenities, productivities, and natality rates. From these fundamentals along with the model's dynamics, CR estimate local GDP for each period in terms of real income. The counterfactual avoids understating costs by assuming a worst-case "business as usual" scenario with no binding global climate policy. To avoid making assumptions about the social discount rate, our analysis uses the *ratio* of local GDP in a world with global warming damages to the counterfactual GDP where temperature has no effect.

Our analyses will also employ economic estimates from the years 2025, 2050, and 2100, to assess how uncertainty may increase farther into the future. Our theory below also acknowledges the uncertainty inherent in these forecasts by explicitly incorporating a model of how political actors process information.

The exercise reveals that geographic features that shape baseline temperatures – latitude, elevation, and coastline – influence whether a location experiences potential damages or benefits. Unlike the implicit climate model underlying collective action and distributive politics, CR show the potential for gains, in addition to greater spatial heterogeneity in damages. Figure 1 illustrates how global warming's economic effects split horizontally across the Earth. Much of the Global North, in latitudinal terms, experiences GDP gains compared to a world without warming. A wide southern band including South America, Africa, South Asia, and Oceania suffers severe damages.

Nations either experience potential net damages, net benefits, or are on the borderline (figure B1). A non-exhaustive collection of countries facing damages includes Brazil, Nigeria, India, and Spain. In contrast, Canada, Russia, Mongolia, and Norway may experience potential net gains, while the United States and China are on the borderline between damages and benefits. These borderline cases confront considerable subnational heterogeneity in damages and benefits.

There are two main causal mechanisms behind potential benefits. First, higher temperatures in places that are presently cool may enhance productivity up to a limit (Burke, Hsiang, and Miguel 2015b; Conte et al. 2021), decrease mortality (Carleton et al. 2022; Hsiang et al. 2017), and ease energy consumption (Rode et al. 2021; Hsiang et al. 2017), whereas higher temperatures in areas currently warm degrade productivity, increase mortality, and heighten energy consumption.

Second, temperature changes lead actors to adapt by trading with new partners, migrating to safer locations, and investing in local technology. These changes will redistribute economic activity from the Global South to the North, generating potential benefits through agglomeration economies but deepening global inequality. The model assumes this adapta-

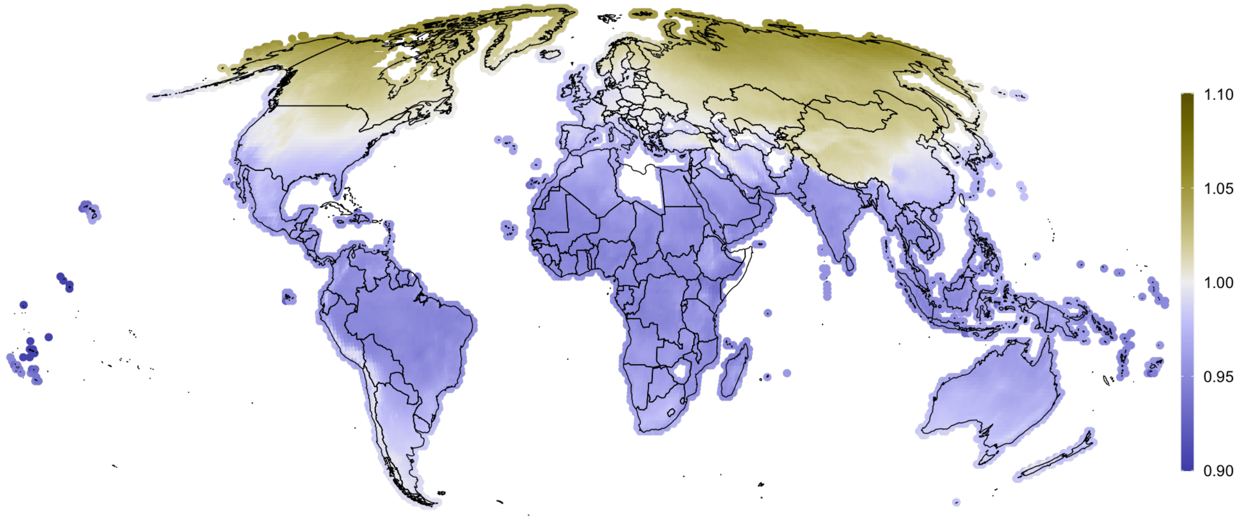

Figure 1: Effects of global warming on GDP in 2100 across the Global North and South. Map depicts the ratio of 2100 GDP in a world of global warming damages to a counterfactual in which temperature has no effect. Values less than 1 denote losses. GDP refers to a location's real income, quantified using Cruz and Rossi-Hansberg's (2021) model.

tion is costly, using actual trade and migration flows to account for the political and physical barriers actors face.

The idea that some regions gain from climate change is not unusual in the context of existing literature. We discuss two prominent studies in *Science* and *Nature* as illustrations. First, Hsiang et al. (2017) estimate the economic damage from climate change in the United States across six sectors – agriculture, crime, coastal storms, energy, human mortality, and labor. They calculate a dose-response function of the effect of temperature, rainfall, and CO_2 on each sector, using Bayesian meta-analysis of appropriate empirical studies. Like CR, Hsiang et al. (2017) find the United States loses in the aggregate, but faces substantial sub-national heterogeneity, which places the country in the borderline classification. There are total direct benefits in the North, but large damages in the South and parts of the West.

Second, Burke, Hsiang, and Miguel (2015b) estimate the effect of global temperature on economic productivity. Like CR, they find that cooler countries in the North experience productivity increases until reaching an optimum temperature, while hotter nations in the South suffer large damages. They conclude that climate change will make two-thirds of countries poorer in 2100. We benchmark CR's results against Burke, Hsiang, and Miguel (2015b) in online appendix A.

Nevertheless, there are limitations. First, while the omission of adaptation may bias previous models in favor of higher damage estimates, CR's focus on temperature may introduce countervailing bias due to other climate hazards such as sea level rise (SLR) and tropical cyclones. There is no study that evaluates all climate hazards on a global scale, so it would be speculative to conclude whether the sources of bias cancel out. However, non-temperature hazards may also have heterogeneous consequences. Desmet et al. (2021) find that SLR creates winners and losers as economic activity redistributes inland. Subsequent empirical tests account for damage from SLR (online appendix B.12).

Second, there are non-economic outcomes from climate change that actors seek to avoid. Some countries may have national security concerns (e.g., Busby 2022). Indigenous groups may face destruction to their way of life. While meaningful, these types of damages do not lend themselves well to economic assessment. Future theorizing should layer these dimensions onto our framework.

Third, any estimate of climate change's effects entails uncertainty given the forecast's horizon. In the best-scenario, CR estimate that 50.51% of the population undergoes welfare losses. In the worst-scenario, only 0.003% of the globe experiences welfare gains. However, while uncertainty exists about the magnitude of damages and benefits, CR's model yields precise predictions about the *spatial distribution* of global warming's effects. This allows us to derive stable preferences.

Theory of Climate Cleavages

In our model of politics, countries and subnational actors respond to the preferences of societal groups, such as individuals and firms, which make their voices heard by voting and lobbying. Politicians have a myopic focus on survival, which means re-election in democracies and control in autocracies. To make matters tractable, we flatten the institutional landscape and treat politics as a numbers game – i.e., the preferences of the majority exert the greatest influence on policy outcomes. While domestic and international institutions play a meaningful role in aggregating preferences, we bracket them for parsimony. Our theory is a first-order concern since institutional approaches lack strong explanatory power without microfoundations.

Actors' preferences over emissions reduction are a cost-benefit calculation of the individualized benefits of mitigation versus the costs. One of the primary benefits of mitigation is the avoided damage from future climate change, which is a function of the global collective effort to reduce emissions and a location's exposure to global warming. Provided complete information, places facing potential damages should care most about slowing temperature increases, whereas areas expecting potential benefits should care less about avoiding higher temperatures and may even support such a trajectory in the extreme.

As in the standard distributive politics account, the costs of mitigation include higher energy prices for consumers and firms, as well as the threat of elimination for fossil fuel-producing industries. These costs tend to be visible and immediate, which elevates their salience. Reductions in the costs of emissions abatement, such as declining photovoltaic prices, may make mitigation more feasible. However, changing technological costs are not a sufficient theoretical foundation because they are globally constant, so they cannot explain variation between nations.

Since politicians, firms, and individuals discount future damages and benefits, changes in behavior can only emerge if actors update their beliefs about the timing and magnitude of global warming's effects. We theorize that belief updating occurs in response to climate information shocks which hold the potential to alter how an actor evaluates the state of the world. Lacking personal experience with global warming, people begin with a view of climate change as an uncertain and distant threat (Weber 2006). As actors experience climate disturbances, such as tropical cyclones, flash floods, or temperature anomalies, these events provide information about how likely a location is to be impacted by global warming.

We conceptualize two types of information shocks: positive and negative. A positive information shock reveals potential benefits from higher temperatures, such as greater crop yields or new Arctic shipping routes. A negative information shock reveals potential damages from global warming, such as a drought causing regional water scarcity. We focus on negative information shocks in this paper since actors should be better equipped to attribute global warming as the cause.

Our argument is that information shocks lead the preferences of actors to increasingly align with what the CR's climate model indicates their self-interested preferences should be if they were fully-informed. Information shocks have two effects that lead to this preference updating. First, experiencing climatic events helps people better understand the range of outcomes from climate change and their associated probabilities. An enhanced understanding of the distribution of outcomes emerges from learning and information processing. Experience provides people with new data points from which they *learn* the true state of the world. While people may have access to analytical information now, psychological research indicates that this statistical evidence is best *processed* when decision-makers can re-categorize the analytic results using concrete images, emotions, and stories, all of which personal experience provides (Marx et al. 2007).

Second, information shocks heighten the urgency of climate change, which eases the constraints of hyperbolic discounting – the preference for short-term consumption over long-term gains. Thus, even if an individual's discount rate remains the same, she may increase the weight placed on climate damages if they are now thought to occur sooner rather than later. These mechanisms – understanding and immediacy – lead people to update their preferences over mitigation in response to information shocks.

Evidence supporting this process comes from multiple disciplines. Although most studies here are observational, since survey experiments are inadequate to capture the lived experience of a disaster, the research designs often draw causal inferences by leveraging the plausible exogeneity of weather. Howe et al. (2019) review 73 studies and find that 81 percent measure a direct effect of personal experience on climate opinions, such as belief on global warming and support for mitigation, although the magnitude varies.[2] Egan and Mullin (2017, 216) review climate opinion studies of the United States and conclude that "results consistently show a positive relationship between exposure to warmer temperatures and higher levels of global warming belief." This effect is substantively large, although short in duration. However, Egan and Mullin (2017, 216) hypothesize that "lasting changes in attitudes" may be produced by "exposure to extreme, memorable events such as floods, drought, and severe storms." These attitudinal changes matter for behavioral outcomes like searching for climate information (Kennard 2021), voting for green parties (Baccini and Leemann 2021; Hoffmann et al. 2022) and reducing energy consumption (Spence et al. 2011). Elites also update their preferences after experiencing information shocks (Clark and Zucker 2021).

The CR model implies that actors in the Global South should face more extreme and frequent damages, which should make them more likely to become concerned about climate change in response to negative information shocks. In contrast, actors in the North should face fewer and less damaging climate disturbances, which should reduce the likelihood they become concerned about climate change, all else equal. We validate these claims using data on disaster frequency in online appendix B.11.

Public opinion research using surveys suggests that the extent of damage matters for whether people update their beliefs. Brody et al. (2008) find that natural hazard events do not increase climate concern unless there is a high level of human fatalities. Albright and Crow (2019) interview flooded communities and conclude that the extent of damages influences risk perceptions and expectations of greater future damage. Corroborating this theorized difference between the North and South, cross-national surveys find that people in developing countries are more concerned about climate change, willing to pay for mitigation, and eager to cooperate international (Kim and Wolinsky-Nahmias 2014).

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[2] Mixed results stem from heterogeneity in measurement and geographic coverage across studies.

Of course, there are barriers that impede efficient information updating. Political polarization could lead people with strong prior beliefs to engage in motivated reasoning (Hazlett and Mildenberger 2020; Howe et al. 2013). We have three responses. First, many of these studies focus on the United States, which do not generalize to the Global South where climate beliefs do not map neatly onto political divides. Second, most people are not strong partisans. Myers et al. (2013) find that while some engage in motivated reasoning, about three-quarters have low levels of engagement, which renders them amenable to information updating. Third, the long-term physical reality of climate change should constrain beliefs. Just as economic incentives can counterbalance motivated reasoning (Prior, Sood, and Khanna 2015), as people pay higher insurance premia for living in vulnerable locations and experience tropical cyclones or wildfires, the incurred costs should become difficult to deny.

An additional barrier to preference updating is that access to quality information may vary across countries. Greater awareness and education in the Global North might make it easier for citizens there to attribute natural disasters. Although education is one of the strongest predictors of climate change awareness worldwide, schooling's effect on risk perception is not uniform across space; in African and Asian nations, perceptions of local temperature change better predict climate concern, which shows the potential for experience to partially compensate for the lack of a formal education (Lee et al. 2015).

Incorporating the CR model with our theory of politics and preference updating leads to the following empirical expectations for individuals, firms, cities, and countries. For individuals, negative climate information shocks should make people in places facing potential damages more concerned about climate change. Greater climate concern should translate into support for pro-emission reduction politicians. Information shocks in places expecting potential benefits should either have no effect on people's climate risk perceptions or make people more supportive of higher temperatures. Both outcomes would imply endorsement of anti-emissions reduction politicians. Leaders may also grow concerned about the *latent* *opinion* of the public which could emerge in the future in response to decision-makers' failure to act on climate change and thus result in political damage (Key 1961).

For firms, negative climate information shocks should make firms located in places incurring damages more concerned about future global warming. This should lead firms to lobby for mitigation. In contrast, firms in locations facing potential benefits should be less concerned about damages; in the extreme, firms might become aware of benefits. Although, we do not expect firms or policymakers to be especially vocal about benefits since this is an ineffective communication strategy. Instead, we expect them to emphasize the costs of mitigation, which achieves the same result. Industries like shipping and agriculture in Northern latitudes may increasingly organize to obstruct climate policy. Russian shipping firms, for instance, may gain from new trade routes. Canadian agricultural producers may enjoy higher crop yields. Real estate owners and investors in areas that experience population influxes may benefit as property prices rise. Even if firms do not engage in active lobbying to increase emissions, inactivity could dampen political momentum necessary for emissions restrictions. These are not purely theoretical claims. Russian port towns are undergoing economic revivals as new Arctic shipping routes open (Kramer 2021). This example suggests the possibility that actors in the North might come to foresee benefits.

However, the very same industries, such as agriculture, may be hurt by global warming in the South, leading to the opposite patterns of behavior there. This demonstrates how *assets* by themselves offer little explanatory power (e.g., Colgan, Green, and Hale 2021) without first attending to *location*, which determines how the same asset class might generate different preferences. Further, incorporating potential benefits generates new distributive politics predictions. For example, low-carbon workers in regions expecting benefits might oppose climate policy, a novel dimension to Mildenberger (2020).

Lastly, national and subnational actors have two classes of actions they can take to affect the global temperature: add or reduce emissions. Whether these representative institutions mitigate emissions depends on the preferences of societal actors and the aggregation technology. On average, we predict that countries and cities experiencing negative information shocks should be more likely to respond by reducing emissions if they face net damages. In contrast, actors facing potential benefits should not curtail pollution and, in the extreme, may increase emissions.

Countries on the borderline with subnational heterogeneity in damages or benefits raise two new theoretical considerations: preference intensity and exit. First, actors that face the worst damage or greatest benefits should have the most intense preferences and thus more motivated to politically mobilize. However, locations facing losses will also experience a decrease in resources with which to engage in political action, creating a relative advantage for actors in areas anticipating potential benefits (e.g., Becker 1983; Colgan, Green, and Hale 2021).

The second complication for borderline cases is the possibility of exit. When subnational heterogeneity exists, voters and capital can relocate from places facing damages to less affected locations. Relocation is easier within country due to fewer restrictions on movement. When there is the possibility of exit, people currently in places facing losses should be less likely to use their voice to advocate for mitigation (Hirschman 1970).

Mobility complicates Colgan, Green, and Hale's (2021) theory, which defines assets broadly to include both labor and capital, yet these asset-owners can often pay a cost and move to a new place. Relocation alters the preferences of asset-owners without changing their asset class, circumventing revaluation. However, asset revaluation remains important for immobile actors in places facing damages, such as a firm with a factory; these actors should be more likely to exercise voice due to the infeasibility of exit.

Our analysis indicates that actors in the North and South will have conflicting preferences over emissions reduction, all else equal. Northern actors face potential net gains, and should be more likely to pollute unabated, whereas Southern actors suffer intense net damages, and should be more likely to curtail emissions. Since the emissions by the North harm the South, a new political cleavage may be forming. Just as divisions between urban and rural or capitalists and workers are thought to structure other dimensions of politics (e.g., Lipset 1959), whether an actor faces potential damages or benefits may act as a new axis of political conflict.

A stipulation is that the theory rests on its model of climate change, which involves uncertainties. Unknown tipping points could be reached, resulting in a civilization-ending event. If true, then cleavages may not form, as all actors are bargaining under the shadow of existential catastrophe, especially given the possibility of tipping points. However, even the worst-case forecasts by the IPCC do not portend the collapse of civilization, although there is likely to be immense human suffering. The lethargic carbon abatement of governments also suggests that this tail-end risk is not guiding decision-making.

