Learning and Free-Riding in International Climate Policymaking[*]

Justin Melnick[†]

July 16, 2025

Job market paper. Please read the latest version of the paper and the appendix.

Abstract

International climate cooperation is often presented as a case of the tragedy of the commons, where individual countries have incentives to free-ride on other nations' emissions reduction efforts. I present empirical evidence to the contrary: countries' climate actions are positively correlated over time, exhibiting a pattern of complementary efforts across nations. I explain this discrepancy with a formal model in which—in addition to providing the global public good of reducing emissions—other countries' mitigation efforts signal information about the economic value and policy success of a green transition. These learning effects are strongest when a country's belief in the economic success of green policy dominates its aversion to risk incurred investing in climate policies with uncertain returns. Analysis linking mass and elite beliefs about climate change to downstream mitigation efforts corroborates support for the learning mechanism, uncovering a positive relationship between expectations and actions.

[*]Many thanks to Tara Slough, Alastair Smith, Sandy Gordon, Peter Rosendorff, Pat Egan, Bruce Bueno de Mesquita, Amanda Kennard, Carolina Torreblanca, Aleksandra Conevska, Rajeshwari Majumdar, Joe Ruggiero, and audiences at New York University and Harvard University for thoughtful comments and feedback.

[†]Ph.D. Candidate, Department of Politics, New York University. Contact: `melnickj@nyu.edu` and `justinmelnick.github.io`.

How does the behavior of other nations influence interstate climate policy adoption? Long-standing scholarship emphasizes the temptations to free-ride inherent to collective action concerns (e.g., Olson 1965; Ostrom 1990; Barrett 2003; Stern 2007; Bernauer 2013; Keohane and Victor 2016). On this view, the local costs of abatement efforts outweigh the global benefits of environmental protection, so countries' emissions reduction efforts should be negatively correlated. This paper challenges the conventional wisdom by engaging in three tasks. First, I document a positive relationship between other nations' behavior and climate mitigation efforts. This reflects potential complementarities in countries' environmental policies on average rather than effort substitution, and suggests that free-riding may not be the only mechanism affecting international climate policymaking. Second, to unpack this empirical finding, I develop a formal model that introduces an additional causal mechanism—learning about the success of green policies—into the global public goods problem of climate mitigation. The theory demonstrates that cross-country climate actions are positively correlated when a country's belief in the economic benefits of green policy, though uncertain, outweighs the risk generated by implementing costly climate policies with unknown success. Finally, I examine empirical implications of the learning mechanism linking mass and elite beliefs about climate change to the stringency of mitigation policies.

In the model, countries engage in climate policymaking over time and observe the mitigation measures implemented by other nations. As in collective action theories, everyone is better off when nations exert more effort to abate the effects of climate change, but there are diminishing marginal returns to subsequent efforts, and taking action is locally costly. However, in contrast to conventional models, there is a fundamental uncertainty about the economic gains from the green transition: countries want to make costly climate policy investments that are commensurate with their beliefs that the green transition will be successful. Optimal emissions reduction policies balance countries' willingness to institute green policies that carry uncertain economic benefits, their marginal impact on global mitigation efforts, and the political costs of implementation (e.g., Bechtel and Scheve 2013; Stokes 2016; Gazmararian and Tingley 2023; Voeten 2025).

I argue that other nations' climate remediation policies influence the decision to implement environmental reforms via two channels. On one hand, previous mitigation efforts diminish the marginal contributions of subsequent policies, which incentivizes free-riding. This causal pathway induces strategic substitution in countries' climate investments. Concomitantly, the adoption of climate policies by other countries is a signal of public optimism in a green economy, which can spur subsequent climate action as other nations learn about the economic success of climate investments and thereby engender complementarities in actions. These dual effects imply that some countries, looking at their expected costs and benefits, will do as the conventional literature says: free-ride. But other nations will in equilibrium conclude that they can reinforce the effects of global cooperation via diffused learning (Elkins and Simmons 2005; Simmons, Dobbin and Garrett 2006), simply "following the leader" upon observing ambitious climate reforms (Torney 2019; Busby and Urpelainen 2020). The theory allows for a characterization of when learning effects dominate free-riding effects, implying a positive correlation in countries' climate actions. I show that the learning effects are strongest when a country's belief in the economic success to green policy dominates the risk incurred by implementing costly climate policies with uncertain returns.

The learning mechanism produces several empirical implications about the relationship between countries' beliefs and their climate efforts that the free-riding mechanism would not predict. Specifically, greater optimism about the economic value of climate policies within countries should incentivize greater efforts. Additionally, since nations are learning from one another, optimism should, in reduced form, engender greater action across countries as well. Using data on mass beliefs about the importance of climate change as well as elite beliefs about the ambition of nationally determined contributions (Victor, Lumkowsky and Dannenberg 2022), I uncover a positive relationship between beliefs and subsequent climate policy stringency within and across nations. Consistent with theoretical expectations, countries are more likely to pursue stringent climate policies when their publics are more likely to prioritize climate change as an important issue. Across countries, I show that more ambitious climate policy positively correlates with the assessments of climate elites from other countries, demonstrating how one nation's beliefs can inspire action in another.

Understanding the effects of learning and policy diffusion also has important consequences for international institutional design. Scholars and policymakers have viewed the free-rider problem as the dominant impediment to progress on international climate policymaking (see Carattini, Levin and Tavoni 2019; Weitzman 2017). Much of the conventional wisdom around international climate cooperation has emphasized deterring free-riding through institutional punishments (Barrett 2003; Victor 2011). This paper argues that a more effective approach may lie in fostering policy complementarities through information-sharing and expectation management. Institutions, as disseminators of information (e.g., Keohane 1982; Johns 2007; Fang and Stone 2012), can play a central role in shaping optimistic and informed expectations about the value of green investments, thus inspiring bolder action (Hale 2020).

The primary contribution of this paper is to provide an overarching, system-level theory of international climate politics that serves as an alternative to canonical free-riding explanations. I argue that countries' incentives to exert costly effort into climate remediation are shaped by more than just free-riding concerns, and are also a function of cross-national learning about the economic success of a green transition. As will be shown, the core implication of free-rider theories, that countries' actions are negatively correlated, does not, on average, find empirical support. I develop a theory that is consistent with the empirical evidence: learning can engender a positive correlation in countries' climate actions.

The learning effect appeals to the literature on path dependence and policy diffusion (Pierson 2000; Elkins and Simmons 2005; Simmons, Dobbin and Garrett 2006; Carattini, Gosnell and Tavoni 2020). Scholars have demonstrated evidence of policy diffusion in carbon pricing (Harrison 2010; Thisted and Thisted 2020; Linsenmeier, Mohommad and Schwerhoff 2023), feed-in tariffs (Baldwin, Carley and Nicholson-Crotty 2019), and domestic and international climate legislation (Sauquet 2014; Fankhauser, Gennaioli and Collins 2016). Rowan (2025) finds evidence of "conditional cooperation" by demonstrating a positive relationship between countries' Paris targets and subsequent pledges, similar to the diffusion effect described here.

Additionally, studies of the value of "increasing returns" to policymaking have identified how action by early movers generates greater effort by subsequent actors (Urpelainen 2011; Levin et al. 2012; van der Ven, Bernstein and Hoffmann 2017). Other scholars have encouraged policy experimentation in order to identify successful policies and ultimately lower costs and increase benefits (Hoffmann 2011; Sabel and Victor 2017). In a closely related paper, Hale (2020) considers how the incentive to act, or lack thereof, affects policymaking and subsequent institutional design. I build on these studies by formalizing the diffusion-by-learning effect and integrating this mechanism into an environment with free-riding, thereby demonstrating when the value of learning can outweigh free-riding temptations.

This paper is not the first to question the dominance of free-rider temptations in international climate policymaking. Indeed, a burgeoning strand of literature argues for a focus on domestic distributive cleavages in explaining variation in climate policymaking (e.g., Aklin and Mildenberger 2020; Colgan, Green and Hale 2021; Ross 2025), with some claiming that international collective action is irrelevant for explaining mitigation (Urpelainen and Van de Graaf 2018). However, in eschewing free-riding, scholars of redistributive politics sidestep the question of how international factors affect climate policy decisionmaking—heterogeneity of preferences domestically could still be compatible with a free-riding story at the international level (Kennard and Schnakenberg 2023). I complement domestic-focused explanations by providing an alternative mechanism that characterizes nations' climate policymaking behavior at an international level.