Emerging National Climate Cleavages

We test whether climate cleavages are forming between countries by exploring the actions nations have taken to mitigate emissions. This section proceeds by describing data and measurement, introducing the causal identification strategy, and finishing with the results.

Data and Measurement

Climate Law Stock Outcome

The outcome is whether nations adopt mitigation policies, defined as laws or regulations that regulate pollutants using caps or taxes, provide incentives for efficiency and clean energy, or manage carbon-negative natural resources. Data come from the Climate Change Laws of the World (Nachmany et al. 2017), a widely used source in the climate politics literature (e.g., Eskander and Fankhauser 2020; Eskander, Fankhauser, and Setzer 2021; Townshend et al. 2013). The database covers 196 countries. Inclusion requires a law or policy to be demonstrably motivated by climate change concerns, with the document having full legal force. There is a dedicated team of coders at the Grantham Research Institute on Climate

Change and the Environment that keeps the database up to date, collecting information from government websites, parliamentary websites and the news. The aim is for the data to be comprehensive, although a potential sources of measurement error include language limitations and lack of media coverage.

We follow the literature by operationalizing the measure by taking the count of national climate laws and regulations for a country-year (Eskander and Fankhauser 2020; Eskander, Fankhauser, and Setzer 2021; Townshend et al. 2013). The stock of policies captures the aggregate effort of countries since policies can be additive and synergistic, which flows would miss. The analysis includes the post-1990 period when countries began pursuing mitigation (Eskander, Fankhauser, and Setzer 2021). Policies, rather than emissions, are the focus because external factors like population, economic activity, and innovation influence pollution (Harrison and Sundstrom 2010). The measure uses *national* climate policies, as they are a direct reflection of country preferences. Online Appendix B.12.4 addresses action by the European Union. Since the quality of policy may differ across nations, our empirical strategy estimates *within*-unit changes in the law change.

We evaluate the quality of the data by investigating whether these laws have a substantive effect on emissions. Existing studies find that each new law reduces annual carbon emissions intensity by 0.78 percent in the short-term and 1.79 percent in the long run – a savings of one year of global CO_2 output (Eskander and Fankhauser 2020). We perform an equivalent test and find a similar pattern (online appendix B.1). However, the relationship between climate policymaking and emission outcomes is complex and requires detailed case studies to ascertain the precise causal mechanism, so these regressions should be treated as suggestive. A robustness exercise subsets laws to the most stringent ones applying across the entire economy (online appendix B.12).

Potential Damages Moderator

An indicator for if a country faces net GDP losses from global warming measures the moderating effect of potential damages and benefits. We aggregate CR's results to the country-level, adjusting each grid by its population, which represents the average residents' preferences. We construct an indicator using global warming's potential damages in 2050. Since actors may have different discount rates, we explore results with damages in the short-term (2025) and long-term (2100), and there is no difference in results due to the stable spatial distribution of damages (figure B11).

The moderator is dichotomous because estimates of global warming's effects contain considerable uncertainty, which decreases the substantive meaning of damage point estimates. Rather than create the false impression of certainty, a binary measure is realistic by recording whether a country is on the damages or benefits side of the distribution. In subsequent tests, we perturb this threshold to assess the behavior of borderline cases.

Information Updating Explanatory Variable

Counts of climate disasters capture information shocks that should lead actors to update their preferences. These disasters may have been made more likely by climate change, but what matters is that the public could interpret a disaster as the consequence global warming. The high visibility of disasters increases the likelihood that citizens observe the event or learn of it through the media. Data come from the Centre for Research on the Epidemiology of Disasters' Emergency Events Database (EM-DAT). The measure includes all disasters categorized as "climatological" or "meteorological." To ensure the events pertain to climate change, we exclude disasters lacking sub-type documentation to classify them as relevant.

For robustness we employ two alternative measures from EM-DAT: the count of tropical storms and the count of flash floods. Online appendix B.10 defines these hazards. We lag the disaster counts by one year to ensure proper causal sequencing.

The theory claims that climate disasters are more frequent and worse in the South than the North, all else equal. We test this and find support (online appendix B.11). These results also alleviate possible concerns that reports of disasters are biased against the South.

Distributive Politics

We adopt several measurement and statistical strategies to account for distributive politics explanations. We begin by using data on oil and gas production from the BP Statistical Review of World Energy to measure the strength of the fossil fuel industry. BP collects these statistics from national statistical agencies, international organizations, and other proprietary sources. For oil, this includes crude oil, shale oil, oil sands, condensates, and natural gas liquids. For coal, the measure includes production of bituminous, anthracite, lignite, and brown coal ranks. Figures B3 and B4 plot the spatial distribution of oil and gas production. The United States, Russia, Canada, and Middle East are top oil producers, while the United States, Russia, China, India, South Africa, Australia, and Indonesia are top coal producers. The units of measurement are standardized to million tonnes produced. Since the data are comprehensive, we code countries not included as producing no fossil fuels.[3] The distribution is right-skewed, so we take the natural logarithm of the amount produced plus one. The intuition of this variable is that countries that produce more fossil fuels will have greater incentives to oppose emissions reductions.

We focus on the location of production since for these countries it is difficult to exit fossil fuel asset holdings, which could create incentives to oppose emissions reductions (Hirschman 1970; Colgan, Green, and Hale 2021). Although financial institutions may have stakes in fossil fuel production abroad, these actors have greater ability to exit their holdings. Likewise, while at first glance it might also be appealing to account for the size of other carbon-consuming industries like automobiles, the presence of a strong automotive industry is not necessarily informative of climate policy; carmakers could pivot to produce electric vehicles, for instance.

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[3] We validate this coding decision by comparing the incidence of non-recorded fossil fuel production the BP data with the same countries and years in the World Bank fossil fuel rent data.

We also use different measures of oil and coal rents in robustness checks (online appendix B.12). Data come from the World Bank. Resource rents capture the total revenue from production minus the costs, then divided by the country's GDP for that year.

Consumers are also potential opponents to climate policy within the distributive politics framework, so we control for the carbon footprint of the average citizen. Specifically, we take the logarithm of CO_2 emissions per capita with data from the World Bank. Citizens with higher carbon footprints should face larger costs from emissions restrictions.

On the potential beneficiaries side of the distributive politics argument, the winners of the green economy include locations with rare earth minerals that will be demanded for batteries for power grids and electric vehicles. Our empirical specification described below will estimate the *within* unit change in climate policy, which by statistical design removes time-invariant features like a country's reserve of cobalt or lithium, minerals used in batteries.

Post-treatment bias is a concern because effective climate policy will curtail fossil fuel production and reduce emissions. As a solution, we fix the measures at their means prior to 1990. For nonexistent countries prior to 1990, we use the first available observation. The results are robust to using time-varying measures of both fossil fuel production and rents (online appendix B.12).

Standard distributive theories would predict that the coefficients for these variables are all negative. This is consistent with our theory, where mitigation costs are an initial barrier to action. However, under our theory it would be possible to observe positive or null coefficients as understanding and salience of climate damages evolves.

Controls

The polyarchy index from V-Dem captures institutionalist theories (Coppedge et al. 2019). The log of GDP per capita, measured by the World Bank, proxies for state capacity that may be necessary to implement climate regulations.

Research Design

For causal identification, we leverage the exogeneity of the moderator and explanatory variable to the climate policy stock. Whether a country faces damages or benefits depends on apolitical and fixed geographic factors such as latitude and coastline. Likewise, disasters are the consequence of climatological changes outside the control of nations, and we control for economic factors that might make nations more exposed or vulnerable. We estimate the following empirical model using ordinary least squares regression:

$$y_{it} = \alpha + \delta(D_{it-1} \times X_i) + D_{it-1} + X_i + \mathbf{W}_{it}^{\intercal}\theta + \eta_t + \lambda_i + \epsilon_{it}. \tag{1}$$

Y_{it} is a nation's annual climate law stock. δ is the coefficient for the multiplicative interaction of the climate disaster treatment, D_{it-1}, and the potential damages moderator, X_i. η_t is a year fixed effect to account for common contemporaneous shocks like technological innovation. λ_i is a country fixed effect to remedy potential confounding from constant differences between countries like culture. $\mathbf{W}_{it}$ is a matrix of pre-treatment covariates. Heteroskedastic-consistent standard errors clustered by country tend to serial dependence. Online appendix B.14 discusses special considerations for causal inference in two-way fixed effects setting and shows that our results also hold when using a heterogeneity-robust estimator (Liu, Wang, and Xu 2022).

The hypothesis is that as countries experience climate disasters, nations facing damages should be more likely to expand their stock of climate laws than countries expecting potential net benefits. We use the `interflex` package in `R` to estimate this interactive effect (Hainmueller, Mummolo, and Xu 2019). We test the linearity assumption by exploring the raw data conditional on the moderator value (figure B7). The assumption appears plausible, though to be conservative we only interpret the effect of a one unit change in disasters. By construction, our empirical specification maximizes the common support of the moderator by using an indicator variable that emulates the binning estimator recommended by

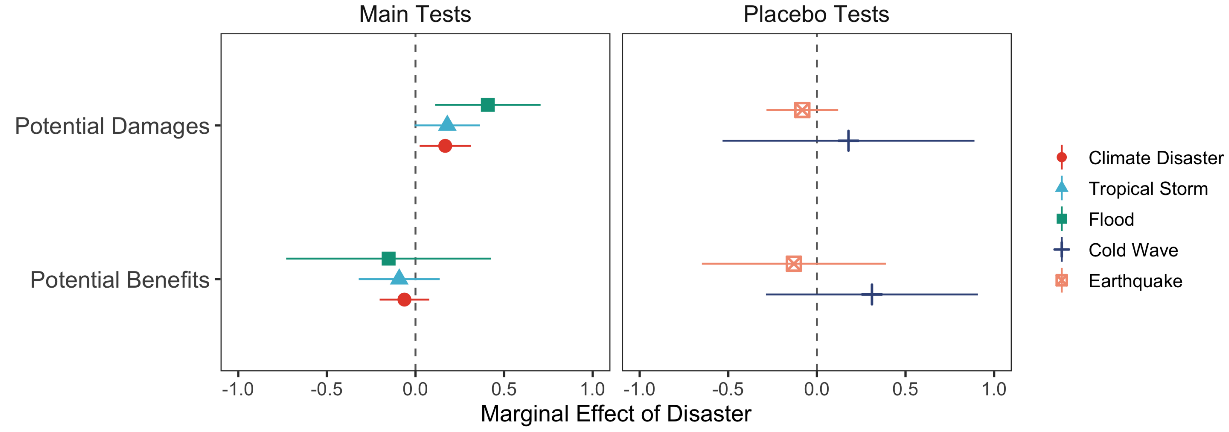
Hainmueller, Mummolo, and Xu (2019).

Results

The left panel of figure 2 reports the main results from estimating (1). As countries update their beliefs in response to disasters, nations facing climate damages are more likely to enact laws and regulations for mitigation compared to countries expecting gains. Countries establish 0.17 more climate policies on average after experiencing a disaster if they face damages, which is substantive since many nations have had no climate laws for much of their history and mitigation entails costs. The potential damages coefficient is positive, as expected, but noisily estimated. This emphasizes how the theorized relationship depends on the informational mechanism. Damage alone is insufficient to compel actors to mitigate emissions absent heightened understanding about how a location will be impacted. We evaluate the microfoundations of this mechanism using subnational opinion data in related research.

The results here further suggest that while it is often assumed that Northern countries like the Scandinavian nations are leaders in addressing climate change, when holding all else equal, actors in the Global South are more likely to curtail pollution. These findings both challenge and complement the literature on the environmental Kuznets curve, which claims that nations become more environmentally conscious as they become richer (e.g., Dinda 2004); the finding shows that richer nations in the Global North are not more likely to support emissions reductions, all else equal, because the marginal benefit of doing so is lower.

We interpret the null effect of a climate disaster on lawmaking in nations facing potential benefits as evidence consistent with a nation supporting higher temperatures. Not passing more climate laws means continuing along a business as usual path, which accelerates climate change. Also note that since the outcome measure has a lower bound at 0, it is unlikely that one would estimate a negative coefficient.



Notes: 95% confidence intervals

Figure 2: Left panel shows the marginal effect of climate disasters on the climate law stock. Right panel depicts the placebo test of non-climate disasters on the climate law stock. Table 1 contains the complete regression results.

Two placebo tests further investigate the information updating mechanism. These tests estimate the marginal effect of *non-climate* disasters, which should convey no information regarding an actor's future climate damages. The first measure counts the number of earthquakes in a country-year. The second measure records the number of cold waves, which the literature has found to be uncorrelated with climate belief updating (Hoffmann et al. 2022; Marlon et al. 2021). The right panel of figure 2 presents the results. The placebos have no effect on the climate law stock. This increases confidence in the mechanism that information shocks via climate disasters lead actors to update their preferences.

While the public opinion literature often finds effects that decay over time (Marlon et al. 2019), when we estimate the model specification using lagged disasters as the predictor, the positive marginal effect persists for countries facing damages (figure B8). The result is strongest when using measures specific disasters like tropical storms or floods, but only suggestive for the aggregate count of climate disasters. This indicates that updated preferences due to information shocks may represent learning rather than a temporary increase in global warming salience and recall-bias.

Above we theorized that countries on the borderline would be less likely to mitigate emissions. We test this by perturbing the threshold used to dichotomize countries as experiencing damages or not. Countries near the cutoff should behave in similar ways as those facing potential net benefits. Figure B6 plots the marginal effects using different damage thresholds estimated from 6606 regressions. The main results hold, and sometimes strengthen, when borderline cases are included. Twenty borderline countries that face less than half a percentage point in damage to GDP in 2050, a group including the United States, China, and Germany, behave as if they anticipate benefits. This emphasizes the role of uncertainty; countries unsure of whether they face damages may prioritize avoiding certain short-term mitigation costs. This renders the borderline cases *de facto* members of the polluting North.

The standard collective action theory fails to predict these results. The usual expectation is that developing countries in the Global South are prime candidates for free riding because they prioritize economic development over the costs of mitigation (Victor 2011). The results here show the opposite, when holding all else equal. Nations in the South are more likely to update their preferences in response to information shocks, then pass mitigation policies. Our results, however, cannot reveal whether the emission reduction policies reflect the social optimum level of mitigation. It is likely that countries are still deficient in their commitments, but this gap could close as climate change accelerates and actors' preferences evolve. This finding should push the literature toward a more nuanced understanding of what constitutes free riding; it is not necessarily the absence of action (e.g., Kennard and Schnakenberg 2022).

The results also obtain when controlling for standard distributive politics explanations, which suggests that changing assessments of climate impacts is a unique dynamic driving mitigation. Distributive concerns do manifest, but not in the ways that extant theories predict. In line with expectations, nations producing large quantities of oil or with high carbon emissions per capita are less likely to enact climate policies. This suggests that for petro-states or countries where the average consumer depends on polluting fuels, cost considerations currently dominate decision calculi. However, contrary to distributive expectations, there is a positive association between coal production and climate laws. Figure B13 shows that among countries with above median coal production, those facing greater damages have a larger climate law stock on average. This lends support to our claim that beyond cost, changing evaluations of the benefits of mitigation shape decision-making. These mixed results also complicate the notion that incumbent interest group prevalence automatically translates into political influence.

There are two alternative explanations that we address here. First, the countries facing potential benefits also have economies reliant on fossil fuels, thus the findings could be spurious. However, the results hold when controlling for coal and oil production, and there is a negligible correlation between fossil fuels and damages.[4]

Second, systemic pressures from membership in international organizations (IO) could have pressured domestic leaders into adopting climate policies. There are theoretical grounds to dismiss contagion as an alternative explanation: it is unclear why IO membership is sufficient for nations to enact costly policies over the objections of incumbent interests; there is considerable variation in domestic climate policy despite a global trend towards IO accession; and such a structural explanation requires assumptions about the preferences of actors that have power in IOs.

Nonetheless, we employ spatial modeling techniques to account for the effect of systemic forces (Chaudoin, Milner, and Pang 2015). Online appendix B.16 contains the results, which show how joint-IO membership has no correlation with the propensity to pass climate laws for over two decades, then it has a mild positive association beginning around 2004. The magnitude of this correlation does not change at key international moments, like the 1997 Kyoto Protocol, indicating that this correlation likely reflects a latent characteristic of countries that join the same organizations rather than a compelling effect of institutions. We are also using these spatial modeling techniques in other work to measure related forces, such as the effect of interdependence and reciprocity, on free riding.

In addition to being robust to perturbing the damage threshold and using different disaster measures, the results obtain when using a lagged dependent variable; including a

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[4] $r = -0.23$ for coal and -0.04 for oil.

composite EU actor; using time-varying controls; accounting for damage from SLR; controlling for the stock of adaptation laws; using the Polity index; subsetting the laws to only economy-wide policies; controlling for trade openness; and using disaster indicators instead of counts (figure B10). These estimates are generally strong or suggestive.