Are Countries' Climate Actions Strategic Substitutes?

In a typical story of global climate policymaking, the marginal value of taking climate action is decreasing in the actions of other countries. This is because the benefits of abatement are global while the marginal costs are local. This theoretical account emphasizes the temptations to free ride off of other nations, often formally assuming that countries' actions are *strategic substitutes* (see Harrison and Lagunoff 2017; McAllister and Schnakenberg 2022; Kennard and Schnakenberg 2023, for formalizations).[1] This premise, which lies at the core of extant theoretical approaches to global climate cooperation, implies that when other nations do more, it is a best response to do less, and when other nations do less, it is a best response to do more.

This section establishes a series of empirical facts about the relationship between a country's climate policy decisionmaking and the behavior of other nations. To operationalize countries' behavior, I study the climate laws that they pass as well as the stringency of their environmental policies. The first exercise studies the enactment and stringency of climate actions as a function of previously adopted climate policies by others. The second exercise leverages United States presidential elections as discontinuities in time to tease out how countries respond to exogenous shocks to expected international climate efforts.

In the theoretical literature on strategic complementarities, it is standard to make comparisons between the average or aggregate action of agents and an agent's own action (e.g., Morris and Shin 2003). The empirical assessments that I conduct operationalize this objective to "test" for the substitutability or complementarity between countries' climate actions in reduced form. To be clear, these strategic adjustments are often assumptions of theoreti-

[1] Strategic substitutability is conceptually distinct from decisionmakers' failure to internalize their negative externalities, or to "under-provide" effort, both of which are often invoked when discussing temptations to free-ride. However, these arguments require a normative optimum so that one can compare equilibrium effort levels to what is socially optimal, and thus demand significantly more theoretical and empirical structure than the exercises here.

cal models, not equilibrium implications. Hence the results in this section should be treated as empirical probes into the validity of these modeling features, capturing simple conditional correlations between nations' actions, rather than as causal statements.

Climate Law Adoption and Environmental Policy Stringency

I study the relationship between a nation's likelihood of taking climate action and the actions previously taken by other countries using data about climate law adoption and the stringency of a country's environmental policies. Contrary to expectations guided by conventional wisdom, I find positive correlations across countries' propensities to enact laws and pursue more stringent environmental policies. These results point toward a strategic complementarity in countries' climate actions rather than effort substitution.

To examine law adoption, I use data from the Climate Change Laws of the World project (Nachmany et al. 2017), which provides information on adopted climate laws from 1990 to 2024. The data covers laws adopted by the national governments of 199 countries plus the European Union. Laws passed by the E.U. are coded at the E.U. level. To be included in this dataset, a document must have full legal force or delineate a current set of government policy objectives, which pertain specifically to challenges of climate change (mitigation, adaptation, loss and damages, climate change research, etc.).

For each country i, I observe the number of climate laws adopted in year t as well as the total count of laws adopted by all other nations besides i (notated as $-i$). To capture the correlation between country i's climate law adoption and that of other nations, I run the following regression model via ordinary least squares with country-clustered standard errors:

$$\text{Laws}_{i,t} = \beta \ \log(\text{Other Laws}_{-i,t-1}) + \alpha_i + \lambda_{i,t} + \varepsilon_{i,t}.$$

The dependent variable $\text{Laws}_{i,t}$ is either the logged count of laws that country i passed in year t, or a binary indicator for whether or not country i passed any laws in year t. The independent variable Other $\text{Laws}_{-i,t-1}$ is the count of laws adopted by all other nations around in the globe besides i, which I lag by one year to avoid simultaneity concerns. Country fixed effects α_i capture any time-invariant factors that affect country i's likelihood of climate policy adoption. Finally, I include country-specific time trends $\lambda_{i,t}$ which should parse out any secular increases over time in countries' climate policymaking behavior or increases in demand for climate policy over time within countries. Additionally, these terms intend to separate general equilibrium effects, or any global benefits to increased mitigation that could correlate with a contemporaneous rise in climate law adoption across countries.

In addition to lawmaking, I also examine policy stringency, a continuous and cumulative measure of efforts into climate remediation that probes the intensive margin of countries' policies. I use two measures of policy stringency, the OECD's Environmental Policy Stringency (EPS) index (Botta and Koźluk 2014; Kruse et al. 2022) and the Climate Action Policies and Measurement Framework (CAPMF) developed by Nachtigall et al. (2024). The EPS covers 40 countries between 1990 and 2020 and ranges from 0 to 6, where greater values imply greater stringency. Stringency is defined as the ability to explicitly or implicitly place a price on pollution through market-based (taxes, trading schemes, feed-in tariffs, and deposit and refund schemes) and non-market policies (command-and-control standards and subsidies). The CAPMF runs between 1990 and 2023 and measures the breadth of mitigation policy actions for 49 countries and the European Union on a scale from 0 to 10. I focus on the CAPMF's measurement of the stringency of "sectoral policies" rather than "cross-sectoral policies" or "international frameworks" although results are robust to the inclusion of these policy variables as well.

For country i in year t, I run the following regression via ordinary least squares with country-clustered standard errors:

$$\text{Stringency}_{i,t} = \beta \text{ Average Other Stringency}_{-i,t-1} + \alpha_i + \lambda_{i,t} + \varepsilon_{i,t},$$

which fits country i's policy stringency in year t as a function of the average policy stringency of all other nations besides i in year $t-1$. I also include country fixed effects α_i and country-specific time trends $\lambda_{i,t}$.

In both specifications, the coefficient β targets the within-country correlation between countries i's behavior and the behavior of other nations. The estimand of interest is its sign, which in reduced form captures the marginal value of country i's climate policymaking behavior—either the laws it passes or the stringency of its environmental policies—given what others have done. Extant theoretical approaches would expect $\beta < 0$, such that the passing of laws or more stringent policies by others reduces country i's tendencies to pass its own laws or adopt its own stringent policies, as, in this view, mitigation efforts are substitutable.

	Laws (Count)		Laws (Binary)		EPS		CAPMF	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(Other Laws)	0.223***	0.329***	0.170***	0.278***				
	(0.010)	(0.022)	(0.004)	(0.018)				
Avg. Other Stringency					0.986***	0.864***	1.01***	0.839***
					(0.062)	(0.131)	(0.033)	(0.053)
Observations	7,000	7,000	7,000	7,000	1,200	1,200	1,650	1,650
R^2	0.394	0.488	0.343	0.383	0.873	0.934	0.930	0.972
Within R^2	0.288	0.398	0.282	0.326	0.775	0.884	0.920	0.968
DV Mean	0.391	0.391	0.335	0.335	1.78	1.78	2.19	2.19
Number of Countries	200	200	200	200	40	40	50	50
Country fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
Country × Year trends		✓		✓		✓		✓

p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Robust standard errors clustered at the country level

Table 1: Effects of Previous Law Adoption and Policy Stringency on Climate Policymaking

Table 1 displays the results. Model 1 presents the relationship between other laws and the count of laws passed by i and uncovers a *positive* and statistically significant conditional correlation. To guard against the possibility that nations are secularly increasing their passage of climate laws over time, regardless of the behavior of other nations, Model 2 introduces country-specific time trends and finds that this positive correlation is robust. Models 3 and 4 present analogous results for the binary version of the dependent variable. Models 5-8 also show that across both operationalizations of stringency there is a positive and statistically significant relationship between the average stringency of nations and the environmental policy stringency of nation i. Moreover, the sample of nations for which stringency data is available further bolsters the results, as these are countries with a larger impact on the climate, so we may have expected to observe greater effort substitution.