Table 1: Regression of the national climate law stock on the interaction of disasters and potential damages in years 2025, 2050, and 2100

	Main Tests:			Placebo Tests:	
	(1)	(2)	(3)	(4)	(5)
GDP per capita (log)	-0.146	-0.149	-0.143	-0.145	-0.144
	(0.303)	(0.303)	(0.302)	(0.303)	(0.304)
Polyarchy	-3.462^{**}	-3.482^{**}	-3.591^{**}	-3.511^{**}	-3.480^{**}
	(1.308)	(1.318)	(1.283)	(1.317)	(1.330)
Coal Production	0.793^{***}	0.794^{***}	0.830^{***}	0.796^{***}	0.792^{***}
	(0.091)	(0.092)	(0.088)	(0.092)	(0.094)
Oil Production	-0.609^{***}	-0.616^{***}	-0.663^{***}	-0.613^{***}	-0.609^{***}
	(0.108)	(0.109)	(0.103)	(0.109)	(0.111)
CO_2 per capita (log)	-3.011^{***}	-3.001^{***}	-3.043^{***}	-3.005^{***}	-2.999^{***}
	(0.365)	(0.365)	(0.363)	(0.365)	(0.363)
Potential Damages	2.520	2.585	3.010	2.641	2.573
	(1.594)	(1.605)	(1.557)	(1.603)	(1.622)
Climate Disaster	-0.063				
	(0.072)				
Potential Damages × Climate Disaster	0.230^{*}				
	(0.103)				
Tropical Storm		-0.092			
		(0.118)			
Potential Damages × Tropical Storm		0.271			
		(0.146)			
Flood			-0.151		
			(0.299)		
Potential Damages × Flood			0.560		
			(0.335)		
Cold Wave				0.161	
				(0.202)	
Potential Damages × Cold Wave				0.086	
				(0.325)	
Earthquake					-0.130
					(0.268)
Potential Damages × Earthquake					0.048
					(0.289)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.715	0.714	0.715	0.714	0.714
N	4549	4549	4549	4549	4549

Notes: Robust standard errors clustered by country. Coal Production, Oil Production, and CO2 per capita fixed prior to 1990 or earliest date available for new countries to ameliorate post-treatment bias. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Sub-National Climate Cleavages

Having shown that a climate cleavage is emerging between countries, we next turn to cities to further test our theory. Cities are relevant for two reasons. First, cities provide a useful unit for analyzing the aggregation of preferences. Though institutions may influence how potential climate damages or benefits aggregate in larger units like countries or regions, especially those with considerable heterogeneity, the smaller size of cities exposes them to relatively homogeneous economic outcomes. Further, while countries vary in terms of their political organization of geographic units, all have urban areas with some control over climate policy. Second, cities contribute the majority of GHG pollution, but they also have the capacity to generate substantial emissions reductions that extend beyond administrative boundaries (IPCC 2022).

Data and Measurement

Climate Reporting Outcome

The outcome is the number of emissions reduction activities reported by a city to the Carbon Disclosure Project (CDP) in a year.[5] CDP is a non-profit that aims to create transparent and uniform climate reporting standards.[6] The organization annually solicits cities for information on their emissions, climate actions, and climate risks. We focus on reported emission reduction activities. For example, in Brazil, Rio de Janeiro reported implementation of a plan to reduce methane emissions from landfills, a potent GHG. In India, New Delhi closed the Badarpur thermal coal plant and disclosed plans to replace the power generation with solar energy.

Disclosure entails two costs, which makes the measure useful in discerning the extent city's commitment to mitigation. First, the provision of information involves bureaucratic costs that resource-constrained actors may not wish to expend. Second, while disclosing

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[5] We focus on policies rather than emissions for the same reason as with countries.

[6] Online appendix C.1 compares CDP with other data sources.

climate information may provide leaders with a political benefit by satisfying environmentalist constituents, enhanced policy transparency also introduces liabilities by allowing the political opposition to hold the city government accountable if it fails to follow through on its commitments (e.g., Hollyer, Rosendorff, and Vreeland 2018).

A potential source of bias is that cities may be unaware of CDP and would have reported otherwise. CDP takes steps to maximize participation by establishing offices and fostering local partners across six continents. The organization is also a touchstone resource on how localities can implement climate policies, so cities exploring mitigation are likely to come across the organization through cursory research. Unaware municipalities are unlikely to be those seeking to reduce carbon emissions. While there may be some under-representation of the Global South, this would introduce bias against our hypothesis.

To avoid selection bias, we construct an extensive list of 42,571 cities using data from the `maps` package in R. This sample frame includes cities with a population greater than 40,000, capital cities, and some towns. Since the names of cities are not standardized, we undertake a labor-intensive process to create a crosswalk between the datasets (online appendix C.2). Figure 3 plots the spatial distribution of cities reporting climate actions.

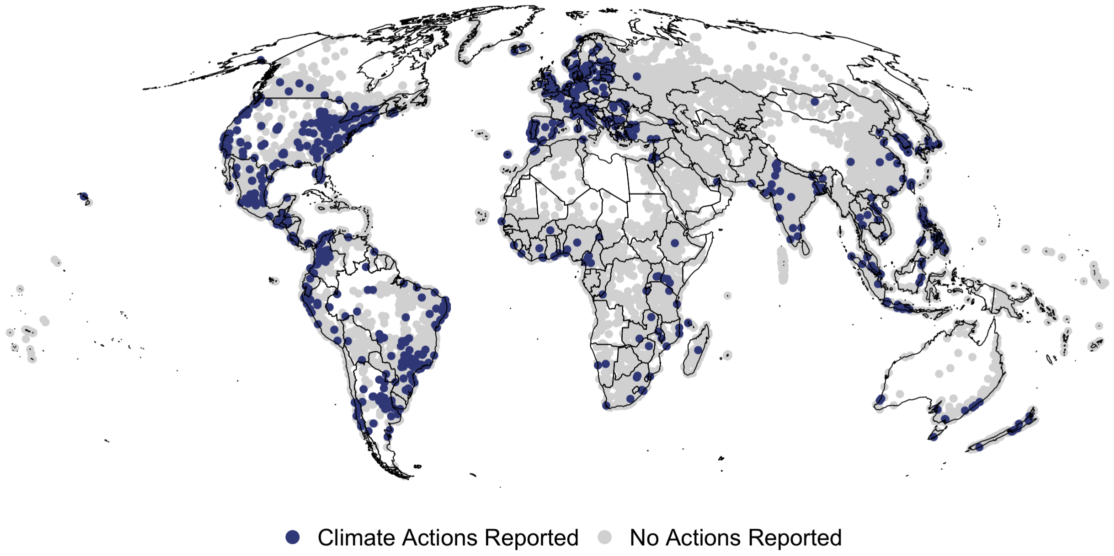

Figure 3: City reporting of climate actions, 2012-2020. Climate reporting data from CDP. City data from the `maps` package in R.

Potential Damages Moderator

We employ the same measure of global warming's economic effects as before, dichotomizing cities into those experiencing potential damages or benefits. The only modification is that instead of aggregating the CR estimates to the country-level, we map them to cities. Around 58 percent of cities in the sample face potential damages.

Information Updating Explanatory Variable

We use global surface temperature anomalies to measure climate information shocks. People perceive temperature anomalies as an indicator of global warming. Data come from the NASA Goddard Institute for Space Studies (GISS).[7] Since people likely do not notice marginal temperature changes, we focus on increased variability, operationalized by calculating the standard deviation in monthly temperature for each year. We lag the measure by one year. Figure 4 shows one slice from the time series.

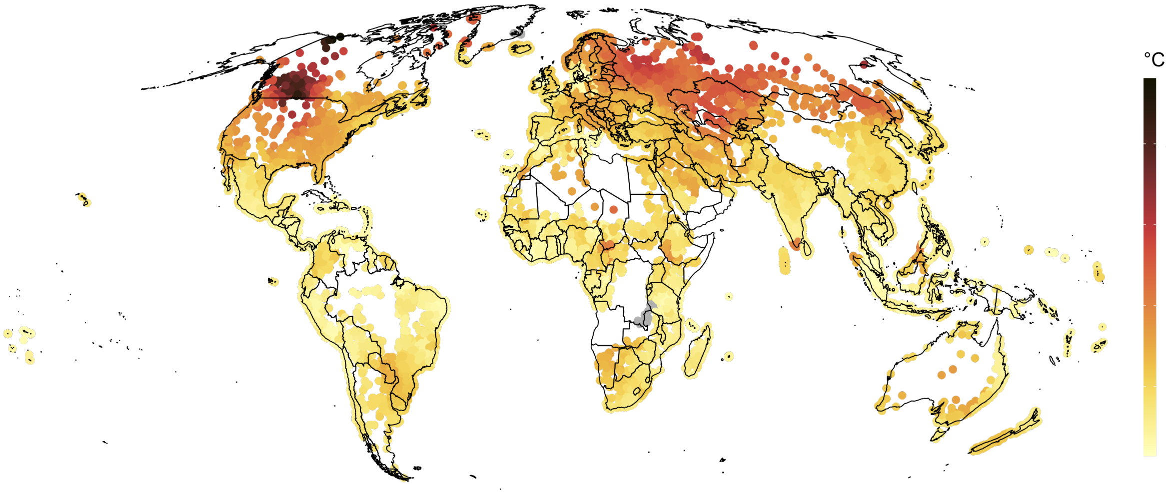

Figure 4: Spatial distribution of city temperature variability in 2020. Spatial distribution of temperature variability in world cities in 2020. Temperature data from NASA GISS. Gray circles denote cities with missing data.

A potential concern is that climate variation is becoming more common in the South,

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[7] See online appendix C.3 for further details.

although this does not appear in our data; there is no meaningful correlation between temperature variability and potential damages ($r = 0.058$).

Distributive Politics

Finding city-level data to capture distributive politics explanations is especially challenging due to the lack of global comprehensive coverage. We overcome this barrier by using geospatial data on air pollution from the Emissions Database for Global Atmospheric Research (EDGAR). This is a bottom-up emissions inventory, which allows for accurate attribution of pollution sources to different sectors of the economy. EDGAR uses the location of energy and manufacturing facilities, road networks, shipping routes, human and animal population density, and agricultural land use to allocate sub-sector emissions on a $0.1^\circ \times 0.1^\circ$ spatial grid, which are validated in part with satellite measurements (Crippa et al. 2020; Crippa et al. 2018).

We focus on air pollution attributed to the power industry and combustion for manufacturing.[8] For each sector, there is annual data on emissions from the following substances: BC, CO, NH_3, NMVOC, NO_x, OC, PM_{10}, $PM_{2.5}$, and SO_2. Since these measures are highly colinear, we use principle components analysis to reduce the measures into single indices for each of the sectors. As an indication of successful index constructing, the first eigenvector explains 75 percent of the variation in the power sector and 87 for manufacturing. To avoid post-treatment bias, we record the average of level of pollution in the five years prior to the start of the panel.

At a conceptual level, these air pollution indices serve as proxies for the strength of incumbent carbon-intensive interests – polluting manufacturing plants and high-emitting electric power generation. Higher pollution levels imply greater emissions mitigation costs, since the capital stock is likely inefficient and the number of polluting interests is potentially substantial.

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[8] In online appendix C1 we also report results including a measure of air pollution from oil refineries and transformation industry.

A limitation is that some large fossil fuel producing and consuming areas have controlled their internal air pollution, so we also employ a measure of anthropogenic CO_2 emissions, as a second proxy for costs incumbents face from regulation along with the potential costs that high carbon footprint consumers face. CO_2 data also come from EDGAR.

Controls

The V-Dem local government index accounts for the flexibility that local governments have to implement policy independent from the central government. Low scores mean that countries have no elected local governments, whereas high scores indicate that local governments are elected and can operate without restrictions from un-elected actors, save for judicial bodies. More federalism should have a positive correlation with city climate disclosures.

Lastly, the natural log of city population provides an approximate measure of government size, which likely correlates with reporting capacity. Population data come from the `maps` package in `R`.

Research Design

The exogeneity of temperature variability to city climate actions allows us to draw causal inferences. We employ a hierarchical model because it best captures the dynamics of city climate reporting. Cities reside within countries with characteristics that influence the flexibility local governments have to implement climate policies. We use the `lme4` package in `R` to estimate the following model of city climate reporting, Y_{it}, with indices j and k standing for a city's local- and country-level characteristics.

$$y_{it} = \gamma + \alpha_{j[i]} + \alpha_{k[i]} + \eta_t \tag{2}$$

Here,

$$\alpha_{j[i]} \sim \mathcal{N}(\tau_{k[i]} + \delta(D_{j[i],t-1} \times X_{j[i]}) + D_{j[i],t-1} + X_{j[i]} + \mathbf{W}^{\intercal}_{j[i]}\beta, \sigma^2_{j[i]}) \tag{3}$$

$$\alpha_{k[i]} \sim \mathcal{N}(\theta C_{k[i]t}, \sigma^2_{k[i]}) \tag{4}$$

The model includes varying-slopes for individual cities modeled as a function of the country within which a city is located. The main coefficient of interest is δ, the interaction of temperature variability and the potential damages indicator. We hypothesize that this coefficient is positive. The city-level of the model also includes a vector $\mathbf{W}_{j[i]}$ of controls described above. The country variable is its own modeled effect, with different slopes for each country, and a vector $C_{k[i]t}$ containing the federalism covariate. η_t is a year fixed effect.

Although computational limits inhibit our ability to spatially model collective action dynamics, we capture some of the spatial dynamic through the hierarchical model and year fixed effects. The structure of the model allows for cities within the same country to share random shocks, while the year indicators account for system-wide effects such as learning from international conferences or increasing awareness of CDP as city networks expand.

While the controls address the obvious sources of confounding, we take three precautionary steps to ameliorate remaining potential for omitted variable bias. First, the aforementioned year intercepts tend to contemporaneous global shocks like energy prices. Second, the varying-slopes capture some confounding because the estimator is a weighted combination of within and between estimators. Third, the hierarchical model provides some traction in taming omitted variable bias by partitioning the variance so confounders at the country-level do not contaminate predictors at the city-level.

Results

Figure 5 plots the marginal effects of potential damages at representative values of temperature variability. The relationship found among countries also appears among cities. A one standard deviation increase in temperature variability corresponds with 0.23 more climate actions reported by cities facing potential damages. Given that the median city reports no climate mitigation activities, this is a remarkable effect size. The results lend support to our information updating model; cities in locations facing damages are more likely to respond to information shocks by reporting emissions reduction activities.

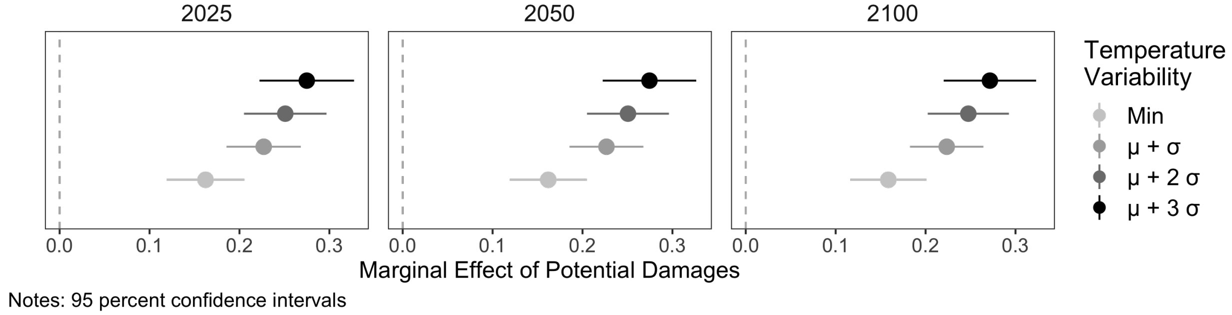

Figure 5: Marginal effect of potential damages on city climate reporting at different levels of temperature variability. Table 2 contains the regression results.

Table 2 shows that the covariates provide mixed evidence for distributive politics. The coefficients for power and manufacturing sector pollution are indistinguishable from zero, while the carbon emissions coefficient is negative but noisily estimated. This suggests that increasing understanding of climate impacts drives city policymaking more so than incumbent interest groups.

These results are especially surprising for collective action. While in the aggregate cities are consequential for global emissions, they are individually insignificant. Thus, of all actors, cities should be the most likely to free ride. Our findings show the opposite: cities facing damages are contributing to the public good. This is likely a consequence of growing climate urgency and the inability of cities to relocate. The climate threat may be leading to strong bottom-up pressure from constituents to reduce emissions.

Table 2: Hierarchical model of number of emissions reductions actions reported to CDP by cities, 2012-2020

	GDP Damage Year:		
	2025	2025	2100
Intercept	-1.234^{***}	-1.231^{***}	-1.218^{***}
	(0.049)	(0.049)	(0.050)
Temperature Variability$_{t-1}$	0.006	0.005	0.002
	(0.010)	(0.010)	(0.010)
Potential Damages	-0.061^{**}	-0.064^{**}	-0.081^{***}
	(0.023)	(0.023)	(0.024)
Power Sector Pollution	0.000	0.000	0.001
	(0.002)	(0.002)	(0.002)
Manufacturing Sector Pollution	-0.000	-0.000	-0.000
	(0.002)	(0.002)	(0.002)
CO_2 Emissions	-19.168	-19.170	-19.245
	(12.449)	(12.448)	(12.448)
Population (log)	0.132^{***}	0.132^{***}	0.132^{***}
	(0.004)	(0.004)	(0.004)
Federalism	0.020	0.020	0.020
	(0.018)	(0.018)	(0.018)
Temperature Variability$_{t-1}$ × Potential Damages	0.031^{*}	0.032^{*}	0.036^{**}
	(0.012)	(0.012)	(0.013)
City Intercept Variance	0.840	0.840	0.840
Country Intercept Variance	0.035	0.035	0.035
Year FE	Yes	Yes	Yes
Cities	42148	42148	42148
Countries	193	193	193
N	405178	405178	405178
Conditional R^2_{GLMM}	0.345	0.345	0.345
Residual	1.779	1.779	1.779

Notes: Model estimated using `lme4` package in R. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

Other coefficients have their expected signs: federalism is positive across the models and cities with larger populations are more likely to report emission reduction activities. To the extent that population size proxies for bureaucratic capacity, this result suggests that capacity is an important determinant of city climate reporting.