Contra extant theories, the adoption of climate laws by other nations in the past year is a positive and statistically significant predictor of climate law adoption. The average stringency of other nations is also a positive and statistically significant predictor of a nation's environmental policy stringency. Since this correlation is positive, it suggests a complementarity rather than a substitutability in the adoption of climate laws across countries. Results are robust to alternative time trend specifications and the inclusion of time-varying controls, see Appendix B.1.

While these results are suggestive of a complementary relationship between efforts across countries, we may still be worried about an omitted variable or some other general equilibrium effect that produces a positive correlation on average, even if the partial equilibrium relationship across countries is negative. In the specifications above, the country-year time trends attempt to correct for this concern, but it should again be noted that this exercise serves as a probe into a theoretical and conceptual assumption rather than a causal test. The next empirical exercise attempts to localize the partial effect in a more disciplined way.

U.S. Presidential Elections

As an additional test, I examine the effects of United States presidential elections on the adoption of climate laws. As one of the globe's largest emitters, the identity of the American president heavily skews the incentives to enact climate laws around the globe: in 2016, Donald Trump campaigned on withdrawing the United States from the Paris Agreement and retrenching the U.S. from the global climate regime, while Joe Biden's 2020 campaign promoted American engagement in climate policymaking. The outcome of the 2016 (2020) election thus represents a negative (positive) perturbation to other countries' best responses and subsequently informs their optimal decisionmaking in light of expected American behavior following the election. The classical logic then predicts that other nations should increase (decrease) their adoption of climate laws following Trump's (Biden's) victory.

To capture the effects of the elections, I run a regression discontinuity in time at the country-month level using the following local linear regression specification:

$$\text{Laws}_{i,m} = \beta \mathbb{1}(m > t_k) + \varphi f(m - t_k) + \alpha_i + \varepsilon_{i,m}.$$

The dependent variable is either, as in the first empirical test, a binary indicator for whether country i adopted a climate law in month m or the logged count of climate laws adopted by country i in month m. As the running variable is time, the independent variable of interest is an indicator of whether time at month m has exceeded t_k, the calendar date of the election (either November 8 2016 or November 3 2020), and $f(\cdot)$ is a smooth function of time, which is measured in days until the election. Fixed effects at the country level α_i are also included to capture country-specific idiosyncrasies in law adoption. I report bias-corrected estimates with optimal bandwidth selection, weight observations using a triangular kernel (Calonico, Cattaneo and Titiunik 2014), and cluster standard errors by country.

The sign of β identifies the sign of the local average treatment effect of the U.S. election on other nations' adoption of climate laws right at the date of the election.[2] Hence this estimate should be thought of as countries' expectations of the value of future effort given the winner of the election. A free-riding argument would expect the sign of β to be positive (negative) in 2016 (2020). In this account, Trump's apathy toward climate policies increases the marginal value of policymaking for other nations to compensate, while Biden's willingness to enact climate policy decreases the incentives for others to exert costly effort.

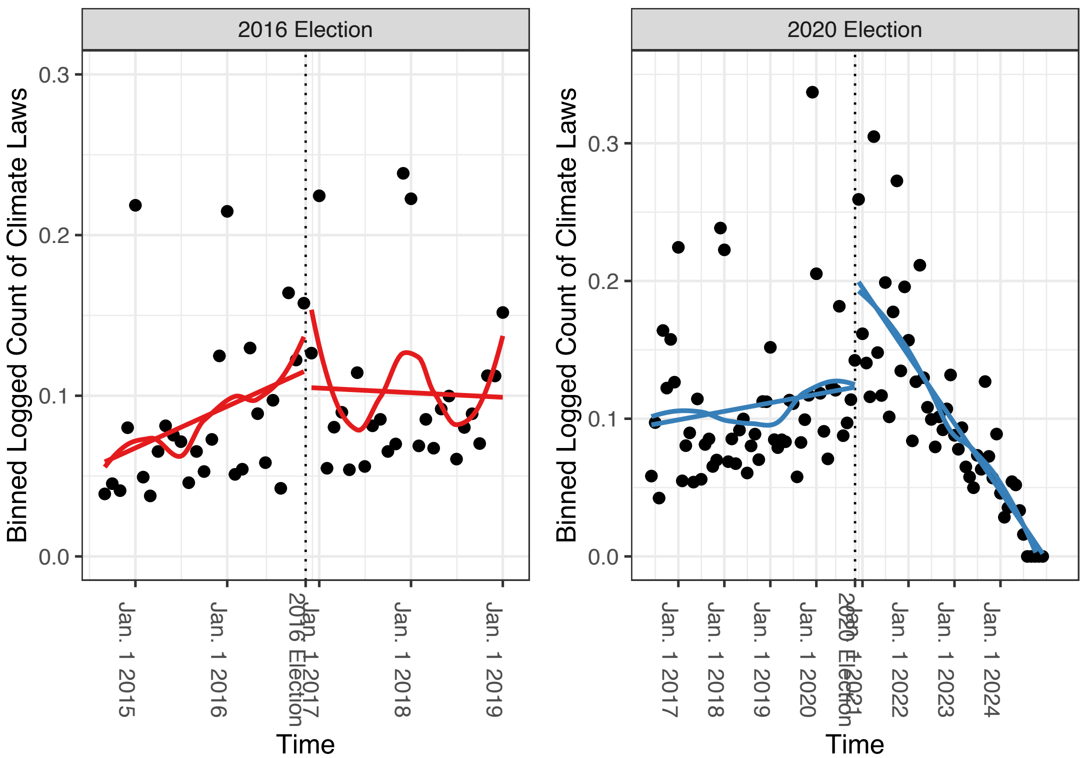

Figure 1: RD Plots of U.S. Presidential Elections on Climate Law Adoption

Figure 1 presents graphical evidence of a change in countries' propensities to adopt climate laws around the 2016 and 2020 United States elections.[3] I fit a linear polynomial as

[2]Given the design, bias in the LATE would emerge if countries strategically adopt climate laws before or after the election. For example, in 2016, the relevant bias in favor of the free-riding argument is if countries were to delay adoption of climate laws until after the election, attenuating the LATE. However, such a case seems unlikely as adoption would only become more difficult with a U.S. president who is less favorable to climate action in power.

[3]RD plots use the logged count outcome; plots for the binary dependent variable display similar results.

well as a loess smoother on each side of the election cutoff. The left panel of the figure suggests that there is a small reduction in the adoption of climate laws when Donald Trump wins the election in 2016. By contrast, the right panel documents a large positive surge in the number of laws adopted when Joe Biden wins the election in 2020.

Table 2 formalizes these estimates, documenting a negative, but statistically indistinguishable from zero, effect in 2016, and a positive and statistically significant effect in 2020. In both cases, the sign of the RD estimate refutes a story of strategic substitutes. That is, the data do not show that countries found it in their interest to do more when the U.S. signaled it would do less by electing Trump, nor would other countries do less when the U.S. elected Biden. When an anti-climate leader was elected in 2016, other countries followed suit and enacted fewer climate laws. In 2020, with the emergence of a pro-climate U.S. presidential winner, the international community responded with more climate action. Results are robust to the inclusion of month fixed effects and country-month trends—which account for the influence of factors like the signing of new international environmental treaties, the onset of a global pandemic, or secular increases in worsening climate that may demand more action—see Appendix B.2.

	Trump (2016)		Biden (2020)	
	(1)	(2)	(3)	(4)
RD Election Effect	-0.009	-0.020	0.067***	0.070***
	(0.017)	(0.019)	(0.022)	(0.020)
DV	Count	Binary	Count	Binary
DV Mean	0.094	0.109	0.105	0.116
Bandwidth	809.875	781.846	1616.020	1504.237
Effective Observations	10547	10149	20497	19701

Table 2: RD Estimates of U.S. Presidential Elections on Climate Law Adoption

Taken together, these empirical findings call into question conventional theoretical accounts of global climate policymaking in which an increase in the effort of other nations decreases the likelihood of effort by other countries. In fact, the evidence suggests the opposite: effort by other nations correlates *positively* with the likelihood that nations take climate action. In what follows, I argue that these empirical findings can be reconciled by augmenting the conventional wisdom to introduce diffused learning as an additional mechanism affecting mitigation investments. Learning effects can engender complementarities, and, if they dominate free-riding temptations, imply positive correlations across climate actions. The formal model now considers how countries' climate policymaking incentives are affected by both free-riding and learning mechanisms.