The results are robust to fixed effects estimation (table C3); alternative temperature variability measures; and controlling for SLR damage and oil pollution (figure C1).

Conclusion

Climate change will be one of the defining events of the 21st century. It will have a profound economic and social toll, especially on actors in the Global South which are most vulnerable to the effects of higher temperatures. From a normative perspective, this warrants swift cuts to emissions. However, our findings provide little cause for optimism. All else equal, countries and cities are acting in terms of their narrow self-interest, mitigating emissions if they stand to lose from global warming and polluting otherwise. Given the immense scope of the climate crisis, we predict that the political cleavage between the North and South will continue to deepen and spill over into other dimensions of international relations, such as trade and security.

As this cleavage deepens, two potential equilibria may emerge. First, in the *climate war* equilibrium, the Global North and South fail to reach a settlement over the Earth's temperature. The unabated emissions by the North could lead the South to pursue strategies that neutralize the North's pollution; countries may impose carbon tariffs, press their people to migrate north, or hold up cooperation on important issues to polluting nations. If these efforts fail, actors in the South may attempt geoengineering or reallocate investments from mitigation to adaptation. Second, in the *climate bargain* equilibrium, the North and South reach an agreement over mitigation levels, where actors facing losses persuade, coerce, or compensate those that benefit into forgoing their potential gains. An alternative bargain might be one where the South accepts Northern pollution in exchange for adaptation support via climate finance or climate-related aid, which borderline countries might be more willing to provide.

Collective action and distributive politics fail to predict these equilibria, which are consistent with the empirical exploration above. Our intervention in this debate shows how both theories have incompletely specified preferences due to the lack of a climate model that accounts for the redistributive effects of adaptation and the possibility of net benefits. By amending the distributive politics model to include preferences as derived from a climate model, we generate novel predictions that free riding and the influence of incumbent interest groups, though once salient, will fade as the climate crisis intensifies.

In doing so, we integrate climate econometrics and political science to develop a workhorse model of climate preferences that scholars can implement to answer new questions. Countries and cities are only two of a universe of actors affected by global warming. Extensions of this project could pair the potential damage measures with firms, civil society organizations, and individuals as we are attempting in other work. Additionally, scholars could add non-material elements to our model, such as identity, ideology, and partisanship. While we focus on the economic effects of global warming because it provides the greatest explanatory leverage, we make no pretense that it is the only factor at work. There are ripe opportunities for productive syntheses.

Another progressive line of research should examine the political cleavages that may form *within* countries in response to climate change. First, the CR model implies countries like the United States face considerable subnational heterogeneity in damages and benefits, which could shape bargaining over climate transitions (e.g., Gaikwad, Genovese, and Tingley 2022), and lead to different political outcomes depending on institutions. Second, refinements of our model should incorporate the disparate effects of global warming on the basis of race and socioeconomic status, which could influence individual preferences (e.g., Zucker 2021). Third, future studies should expand the one-sector model of the economy to consider the distributive effects of global warming within sectors and between firms, just as the trade literature has fruitfully pursued.

Beyond preferences, our theory incorporates informational dynamics into the standard Open Economy Politics approach (e.g., Lake 2009). Rather than assuming actors know how their position in the international economy translates into economic outcomes, we permit uncertainty in these evaluations whereby information shocks can increase the understanding and salience of distributive costs. This has broader theoretical applicability to issue areas where actors are uncertain about the state of the world, as is the case with the regulation of emerging technologies.

A limitation of our project is that all climate models, even ones as sophisticated as CR's, face the inescapable difficulty of forecasting the state of the world centuries from now. This is an uncertain enterprise, which is why our theory contains a model of decision-making under uncertainty. We do not claim that CR are climate oracles. Rather, the aim is for our theory to serve as a framework for analyzing climate politics. As climate modeling advances, scholars could use the latest assessments to update the interests of actors. Although new models might find that all actors lose from climate change, the heterogeneity of damages should still lead to a conflict between the North and the South due to their differential exposure.

In all, our theory points in a new direction for climate politics research. The physical effects of global warming will increasingly act as a structural constraint on actors, while reinforcing pre-existing inequalities between the Global North and South. To understand climate politics requires a deeper understanding of how climate change will materially affect each part of the world. Our article offers new steps in this endeavor.

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Online Appendix
"Political Cleavages and Changing Exposure to Global Warming"

A Climate Model Appendix

The estimates from Burke, Hsiang, and Miguel (2015) and CR have strong, positive correlations. The CR model expects relatively larger damages in much of the Global South, although this could be the consequence of greater heterogeneity found by CR. This comparison reinforces our trust in the CR model.

Table A1: Correlation between CR and Burke economic estimates

	CR: 2025	CR: 2050	CR: 2100	Burke: 2025	Burke: 2050	Burke: 2099
CR: 2025	1.0000	0.9999	0.9983	0.9163	0.9054	0.6494
CR: 2050	0.9999	1.0000	0.9991	0.9159	0.9058	0.6531
CR: 2100	0.9983	0.9991	1.0000	0.9144	0.9062	0.6630
Burke: 2025	0.9163	0.9159	0.9144	1.0000	0.9911	0.7418
Burke: 2050	0.9054	0.9058	0.9062	0.9911	1.0000	0.8140
Burke: 2099	0.6494	0.6531	0.6630	0.7418	0.8140	1.0000

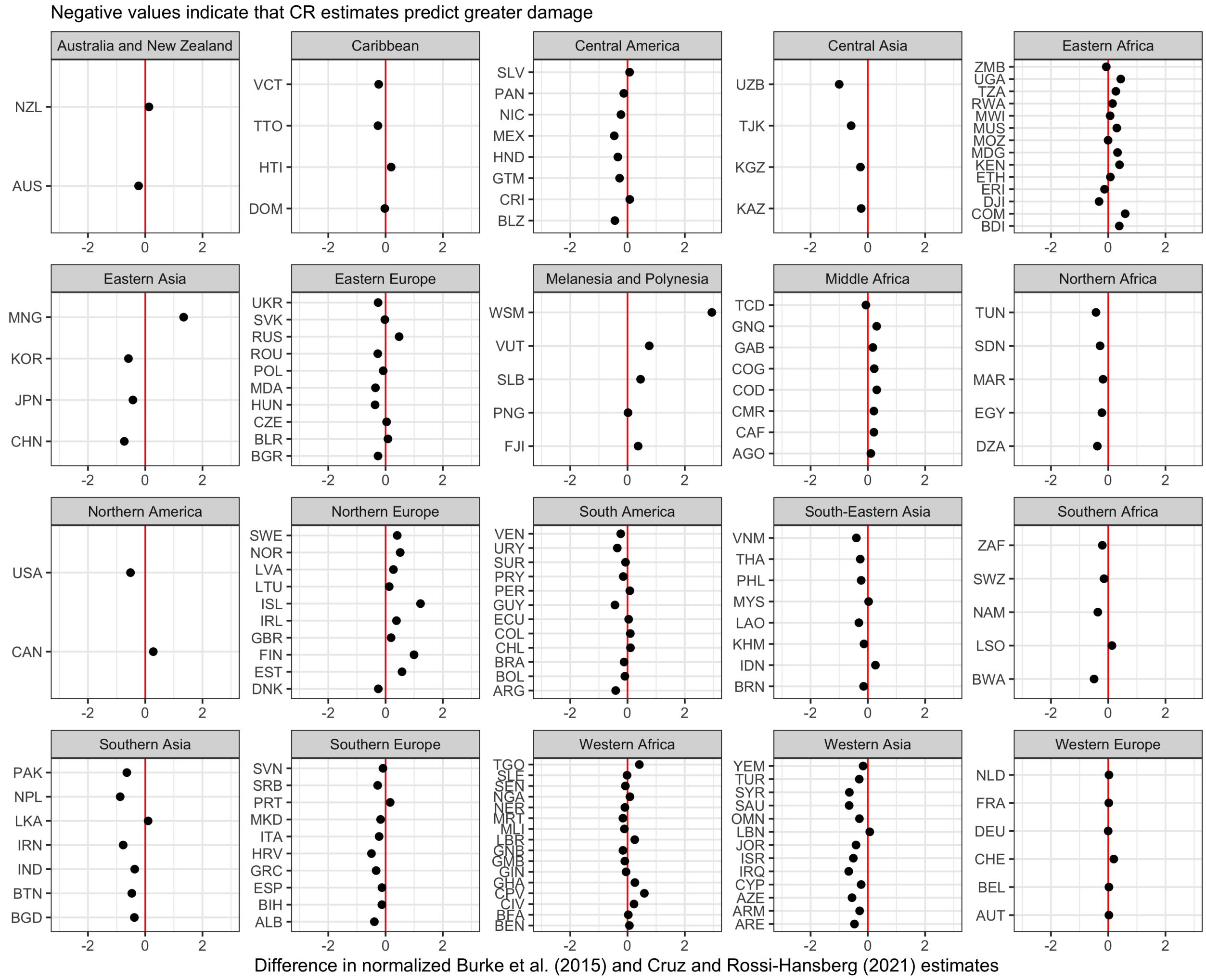


Figure A1: Comparison of normalized estimates from Burke et al. and CR

B Country Model Appendix

B.1 Substantive Effect of Climate Policy Measure

This appendix evaluates the substantive effect of climate laws by regressing improvement in carbon emissions intensity on the count of the previous year's mitigation laws. Lagging climate laws provides time for policy implementation and avoids reverse causality from countries adopting legislation if lower emissions render it less costly. If policies are shallow, they should have no impact on pollution. The outcome is the GHG intensity growth rate sub-index from the EPI (Wendling et al. 2020). This captures the decoupling of emissions from economic growth, the goal of climate policy. The index ranges from 0 to 100, with higher values denoting salubrious outcomes.

Table B1 presents the results from estimating the model. Model (1) is a bivariate regression that shows a positive correlation between an expansion of the climate law stock and subsequent improvements in emissions intensity. Model (2) adds controls for GDP and population, which may influence the number of mitigation laws a country has, and regime type, which may affect enforcement of emissions regulations. The model also includes country and year fixed effects, so the coefficients represent the effect of a within-unit increase in climate laws on emissions intensity. The coefficient of interest – climate law stock – remains positive and increases in magnitude, while the standard error widens slightly. Models (3) and (4) examine different lagged values of the climate law stock, since the benefits of climate laws may take time to manifest. As expected, the coefficient of interest remains positive and their magnitude grows slightly.

Table B1: Regression of carbon emissions intensity improvements on climate law stock, 1995-2020

	(1)	(2)	(3)	(4)
Climate Law Stock$_{t-1}$	0.552**	0.692†		
	(0.185)	(0.359)		
Climate Law Stock$_{t-2}$			0.720†	
			(0.386)	
Climate Law Stock$_{t-3}$				0.748†
				(0.420)
GDP (log)		4.959	4.951	4.991
		(3.298)	(3.301)	(3.306)
Population (log)		26.674†	26.592†	26.576†
		(14.223)	(14.180)	(14.157)
Polyarchy		−2.300	−2.239	−2.419
		(8.810)	(8.818)	(8.830)
Country FE	No	Yes	Yes	Yes
Year FE	No	Yes	Yes	Yes
Adjusted R^2	0.009	0.424	0.423	0.423
N	4280	3831	3831	3827

Notes: Robust standard errors clustered by country. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$; $^{\dagger}p < 0.1$

B.2 Potential Global Warming Damages by Country

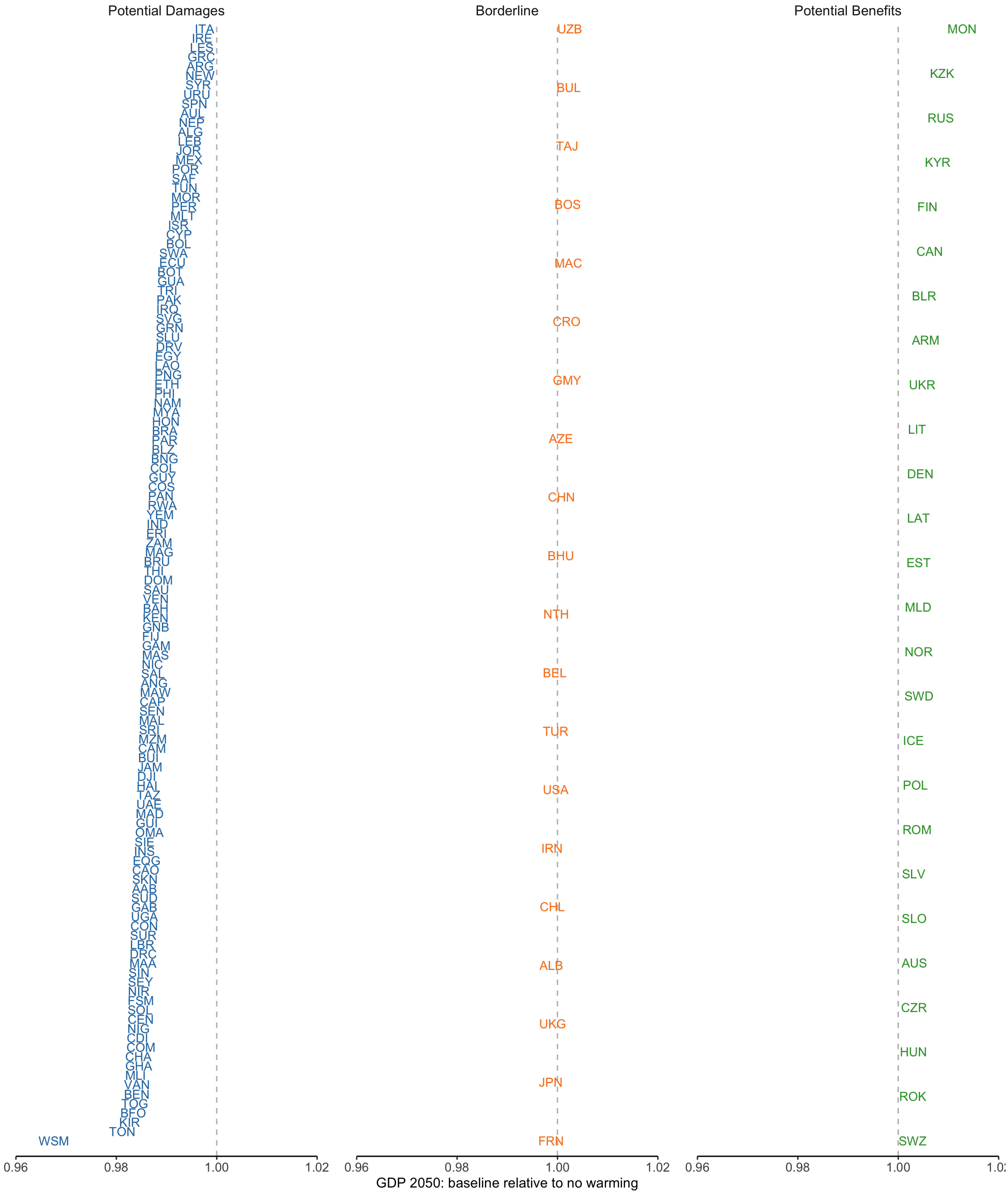


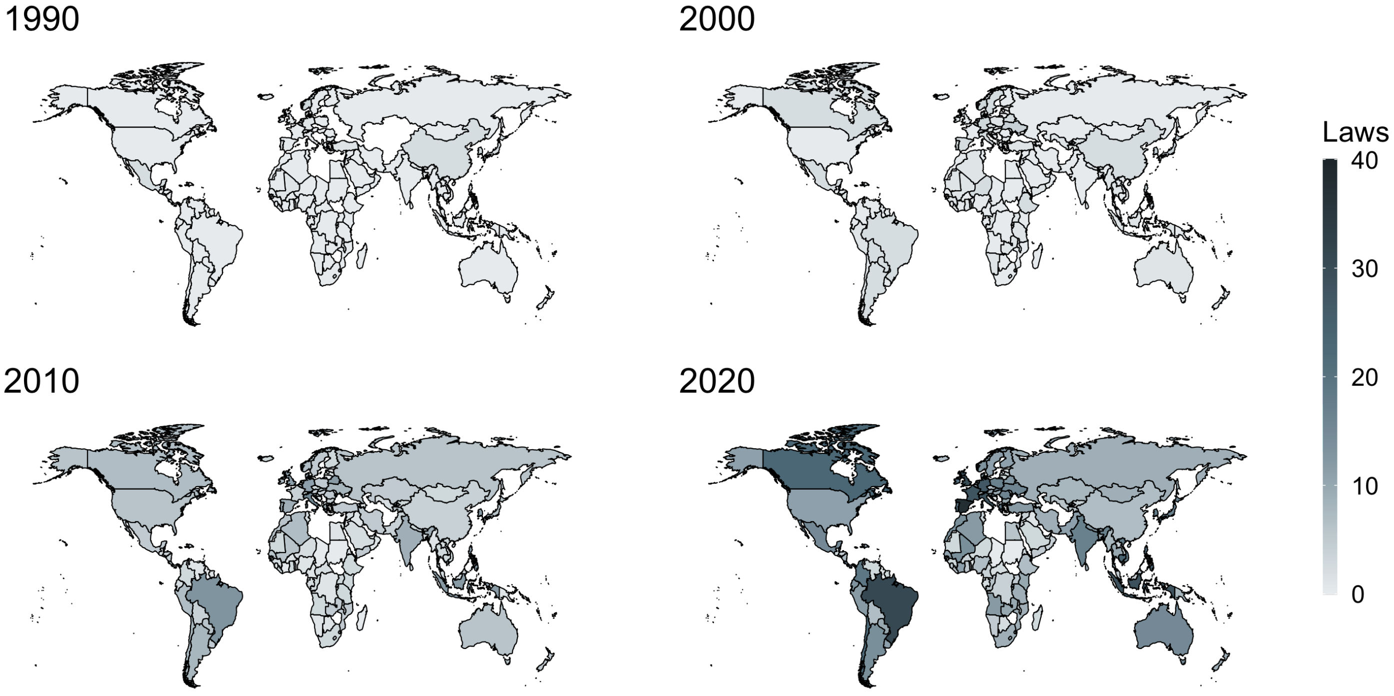
Figure B1: Countries categorized according to global warming's economic effects