Formal Model

Consider climate policymaking by $n = 2$ countries indexed by i. Each country determines a level of climate mitigation efforts $a_i \in \mathbb{R}$. Positive levels of effort $a_i > 0$ signify climate reforms that contribute to global abatement and remediation, while negative effort $a_i < 0$ can be thought of as anti-climate measures like deforestation or other means of increasing carbon emissions. The game features sequential moves, meaning that country 1 ("he") moves before country 2 ("she"), and country 2 observes country 1's choice prior to taking an action. While I refer to countries as unitary actors, we can think of each nation as being ruled by a policymaker who is determining remediation policy, or we can think of a median voter in each nation deciding how much to comply with environmental regulations.

Countries' payoffs from efforts toward climate reform depend on a fundamental uncertainty, the global economic returns from a green transition. This is modeled as a state of the world, θ. Neither country knows the true realization of θ—whether or not the green transition will ultimately pay off is unknown—but share the common prior $\theta \sim N(\mu, \frac{1}{\gamma})$. In addition, each country observes a noisy signal of the state of the world, $x_i = \theta + \varepsilon_i$ where $\varepsilon_i \sim N(0, \frac{1}{\beta})$. Countries' signals are their private information and are thus their private beliefs about the economic returns to green policy; higher signals are on average more likely to indicate larger θ, so a country with a higher signal is more optimistic about the success of a green transition. Countries' returns from effort depend on the value of θ and thus capture the idea that countries only want to exert effort in mitigating the effects of climate change if they are sufficiently optimistic that a green transition would reap economic benefits.

As in conventional theoretical accounts of international climate policymaking, countries' abatement efforts generate global benefits but impose local costs. Let $A = a_1 + \lambda a_2$ be the weighted average of global efforts where $\lambda \geq 0$ parameterizes the relative weight of country 2's subsequent efforts vis-à-vis country 1's effort. This parameter can be interpreted either as the relative size and scale between the two countries or as a measure of temporal discounting in mitigation efforts. Countries receive a global benefit of $g(A)$ given total global policy implementation where $g(\cdot)$ is an increasing and concave function. Additionally, adopting climate-friendly policies is costly—there are technological, financial, and political consequences from imposing costs on citizens or large domestic polluters to implement reforms—and exerting effort comes at a cost $c(a_i)$ where $c(\cdot)$ is an increasing and convex function. To keep the problem tractable, let

$$g(A) = \begin{cases} \sqrt{A} & A \geq 0 \\ -\sqrt{|A|} & A < 0, \end{cases}$$

and $c(a_i) = c_i|a_i|$.[4]

Putting things together, country i's utility is written as

$$u_i(a_i, A; \theta) = \theta g(A) - c(a_i).$$

[4]These functional forms allow substantively for the inclusion of negative effort, rather than truncating effort at zero, but are also useful technically in allowing for feasible integration over negative-valued signals, obtaining a one-to-one mapping between signals and effort.

Countries' utility functions capture the logic of strategic substitutes encoded in canonical models—countries derive global benefits from mitigation actions but these gains exhibit diminishing marginal returns—while also allowing for the generation of strategic complementarities in countries' behavior because of the incentives to learn about the economic returns to green policy from the actions of others. Both mechanisms are present in countries' effort decisions and the goal of the theoretical analysis will be to characterize the conditions under which one effect dominates the other. Formally, the theory targets the sign of $\frac{da_2}{da_1}$.

I examine weak Perfect Bayesian equilibria. Country 1's strategy is a function $\alpha_1 : \mathbb{R} \to \mathbb{R}$ that maps his signal x_1 into an effort level a_1. Country 2's strategy is a function $\alpha_2 : \mathbb{R} \times \mathbb{R} \to \mathbb{R}$ that maps her signal x_2 and country 1's effort a_1 into an effort level a_2. Beliefs about θ are formed via Bayes's rule.