B.3 Descriptive Statistics

Table B2: Descriptive statistics for country models

	Mean	Std.Dev.	Min	Max	N
Climate Law Stock	3.01	4.50	0.00	38.00	5263
Potential Damages (25 Years)	0.82	0.39	0.00	1.00	5263
Potential Damages (50 Years)	0.85	0.36	0.00	1.00	5263
Potential Damages (100 Years)	0.92	0.28	0.00	1.00	5263
Climate Disasters	0.63	1.81	0.00	25.00	5263
Tropical Storm	0.27	0.93	0.00	13.00	5263
Flood	0.12	0.44	0.00	8.00	5263
GDP pc (log)	8.05	1.56	3.17	11.95	4863
Polyarchy	0.53	0.26	0.01	0.92	4771
Coal Production (log)	2.34	4.86	0.00	15.27	5263
Oil Production (log)	0.78	1.54	0.00	6.18	5263
CO_2 pc (log)	1.16	0.94	0.00	3.83	5263

B.4 Spatial Distribution of Climate Laws



Notes: Data from Climate Change Laws of the World

Figure B2: Spatial distribution of climate mitigation laws

B.5 Spatial Distribution of Fossil Fuel Production

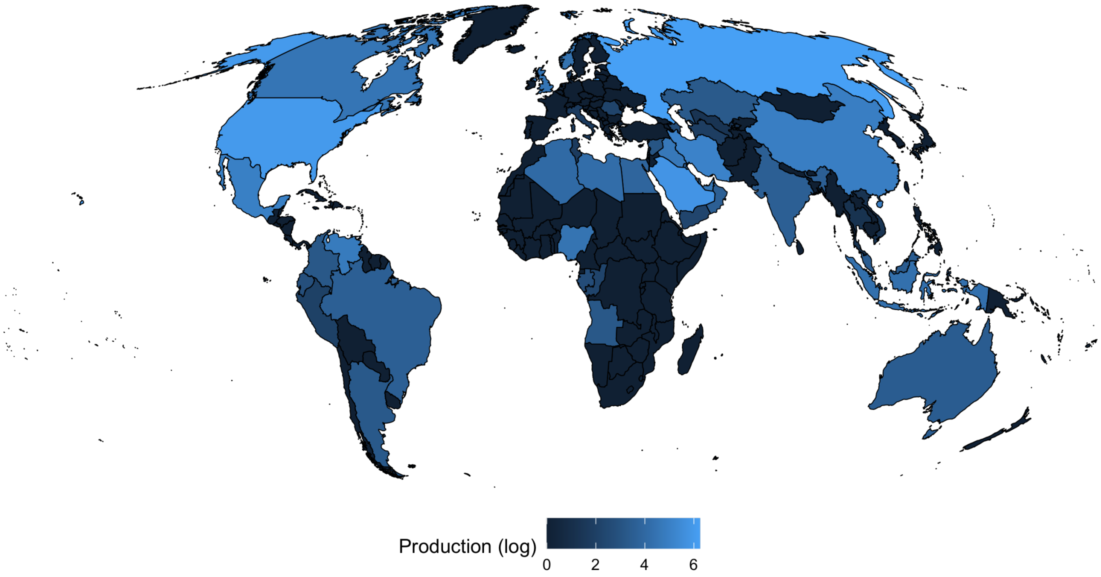


Figure B3: Spatial distribution of oil production (log), 1990. Data from the BP Statistical Review of World Energy.

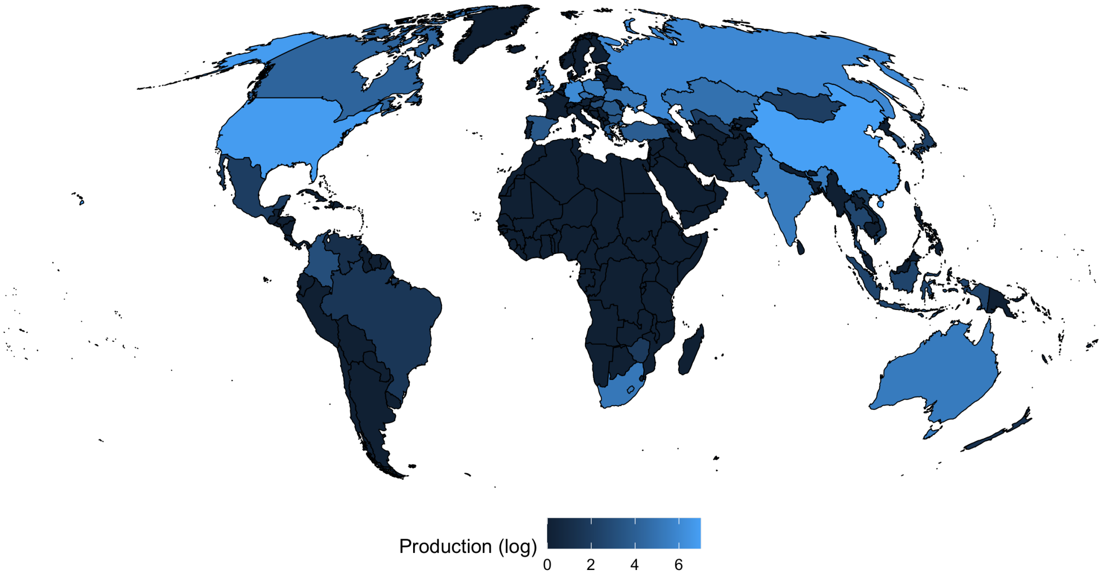


Figure B4: Spatial distribution of coal production (log), 1990. Data from the BP Statistical Review of World Energy.

B.6 Regression Results

One result to note is the negative polyarchy coefficient. We do not have strong prior expectations as to the direction of this coefficient, since there are conflicting theories for why democracies or autocracies might better protect the environment (e.g., von Stein 2020). If one held a strong prior belief that the democracy coefficient should be positive, this estimate would be cause for concern if it were inconsistent with patterns in the underlying data. It is not. Figure B5 shows that while higher *levels* of democracy are associated with larger climate law stocks, positive *changes* in democracy correspond with smaller stocks. Since the fixed effects model estimates *within* unit changes, the polyarchy coefficient is negative. Future research should explore why.

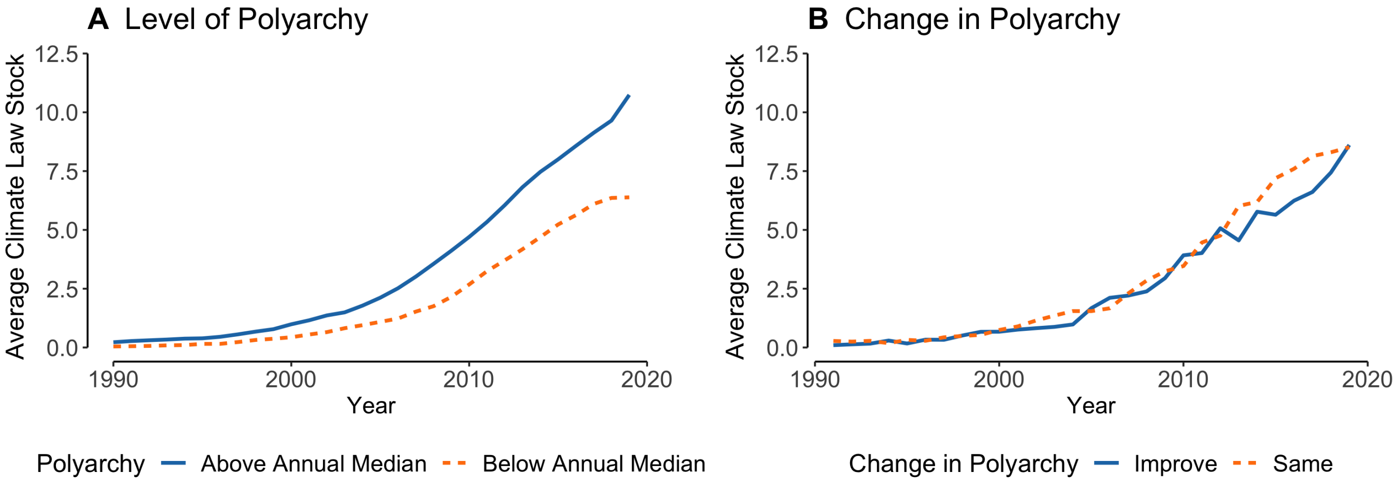


Figure B5: Average annual climate law stock conditional on level and change in democracy

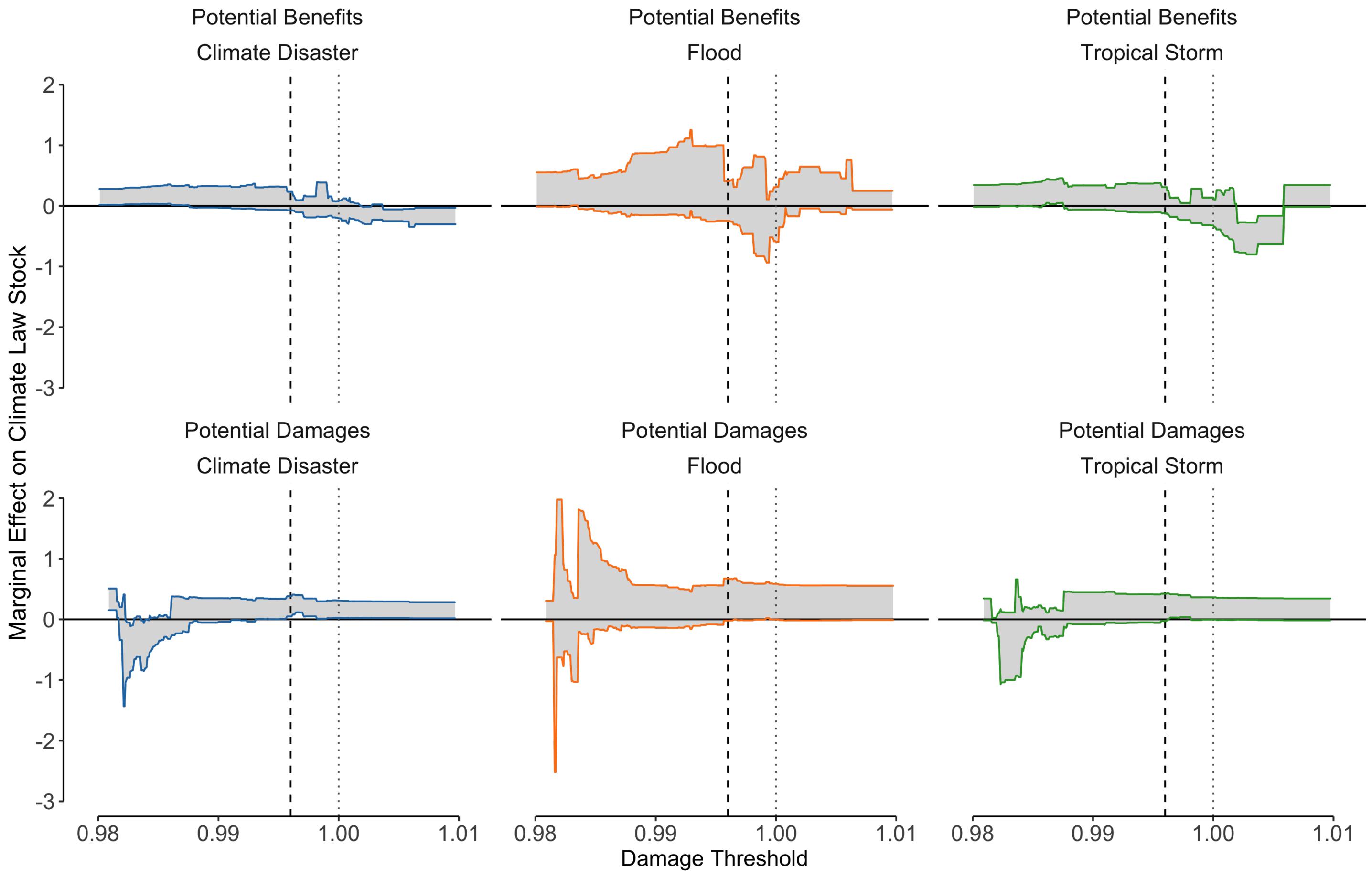
B.7 Borderline Cases

Figure B6 presents the marginal effects estimated from 6606 regressions of equation 1. Each specification perturbs the threshold for dichotomizing a country as experiencing potential damages by 0.0001. The continuous damage measurement is a ratio of GDP in a counterfactual world without temperature damages to a world where temperature impacts economic fundamentals. Values 1 or larger indicate that a country experiences potential benefits, which is the threshold at which the main analysis dichotomizes the indicator.

The top row of figure B6 presents the marginal effect of disasters for countries facing potential benefits, while the bottom row presents the marginal effect of disasters for countries expecting potential damages. The x-axis is the value to which we perturb the damage threshold. Values less than 1 represent lowering the damage threshold to include borderline cases within the category of countries experiencing potential benefits. Note that the marginal effect of disasters when a country faces potential damages plot only extends to a damage threshold of about 0.98 since there are not sufficient observations for valid estimation beyond that cut-point.

We see that as we lower the threshold below 1, the marginal effect size for climate disaster remains positive among countries facing damages and the confidence intervals even tighten. At the same time, the marginal effect for actors facing potential benefits now inclusive of borderline cases is indistinguishable from zero. Together, this suggests that countries on the borderline of damages and benefits act as *de facto* members of the Global North. They are less responsive to information shocks, which is likely due to their uncertainty about future benefits from reducing emissions.

There are 20 countries on the borderline of damages and benefits where the main results obtain at the 5 percent significance level: Albania, Azerbaijan, Belarus, Bhutan, Bosnia and Herzegovina, Bulgaria,

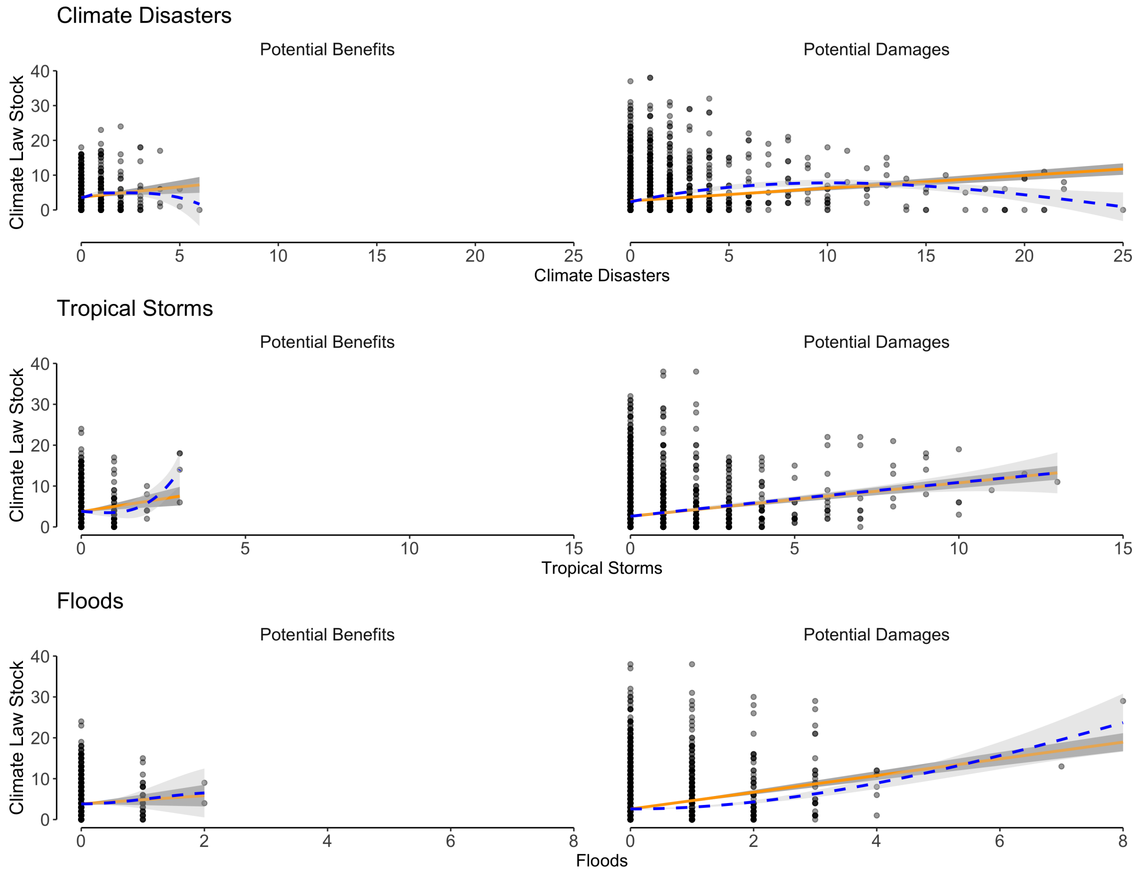


Notes: 95% confidence intervals

Figure B6: Marginal effects when perturbing the potential damages threshold to explore borderline cases. Vertical gray dotted line represents the original value of the damage threshold. Vertical black dashed line represents the value to which the threshold can be perturbed while results obtain at the 5 percent level of significance.

Chile, China, Croatia, France, Germany, Iran, Japan, Macedonia, Netherlands, Tajikistan, Turkey, United Kingdom, United States, Uzbekistan.

B.8 Linearity Assumption



Notes: Dark gray bands denote 95% confidence interval around OLS line in solid orange. Light gray bands denote 95% confidence interval around LOESS line in dashed blue. LOESS span parameter selected using k-fold cross-validation with 10 folds.

Figure B7: Validating the linearity assumption for disaster and potential damage interactions

B.9 Durability of Preference Change

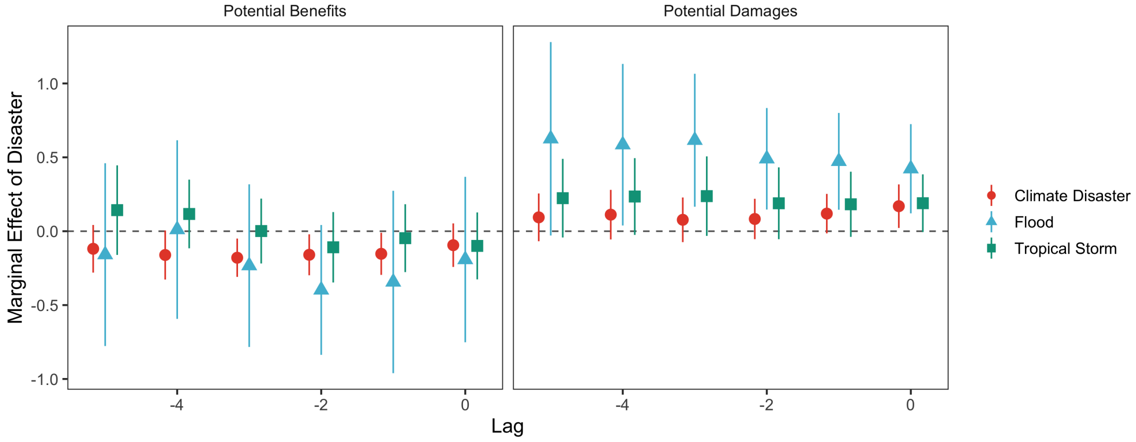


Figure B8: Marginal effects estimated using lagged disaster counts. 95% confidence intervals reported. Model includes controls specified in equation (1).

B.10 Climate Hazard Definitions

This appendix provides the EM-DAT definitions of the climate hazards and further discusses variable construction.[9] EM-DAT compiles information on the occurrence and effects of mass disasters from United Nations agencies, non-governmental organizations, insurance companies, research institutes, and press reports. In general, the database requires that disasters meet one of four criteria: 10 or more people reported killed; 100 or more people reported affected; declaration of a state of emergency; or a call for international assistance. The overall disaster variable excludes winter-related disasters because while climate change will cause more extreme colds, people mistakenly fail to associate cold spells with global warming (Hoffmann et al. 2022; Marlon et al. 2021).

- Floods: The count of floods comes from the "flash flood" sub-type measure. EM-DAT defines flash floods as "Rapid inland floods due to intense rainfall." We select flash floods because they are forecasted to become more likely due to climate change (e.g., Mirza 2002; Alfieri et al. 2015).
- Tropical Storms: The count of tropical storms is the sum of the "tropical cyclone" and "extra-tropical storm" disaster sub-types. EM-DAT define the former as follows: "A tropical storm originates over tropical or subtropical waters. It is characterised by a warm-core, non-frontal synoptic-scale cyclone with a low pressure centre, spiral rain bands and strong winds. Depending on their location, tropical cyclones are referred to as hurricanes (Atlantic, Northeast Pacific), typhoons (Northwest Pacific), or cyclones (South Pacific and Indian Ocean)." Extra-tropical storms are defined as follows: "A type of low-pressure cyclonic system in the middle and high latitudes (also called mid-latitude cyclone) that primarily gets its energy from the horizontal temperature contrasts (fronts) in the atmosphere." We focus on tropical storms because they are forecasted to increase in frequency and intensity due to climate change (e.g., Walsh et al. 2016).

The disasters for the placebo tests are defined as follows:

- Cold Wave: "A period of abnormally cold weather. Typically a cold wave lasts two or more days and may be aggravated by high winds. The exact temperature criteria for what constitutes a cold wave vary by location."
- Earthquake: "Sudden movement of a block of the Earth's crust along a geological fault and associated ground shaking." We focus on "ground movements."

B.11 Climate Hazards in the North and South

B.11.1 Global South More Likely to Experience Disasters

The CR model predicts that climate damages will be more intense in the Global South than in the North. One implication of this is that there will be more disasters in the South, and disasters will generally be worse in the South than the North. In the context of heat, Dell, Jones, and Olken (2012) finds that higher temperatures decrease growth in poor, but not rich, countries. At first glance, the Global North appears to incur more frequent disasters (figure B9). Bracketing whether disasters in the North are of greater magnitude than disasters in the South, these raw data are likely confounded by country size and factors that influence the quality of disaster reporting. To tend to these omitted variables and test the first claim about the spatial distribution of disasters, we regress the annual count of climate disasters on our indicator for if a country faces potential damages from global warming, while controlling for alternative explanations as described below.

Table B3 presents the results, which show that countries facing damages in the Global South are more likely to experience climate disasters, all else equal. Model (1) includes the following controls: regime type,

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[9] https://www.emdat.be/Glossary

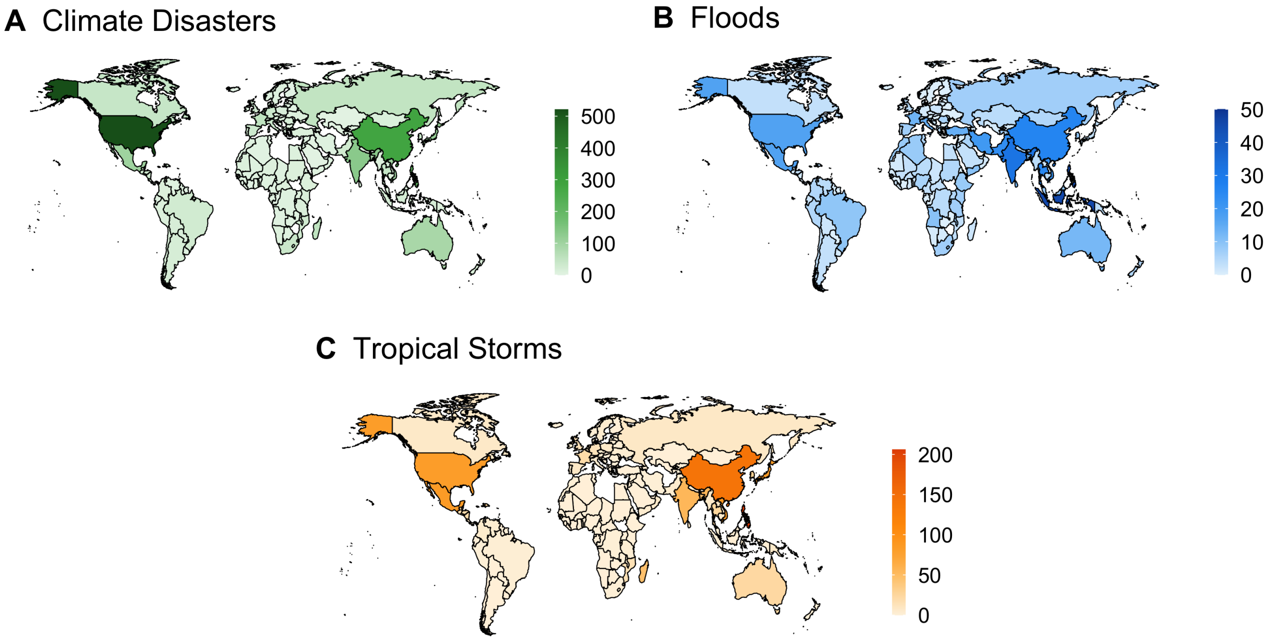


Figure B9: Spatial distribution of disasters, 1990-2020

which might influence reporting about climate disasters; population, which proxies for country size that in turn increases the area for disasters to occur; and GDP, which might correlate with disaster reporting. Model (2) adds year fixed effects, which marginally increases the standard error and the magnitude of the point estimate in the hypothesized direction ($p = 0.0522$). Model (3) drops the United States, which is an outlier in terms of number of climate disasters reported. The magnitude of the coefficient falls, but the direction remains the same while precision increases. Note that the models do not include country fixed effects since they would be perfectly co-linear with potential damages, a country-specific and time-invariant indicator.

The other covariates have no effect, save for population. This accords with intuition, as larger countries with substantial populations have more surface area where disasters might occur. The null finding for polyarchy and GDP is relevant, as it indicates that measurement bias is of a lesser concern for the EM-DAT data. While one might reasonably think that non-democratic countries suppress news about disasters or that wealthier countries have greater capacity to track disasters, the data do not support these conjectures.

B.11.2 Worse Impacts in the Global South

We claim that part of the reason that there are differences in how actors in the Global North and South update their beliefs in response to information shocks is because climate disasters – i.e., information shocks – often have worse impacts in the South. To test this mechanism, we regress the natural logarithm of the total number of people affected by climate disasters on an indicator for potential climate damages. The total affected is the sum of "injured," "homeless," and "affected" from the EM-DAT database. Injured refers to "[p]eople suffering from physical injuries, trauma or an illness requiring immediate medical assistance..." Homeless refers to "people whose house is destroyed or heavily damaged..." Affected refers to people "requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance." This measure encapsulates the commonsense notion that disasters impacting a larger number of people are worse.

Table B4 presents the results, which show that countries facing potential damages experience disasters that affect a greater number of people. The substantive magnitude of the effect is large. In model (1), a climate disaster in country facing potential damages affects 135 percent more people than a disaster in a

Table B3: Regression of climate disasters on potential damages, 1990-2020

	(1)	(2)	(3)
Intercept	-8.378^{**}	-8.422^{**}	-5.546^{***}
	(3.023)	(3.091)	(1.590)
Potential Damages	0.550^{*}	0.561	0.287^{**}
	(0.278)	(0.289)	(0.105)
Polyarchy	0.445	0.414	0.164
	(0.520)	(0.515)	(0.454)
Population (log)	0.301^{***}	0.288^{***}	0.279^{***}
	(0.081)	(0.082)	(0.081)
GDP (log)	0.145	0.162	0.055
	(0.099)	(0.116)	(0.056)
Year FE	No	Yes	Yes
N	4576	4576	4546
Adjusted-R^2	0.188	0.187	0.179

Notes: Robust standard errors clustered by country. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

country facing potential benefits. This effect obtains while controlling for GDP and population. Model (2) adds a control for regime type, which might influence reports regarding the social toll of disasters. The results do not change upon adding the polyarchy variable. Model (3) adds year fixed effects, which might not be necessary to include since disasters are plausibly exogenous to time, but these year indicators might help address potential differences in disaster reporting across periods. Including year indicators marginally attenuates the effect size. Model (4) adds a categorical variable for the disaster group – climatological, meteorological, or hydrological – which could influence the size of disasters. This variable increases the standard error of potential damages, which is expected, since we find above that climatological disasters are correlated with whether a nation faces potential damages (table B3). Nonetheless, the coefficient remains positive ($p = 0.0697$).

Across the model specifications, GDP is negative. This aligns with our claim that preexisting state capacity reduces the cost of disasters for actors in the North, which tend to have larger economies. Economic capacity is an additional mechanism through which disasters have differential effects in the Global North and South.

A concern is the extent of missingness in data on the total number of people affected by disasters. Around one-third of the observations lack data on the total number of people affected. To tend to missingness, we re-estimate the models presented above using imputed data. We use the `mice` package in `R` to execute sequential regression multiple imputation. We perform 30 imputations.

Table B5 presents regression results using the imputed data. The magnitude of the coefficients shrinks, while the direction of the effect remains the same. In the model (1) specification, a disaster in a country facing potential damages results in 8.3 percent more affected people than a disaster in a country facing potential benefits. The magnitude of the coefficient for GDP grows, which is another channel through which climate disasters differentially impact the North and South. Taken together, the results from the un-imputed and imputed model converge in their assessment that there is a positive directional effect of potential damages on the number of people affected by climate disasters.

Table B4: Regression of disaster impact on potential damages, 1970-2019

	(1)	(2)	(3)	(4)
Intercept	12.371^{***}	12.528^{***}	11.691^{***}	12.082^{***}
	(2.253)	(1.452)	(1.493)	(1.464)
Potential Damages	0.855^{*}	0.853^{*}	0.773^{*}	0.769
	(0.369)	(0.381)	(0.380)	(0.424)
GDP (log)	-0.840^{***}	-0.599^{***}	-0.650^{***}	-0.657^{***}
	(0.099)	(0.108)	(0.127)	(0.137)
Population (log)	1.004^{***}	0.710^{***}	0.754^{***}	0.835^{***}
	(0.152)	(0.116)	(0.135)	(0.138)
Polyarchy		-2.191^{**}	-2.054^{**}	-2.053^{**}
		(0.759)	(0.763)	(0.684)
Hydrological Disaster				-2.518^{***}
				(0.388)
Meterological Disaster				-1.952^{***}
				(0.403)
Year FE	No	No	Yes	Yes
N	3021	3021	3021	3021
Adjusted-R^2	0.173	0.189	0.202	0.26

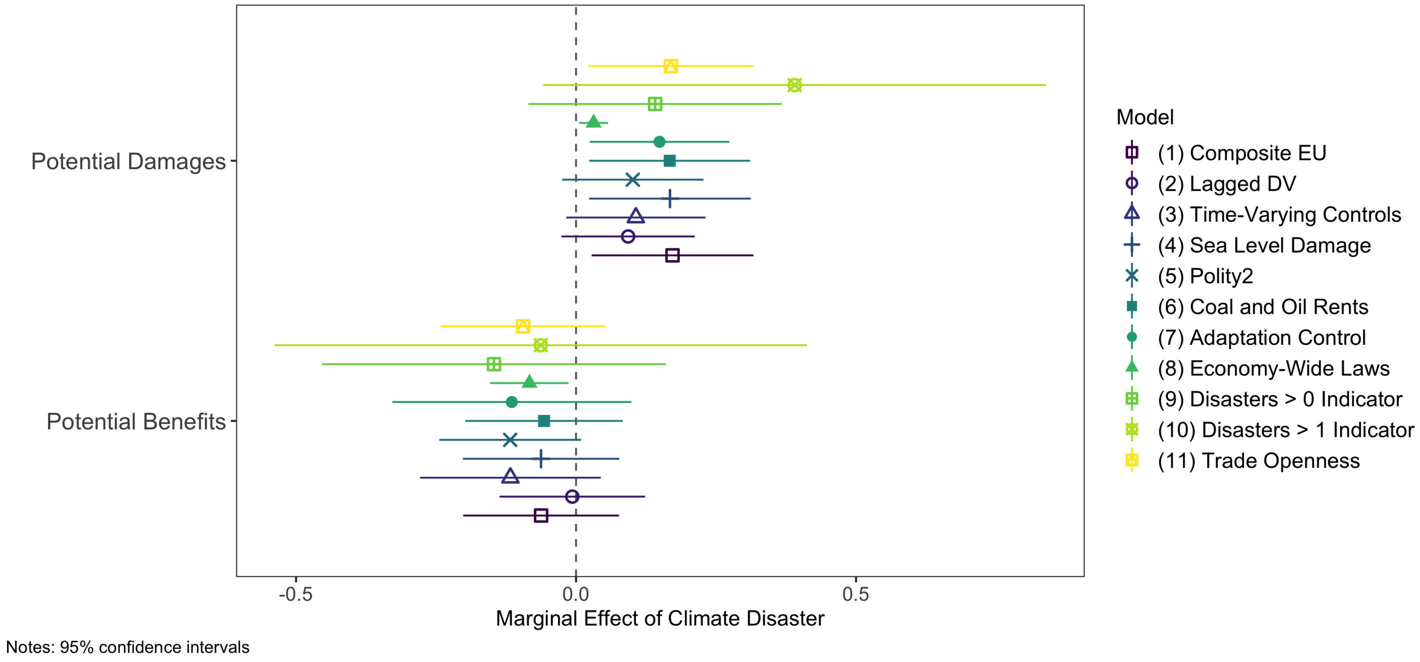
Notes: Robust standard errors clustered by country. Reference category for disaster grouping is climatological. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table B5: Imputed data regression of disaster impact on potential damages, 1970-2019

	(1)	(2)	(3)	(4)
Intercept	4.162^{***}	3.663^{***}	3.848^{***}	3.645^{***}
	(0.534)	(0.379)	(0.365)	(0.370)
Potential Damages	0.080^{**}	0.081^{**}	0.075^{**}	0.077^{*}
	(0.030)	(0.030)	(0.028)	(0.033)
GDP (log)	-2.128^{***}	-1.465^{***}	-1.629^{***}	-1.600^{***}
	(0.186)	(0.238)	(0.254)	(0.265)
Population (log)	1.718^{***}	1.185^{***}	1.276^{***}	1.353^{***}
	(0.203)	(0.184)	(0.194)	(0.203)
Polyarchy		-0.215^{***}	-0.201^{***}	-0.203^{***}
		(0.059)	(0.061)	(0.056)
Hydrological Disaster				-0.169^{***}
				(0.027)
Meterological Disaster				-0.132^{***}
				(0.027)
Year FE	No	No	Yes	Yes
N	4392	4392	4392	4392
Adjusted-R^2	0.141	0.154	0.16	0.183

Notes: Robust standard errors clustered by country. Reference category for disaster grouping is climatological. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

B.12 Robustness Checks



Notes: 95% confidence intervals

Figure B10: Summary of robustness checks described below. Each model number in this plot corresponds with the model number in table B7, which contains the regression results.

B.12.1 Time-Varying Controls

The main model presents results from a model with pre-treatment controls for coal and gas production, along with CO_2 emissions. This is necessary because these variables are impacted by the stock of climate laws, which would introduce a subtle form of selection bias were time-varying versions included in the model. Nonetheless, if we include time-varying covariates, the results obtain, as depicted in figure B10.

B.12.2 Sea Level Rise

To address other dimensions of climate damage, we estimate a model specification that accounts for the economic effects of sea level rise (SLR). We employ Desmet et al.'s (2021) dynamic economic assessment model. This model is built from the same framework as CR, which enhances comparability. The results show that coastal flooding due to SLR also gives rise to potential damages and benefits through the redistributive effects of endogenous adaptation. We incorporate an indicator into our main empirical specification for if a country experiences potential damages from SLR. The indicator for coastal flooding damage is positive as expected. Areas facing concentrated damage from SLR have a strong motivation to mitigate emissions. Figure B10 shows that the main marginal effects are unchanged by tending to damage from sea level rise.

B.12.3 Trade Openness

Trade openness may influence firm preferences over climate policy (Kennard 2020; Genovese 2019). We control for trade openness using the KOF measure of *de factor* trade openness (Gygli et al. 2019). The coefficient for this measure is positive. One hypothesis is that trade openness creates opportunities for more efficient firms to embrace environmental regulations that undermine their competitors (Kennard 2020). It is beyond the scope of this paper to test this contention, which would require more fine grain data on industry-level trade exposure and firm characteristics.

B.12.4 Composite European Union

This appendix explains how we account for the European Union's (EU) unique climate competence. The results presented in the main text focus on *national* climate policies because they are direct manifestations of country preferences whereas the policies of international organizations represent a distinct political process and cannot automatically be assumed to reflect national preferences. In particular, international organizations may often reflect the interests of the most powerful members. Despite the existence of the EU's supranational climate institutions, which may follow a distinct political logic, member states may still pursue domestic climate policies or shirk implementation of the EU's mandates.

Nonetheless, the EU has taken actions to address climate change, which are important to address. We do so by creating a composite EU actor that is a population-weighted average of its member states. This procedure has the advantage of transparency, making clear the relative contribution of each country to the composite. We code the outcome measure by taking the count of supranational EU climate laws from the Climate Change Laws of the World database. Table B6 presents descriptive statistics for the composite EU actor. Note that while this codes the European Union as experiencing potential damages, the EU is best characterized as a borderline case. Indeed, analysis in Appendix B.7 shows that key EU members like France and Germany fall on this borderline and behave as if they face potential benefits. Figure B10 presents the results for this robustness test.

Table B6: Descriptive statistics for composite EU, 1993-2019

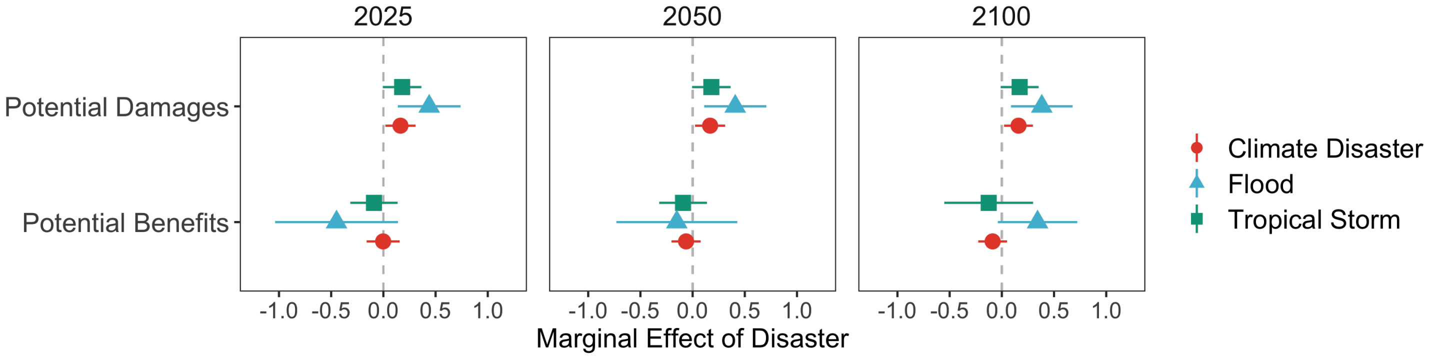
	Mean	Std.Dev.	Min	Max	N
Climate Law Stock	6.64	6.08	0.26	20.26	27
Potential Damages (25 Years)	1.00	0.00	1.00	1.00	27
Potential Damages (50 Years)	1.00	0.00	1.00	1.00	27
Potential Damages (100 Years)	1.00	0.00	1.00	1.00	27
Climate Disasters	0.95	0.61	0.08	2.64	27
Tropical Storm	0.30	0.37	0.00	1.33	27
Flood	0.19	0.19	0.00	0.70	27
GDP pc (log)	10.29	0.20	9.91	10.55	27
Polyarchy	0.87	0.01	0.84	0.88	27
Coal Production (log)	13.61	0.00	13.61	13.61	27
Oil Production (log)	2.92	0.00	2.92	2.92	27
CO_2 pc (log)	2.22	0.00	2.22	2.22	27

Table B7: Country-level model robustness checks

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Disaster	−0.062	−0.007	−0.117	−0.063	−0.118	−0.110	−0.115	−0.083*			−0.094
	(0.072)	(0.067)	(0.083)	(0.072)	(0.065)	(0.066)	(0.110)	(0.036)			(0.076)
Damages	2.691	1.667	−4.377	−5.781	0.130	−7.870***	3.060*	1.422***	2.506	2.684	3.728
	(1.599)	(1.073)	(6.700)	(4.528)	(1.358)	(0.652)	(1.259)	(0.336)	(1.582)	(1.612)	(1.919)
Damages × Disaster	0.235*	0.100	0.224*	0.230*	0.219*	0.211*	0.264*	0.115**			0.264*
	(0.103)	(0.091)	(0.113)	(0.103)	(0.091)	(0.091)	(0.126)	(0.038)			(0.110)
Climate Law Stock$_{t-1}$		0.430***									
		(0.061)									
Coal Production (time-varying, log)			0.181								
			(1.678)								
Oil Production (time-varying, log)			−0.484								
			(0.669)								
CO$_2$ per capita (time-varying, log)			−0.650								
			(0.703)								
Sea Damage				5.118**							
				(1.835)							
Polity2					−0.046	−0.040					
					(0.044)	(0.044)					
Oil Rents						−0.012					
						(0.020)					
Coal Rents						0.101					
						(0.125)					
Adaptation Law Stock							0.758***				
							(0.112)				
Disaster > 0									−0.147		
									(0.159)		
Damages × Disaster > 0									0.288		
									(0.193)		
Disaster > 1										−0.063	
										(0.246)	
Damages × Disaster > 1										0.453	
										(0.339)	
Trade Openness											0.025*
											(0.012)
Adjusted R^2	0.717	0.808	0.714	0.715	0.712	0.714	0.794	0.560	0.714	0.714	0.718
N	4576	4549	4396	4549	4209	4180	4549	4549	4549	4549	4549

Notes: Robust standard errors clustered by country. All models include year and country fixed effects. Potential damages and climate disaster abbreviated to damages and disaster. Covariates for GDP per capita, polyarchy, coal production, oil production, and CO$_2$ per capita not displayed. Models (1), (2), (4), (7), (8), (9), (10), (11) include these covariates. Model (3) replaces pretreatment measures with time-varying equivalents. Model (5) includes the covariates, but uses Polity2 instead of polyarchy. Model (6) includes the covariates, but uses oil and coal rents instead of production. Model (1) includes a composite EU actor. Model (8) uses the economy-wide law stock as the outcome. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

B.13 Marginal Effect at Different Damage Time Horizons



Notes: 95% confidence intervals. Facets correspond to the year up to which global warming's effects on GDP are simulated.

Figure B11: Marginal effect of climate disasters for countries facing potential damages or benefits in 2025, 2050, and 2100

B.14 Heterogeneity-Robust Estimator

The two-way fixed effects model is a workhorse approach to estimating causal relationships using long panel data. Although, recent scholarship has noted drawbacks to this estimator (c.f. de Chaisemartin and D'Haultfoeuille 2022). There are two sets of assumptions for causal identification in the TWFE setting: strict exogeneity and functional form (Blackwell and Glynn 2018; Imai and Kim 2021; Liu, Wang, and Xu 2022). This appendix explains how we either satisfy or address potential violations to these identification assumptions.

Strict exogeneity means that there are no time-varying confounders, which our model specification attempts to satisfy by controlling for likely culprits. The second aspect of strict exogeneity in the TWFE context is no feedback – that is, past outcomes do not affect current treatment assignment. This is plausible given how the greenhouse gas effect works; any benefits of mitigation will not be felt until long in the future since CO_2 is a stock pollutant.

The functional form assumptions state that treatment effects are constant and do not carryover. We employ the fixed effects counterfactual (FEct) estimator form Liu, Wang, and Xu (2022) to see if our results are biased by treatment effect heterogeneity and to test for carryover. The advantage of this estimator over other remedies to TWFE limitations proposed in the literature is that the FEct requires dropping fewer observations, which is less statistically inefficient. The FEct approach works by taking treated observations as missing and using data from the control condition to impute counterfactual estimates.

Using this approach requires modifications to the empirical specification. First, the FEct estimator can only handle dichotomous treatments, so instead of a count of disasters, we define treated status as follows: if a country faces potential climate damages in 2050 and experiences one or more climate disasters in a year, the unit is treated. Since this dichotomous treatment cannot distinguish the "dosage" of disasters, we add a control for the number of disasters a country experiences. Second, the pre-treatment controls fall out due to colinearity with the fixed effects, so instead we employ time-varying controls.

We estimate the model using the `fect` package in R. We construct confidence regions using 2000 bootstrapped replications. Figure B12 reports the results from this analysis. The top-left plot shows the dynamic treatment effects estimates. In the first period after treatment begins, we see a positive effect that grows in magnitude in the second period. In the pre-trend period, there is no apparent violation of the parallel trends assumption, which we later explicitly test.

The panel on the top-right shows our test of the carryover assumption. This test works by using periods after treatment ends to predict potential outcomes in those period. If there are no carryover effects, the average prediction error should be near zero. The x-axis in this plot is aligned based on treatment exit rather than onset. The results show that there is little no carryover effect. The first p-value comes from the conventional difference-in-means (DIM) test of a null of no difference, and the second p-value comes from an equivalence test which tests against a pre-specified difference to achieve greater power (Hartman 2021).

The last panel on the bottom-left presents results from an equivalence test for violations of pretrends (Liu, Wang, and Xu 2022). This procedure is stronger than a typical placebo test, which can sometimes fail to detect pretrend violations when time-varying confounders are cyclical or not present before treatment. The equivalence test rejects the null hypothesis of no difference only when the test for all pre-treatment periods produce significant results. The plot also shows the minimum range, which is "the smallest symmetric bound within which we can reject the null of inequivalence using our sample" (Liu, Wang, and Xu 2022). When the minimum range falls within the equivalence range, the model passes the pretrend test, which is the case here.

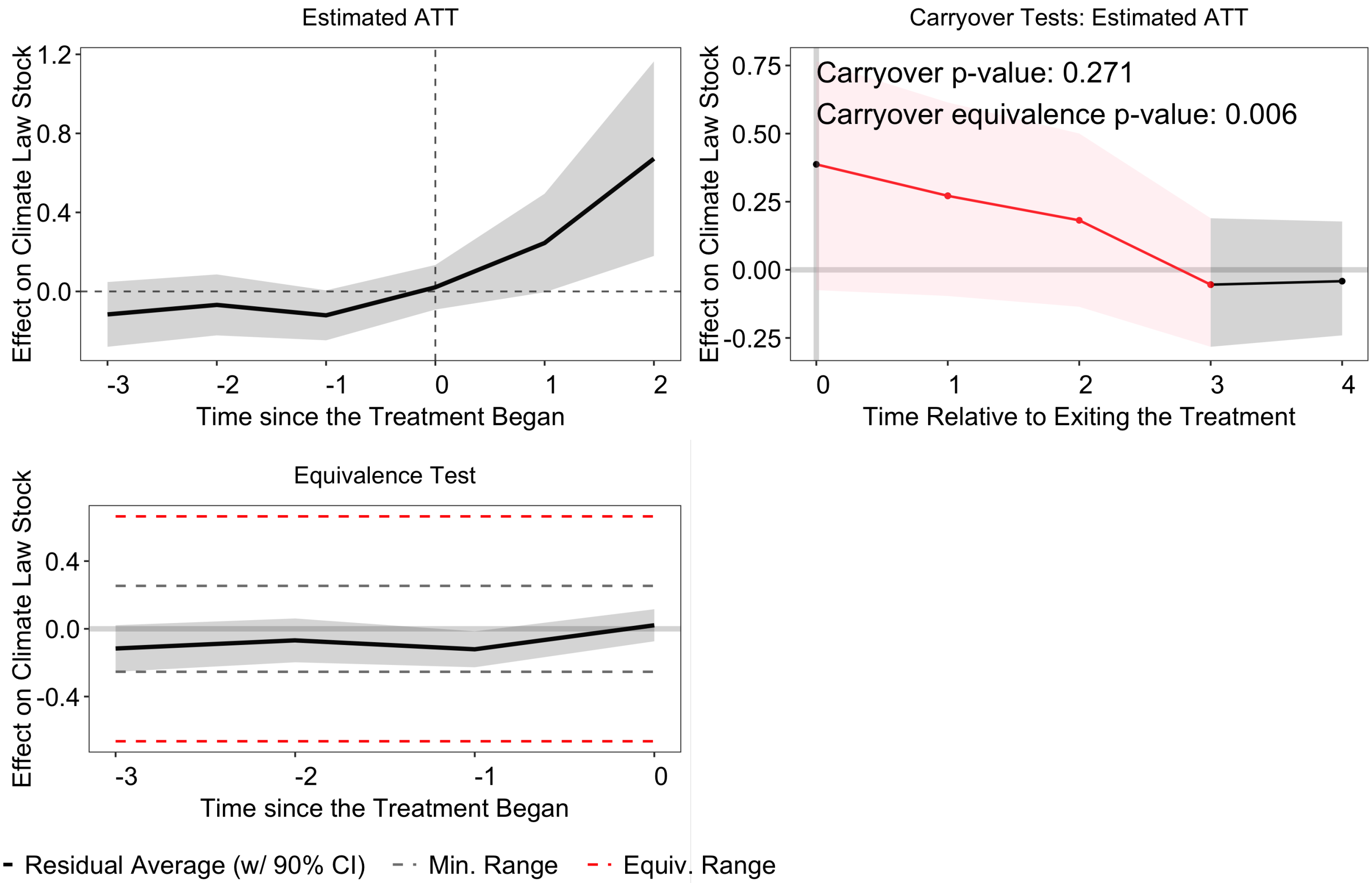


Figure B12: Dynamic treatment effects estimates using the FEct estimator and 95% confidence intervals; results of equivalence tests for pretrends, with red lines marking the equivalence range and gray lines marking the minimum range; results of the tests for no carryover effects with the three periods after the treatment ends depicted in red and p-values for the t test of the carryover effect and for the two one-sided tests (TOST) shown in the top-right corner.

B.15 Climate Laws by Coal Production

The purpose of this figure is to provide intuition behind the positive coefficient for coal production in the main model specification, in addition to illustrate how potential damages can lead even fossil fuel-producing nations to mitigate emissions. Figure B13 presents the average climate law stock, conditional on potential damages, among countries with above median coal production. Nations facing potential damages in the late 2010s period are more likely to pass climate laws, despite producing large quantities of coal, which standard distributive politics accounts would expect to inhibit climate lawmaking.

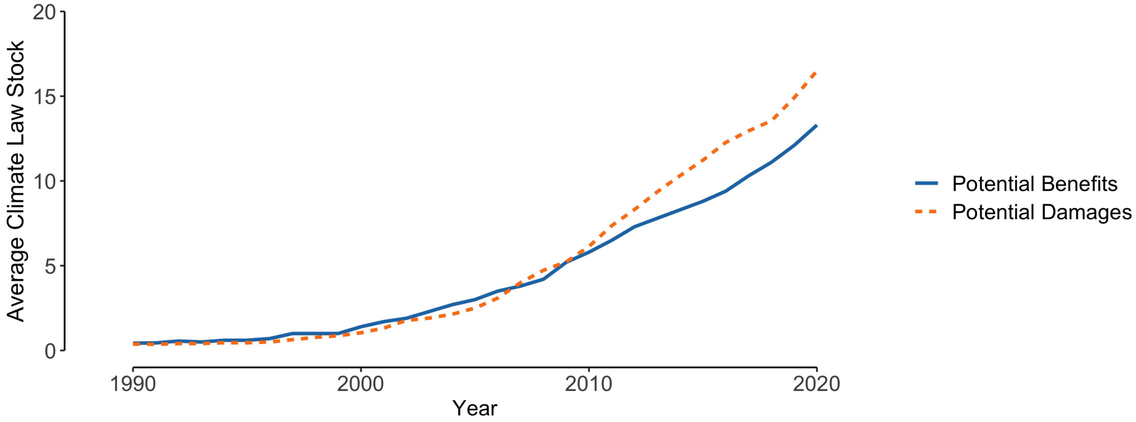


Figure B13: Average climate law stock in countries with above median coal production, condition on whether they face potential damages or benefits

B.16 Spatial Model Appendix

At the heart of the spatial model is a matrix, W, that measures the connectivity of units. Accompanying W is ρ, the spatial dependence coefficient, which reveals the strength and direction of units' influence on each other. We account for systemic forces by constructing a row-standardized W with a count of the IOs for each country-dyad. Data come from Pevehouse et al. (2020). Although the decision to join an IO is a domestic behavior, the literature often considers this a system-wide force. We adhere to this convention. This literature expects a sustained, positive ρ.

Since our spatial model is complex and parameter-rich, we estimate it with a Bayesian approach. This technique uses Markov Chain Monte Carlo simulation to integrate the posterior distribution with respect to the parameters. We run the simulation using a high-performance computing cluster. We specify uninformative priors, so inferences are based primarily on the data. The empirical model takes the following form:

$$y_{it} = \rho_t \boldsymbol{w}_t \boldsymbol{y}_t + \boldsymbol{x}_{it} \boldsymbol{\theta} + \eta_t + \lambda_i + \epsilon_{it} \tag{5}$$

Our quantity of interest is ρ, the spatial dependence parameter. The model includes $\boldsymbol{x}$, a vector of the covariates from equation (1). η and λ represent year and country fixed effects to tend to time-invariant omitted variable bias.

We implement a rank-based diagnostic of convergence for the MCMC simulation, for which we run four independent Markov chains to detect multimodality and poor mixing (Vehtari et al. 2021). The first diagnostic is the rank-normalized split-$\hat{R}$; values equal to or less than 1.01 indicate good mixing. The next diagnostic is the effective sample size (ESS). The bulk-ESS calculates the ESS based on rank normalized draws. The tail-ESS checks that convergence occurs across the parameter space. The suggested minimum for the bulk- and tail-ESS is 400. The model satisfies these criteria. This procedure leads us to employ a thinning parameter of 50, a burn in period of 20,000, and 50,000 thinned iterations in total after burn in.

Figure B14 presents the posterior mean regression coefficients, the posterior mean ρ estimates, and the marginal effect of climate disasters at different levels of the potential damages moderator, calculated using the posterior draws. As discussed in the main text, the credible intervals around the posterior ρ estimates cover zero until 2004. For the marginal effects, there is a positive effect of an additional disaster on the stock of climate laws for nations facing damages, but not those facing benefits.

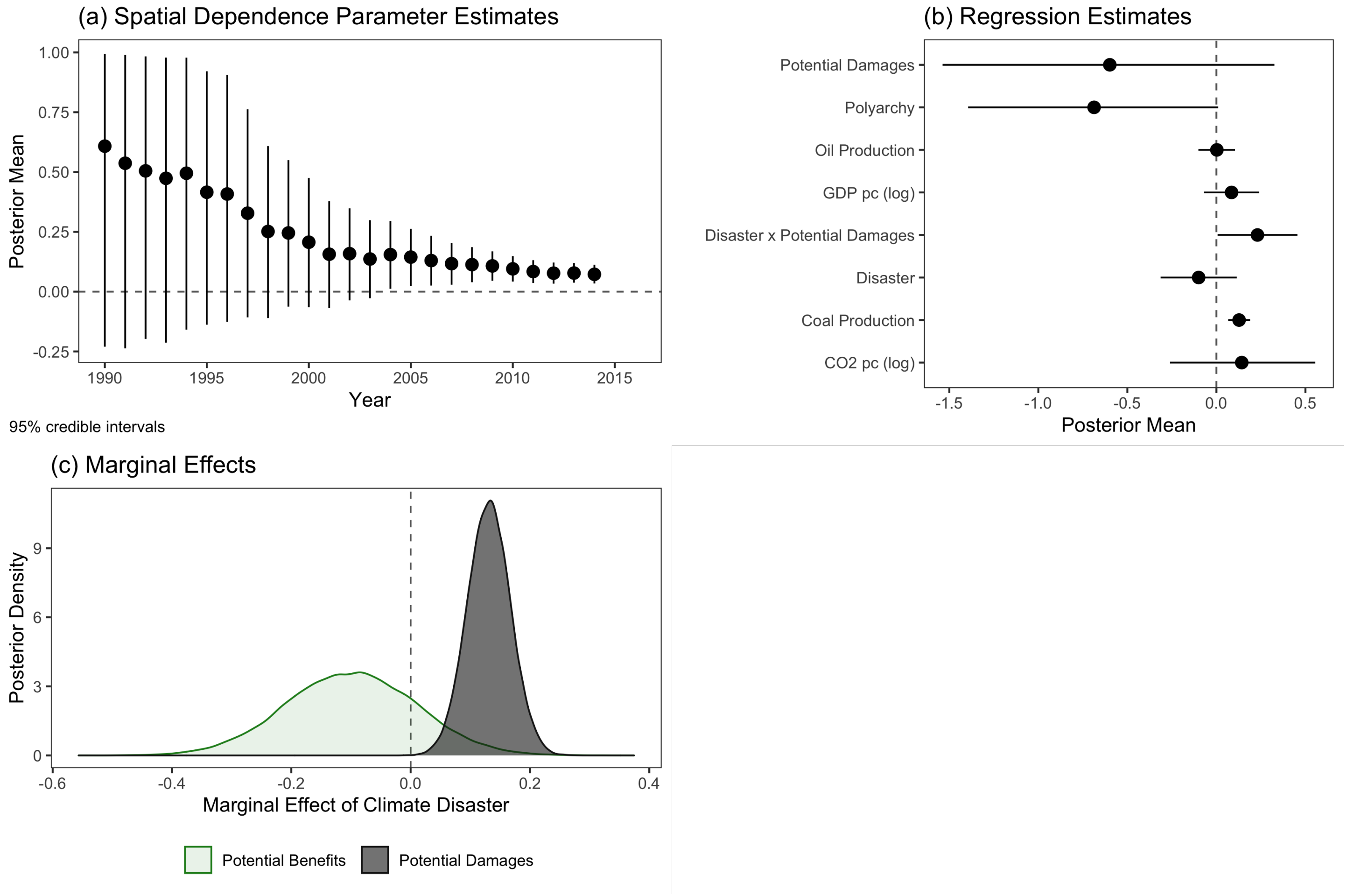


Figure B14: Summary of spatial model results

C City Model Appendix

C.1 City Data

We use data from CDP because the organization is the main climate reporting platform. While cities used to have choice between several reporting platforms, “many of these reporting platforms have been absorbed by the Carbon Disclosure Project” (Hughes, Giest, and Tozer 2020). Transnational organizations like the Global Covenant of Mayors, for example, leverage the CDP disclosure platform.

Data on cities does exist outside of the CDP network, although it often lacks global coverage and tends to focus on emissions rather than policies. For example, the Global Covenant of Mayors’ Data Portal for Cities provides estimates of carbon emissions for 30,000 cities in 10 countries.[10] RMI also provides data to help estimate city emissions.[11] Google’s Environmental Insights Explorer provides data to cities, although not members of the public nor researchers, on both emissions and potential emission reduction opportunities.[12] The World Resources Institute supplies energy consumption and waste production for

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[10] Global Covenant of Mayors for Climate and Energy, Data Portal for Cities, https://bit.ly/3JgVk2d

[11] RMI, City Climate Intelligence, https://bit.ly/3Jaelne

[12] Google, Environmental Insights Explorer, https://bit.ly/3xaF8NJ

60,000 cities in 12 countries.[13]. While valuable, these alternative measures are inadequate for our objective of capturing cities emission reduction *activities* across the globe. While a potential solution could be to infer city climate policies from their observed emission levels, this would be inappropriate since carbon pollution results from external dynamics like urbanization.

C.2 Matching Diagnostics

We implement the following reproducible matching procedure to pair the list of cities reporting emission reduction activities to CDP with the sample frame of world cities from the `maps` package in `R`. First, we pre-process the CDP city names to best approximate the format in the sampling frame and exclude duplicates or cities that fail to meet the criteria for the world cities sample frame.[14] Using this cleaned data, we succeed in matching 52 percent of the cities. Second, for the unmatched cities, we implement a "fuzzy" matching procedure that searches for approximate matches to the pattern within the string characters using a generalized Levenshtein edit distance. We set the maximum of this distance, which is the minimal weighted number of insertions, deletions, and substitutions necessary to convert one string into the other, to 0.2 in order to avoid false matches. We manually inspect each fuzzy-matched city to avoid erroneous pairs. This step identifies 54 more cities. Third, a human coder investigates the remaining unmatched cities. For each, the coder searches for the city name in the `maps` world cities data frame, using multiple versions of the city name. This manual matching backstop identifies another 51 cities.

In all, we succeed in matching 73 percent of cities reporting climate actions to CDP with cities in the `maps` world cities sample frame. Reviewing these remaining cities, it quickly becomes apparent why some do not achieve matches. For example, both the city of Chicago and the "Chicago Metropolitan Mayors Caucus" report climate actions. We record only the official city of Chicago and exclude the latter because it has no natural analogue in the sampling frame. This allows for valid comparison between cities; otherwise, we risk comparing different units with distinct political processes. Table C1 reports the proportion of cities in each United Nations sub-region that reported climate actions but did not obtain a match. The largest share of unmatched cities is in Latin America and the Caribbean, which should bias against our results because this region is especially exposed to climate damages.

Table C1: United Nations sub-regions for cities that reported climate actions but obtain no matches with sampling frame of cities

	Percent
Australia and New Zealand	2.5
Eastern Asia	11.1
Latin America and the Caribbean	51.4
Northern America	12.4
Northern Europe	7.4
South-eastern Asia	5.0
Southern Asia	0.9
Southern Europe	1.2
Sub-Saharan Africa	5.6
Western Asia	1.5
Western Europe	0.9

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[13] World Resources Institute, Data Portal for Cities, https://bit.ly/3KfmNTh

[14] The main criterion is that the city should have a population greater than 40,000.

C.3 Temperature Data

The temperature data come from GISS cover nearly the entire globe with positive land mass from the 1960s onward (Lenssen et al. 2019). These data are a widely used source for estimating global temperature changes and have been validated by other models. The collection procedure relies on a combination of 26,000 weather stations and satellite classification. Anomalies are measured relative to a 1951-1980 base period, with observations recorded on a 2° × 2° grid.

C.4 Descriptive Statistics

Table C2: Descriptive Statistics for City Models

	Mean	Std.Dev.	Min	Max	N
Climate Actions Reported	0.06	1.66	0.00	199.00	413622
Temperature Variability	1.18	0.64	0.08	5.63	409611
Potential Damages (25 Years)	0.57	0.50	0.00	1.00	413622
Potential Damages (50 Years)	0.59	0.49	0.00	1.00	413622
Potential Damages (100 Years)	0.64	0.48	0.00	1.00	413622
PCA: Power Sector Pollution	-0.01	2.54	-0.12	169.64	413622
PCA: Manufacturing Sector Pollution	-0.02	2.72	-0.22	226.59	413622
Carbon Emissions	0.00	0.00	0.00	0.03	413622
City population (log)	9.28	1.85	0.00	16.52	413622
Federalism	0.82	0.28	0.00	1.00	409029

C.5 Fixed Effects Estimator

For robustness we estimate the city models using the `fixest` package in R, which employs an efficient algorithm to estimate models with a considerable number of fixed effects. While the multiplicative interaction coefficient is positive and significant, we urge caution in interpretation since the proliferation of nuisance parameters leads variables to be dropped due to collinearity. This motivates our hierarchical modeling strategy in the main text.

Table C3: Fixed effects regression of city model

	No Controls	City Controls	Federalism
Temperature Variability$_{t-1}$	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)
Temperature Variability$_{t-1}$ × Potential Damages	0.04*	0.04*	0.04**
	(0.01)	(0.01)	(0.01)
Federalism			-0.01
			(0.00)
Year FE	Yes	Yes	Yes
City FE	Yes	Yes	Yes
N	409611	409611	405178
Cities	42566	42566	42148
Years	9	9	9
Adjusted R^2	0.30	0.30	0.32

Notes: Standard errors clustered by city. Potential damages and other time-invariant controls removed due to collinearity. Model estimated using `fixest` in R. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

C.6 Alternative Model Specifications

As with the robustness check in online appendix B.12, here we add an indicator for SLR damage to the city model specification. Figure C1 presents the results, which are unchanged.

Next, we probe the robustness of the main result to a different functional form for temperature variability. Perhaps there are diminishing returns to increased variability, in which case a logarithmic relationship might better capture the theorized information updating mechanism. To explore this possibility, we take the natural logarithm of temperature variability, and figure C1 shows how the results strengthen; there is an even larger gap between the minimum representative value for temperature variability and one standard deviation above the mean.

Finally, we estimate a model specification that adds a variable capturing air pollution from oil refineries. Data come from EDGAR and, as before, we use principal components analysis to construct an index that reduces nine air pollution measures into a single dimension. Figure C1 presents the results.

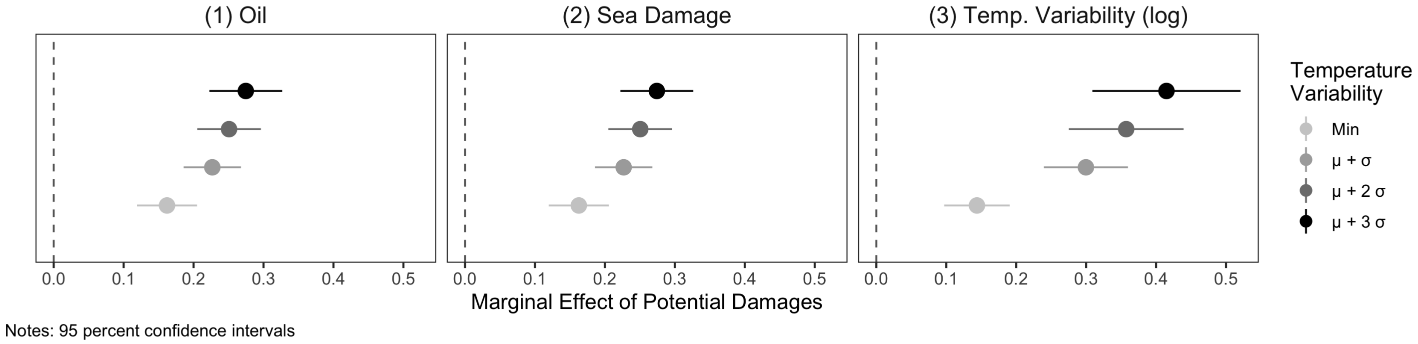

Figure C1: Summary of city model robustness checks. Table C4 contains the regression results.

Table C4: City model robustness checks

	Model 1	Model 2	Model 3
Intercept	-1.232^{***}	-1.232^{***}	-1.231^{***}
	(0.049)	(0.049)	(0.051)
Temperature Variability$_{t-1}$	0.005	0.005	
	(0.010)	(0.010)	
Potential Damages	-0.064^{**}	-0.063^{**}	-0.087^{**}
	(0.023)	(0.023)	(0.028)
Power Sector Pollution	0.000	0.001	0.000
	(0.002)	(0.002)	(0.002)
Oil Sector Pollution	-0.003		
	(0.003)		
Manufacturing Sector Pollution	0.001	-0.000	-0.000
	(0.002)	(0.002)	(0.002)
CO_2 Emissions	-15.512	-19.279	-18.859
	(13.031)	(12.449)	(12.450)
Population (log)	0.132^{***}	0.132^{***}	0.132^{***}
	(0.004)	(0.004)	(0.004)
Federalism	0.020	0.020	0.020
	(0.018)	(0.018)	(0.018)
Temperature Variability$_{t-1}$ × Potential Damages	0.032^{*}	0.032^{*}	
	(0.012)	(0.012)	
Sea Damage		-0.070	
		(0.059)	
Temperature Variability$_{t-1}$ (log)			0.008
			(0.023)
Temperature Variability$_{t-1}$ (log) × Potential Damages			0.081^{**}
			(0.030)
Year FE	Yes	Yes	Yes
Conditional R^2_{GLMM}	0.345	0.345	0.345
N	405178	405178	405178
Cities	42148	42148	42148
Countries	193	193	193
City Intercept Variance	0.840	0.840	0.840
Country Intercept Variance	0.035	0.035	0.035
Residual	1.779	1.779	1.779

Notes: Model estimated using `lme4` package in R. $^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$.

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