Comments on the Model

The model's assumptions are motivated by canonical theories of observational learning (for a review, see Bikhchandani et al. 2024). In particular, two assumptions require further comment: the restriction to $n = 2$ countries and the sequentiality of moves among them. In contrast to extant observational learning models which allow the number of agents n to grow arbitrarily large, I fix the number of countries at $n = 2$. Agents in these models are typically backward-looking as their behavior is only linked through the information conveyed by prior movers, essentially boiling down to a decision-theoretic problem. However, since countries' actions exhibit forward-looking strategic interdependence in this model, increasing the number of countries adds mathematical complexity without developing further theoretical nuance. In Appendix C, I present a simplified model with more than two countries that is closer to the traditional observational learning setup. Within the current model framework, the effect of other countries' climate policy adoption behaviors could be accommodated either by changing the prior expected economic gains from green investments μ or the concavity of the global abatement value function $g(\cdot)$.

In a departure from extant collective action models of international climate policymaking (e.g., Kennard and Schnakenberg 2023), I introduce uncertainty about the benefits accrued from climate abatement efforts and sequential moves. Both of these elements are necessary to model the learning mechanism. In introducing sequential moves, I treat the timing of countries' climate actions as exogenously determined. This is a simplifying assumption, and there are plausible foundations for endogenizing the order of moves. For instance, differences in the precision of countries' information, such as more reliable assessments of the economic or technological feasibility of a green transition, could lead better-informed countries to act earlier (e.g., Zhang 1997). Similarly, variation in climate vulnerability may create incentives for more exposed countries to lead. In both cases, strategic first-mover behavior is consistent with a strong learning mechanism.

Analysis

I begin by establishing the equilibrium of the game (Proposition 1). Then I demonstrate that learning effects dominate free-riding concerns when optimism about the green transition's success outweighs the risk of investment in policy with uncertain returns (Proposition 2).

Equilibrium Climate Efforts

To solve for the equilibrium of the model, I conjecture the existence of country 1's strategy $a_1 = \alpha_1(x_1)$ where $\alpha_1(\cdot)$ is one-to-one. Then, for any a_1 that country 2 observes, she can infer country 1's signal, $x_1 = \alpha_1^{-1}(a_1)$. This means that, conditional on her signal x_2 and country 1's effort level a_1, country 2 believes that $\theta | x_2, a_1 \sim N(\frac{\gamma\mu + \beta\alpha_1^{-1}(a_1) + \beta x_2}{\gamma + 2\beta}, \frac{1}{\gamma + 2\beta})$. Given her private signal x_2 and country 1's effort a_1, country 2's expected utility is

$$u_2(a_2; x_2, a_1) = E[\theta|x_2, a_1]g(a_1 + \lambda a_2) - c(a_2),$$

where her optimal mitigation effort $\alpha_2(x_2, a_1)$ solves the following first-order condition:

$$\underbrace{E[\theta|x_2, a_1]}_{\text{expected green benefits}} \cdot \underbrace{g'(a_1 + \lambda\alpha_2(x_2, a_1))\lambda}_{\text{marginal global contribution}} - \underbrace{c'(\alpha_2(x_2, a_1))}_{\text{marginal costs}} = 0.$$

Given the functional form specifications, I obtain a closed-form solution for country 2's optimal effort:

$$\alpha_2(x_2, a_1) = \begin{cases} -\frac{1}{\lambda}a_1 + \frac{\lambda(\gamma\mu+\beta\alpha_1^{-1}(a_1)+\beta x_2)^2}{4c_2^2(2\beta+\gamma)^2} & x_2 \geq -\frac{\gamma\mu}{\beta} - \alpha_1^{-1}(a_1) \\ -\frac{1}{\lambda}a_1 - \frac{\lambda(\gamma\mu+\beta\alpha_1^{-1}(a_1)+\beta x_2)^2}{4c_2^2(2\beta+\gamma)^2} & x_2 < -\frac{\gamma\mu}{\beta} - \alpha_1^{-1}(a_1). \end{cases} \tag{1}$$

Note that if $x_2 < -\frac{\gamma\mu}{\beta} - \alpha_1^{-1}(a_1)$ then country 2 has particularly pessimistic signal about the value from exerting effort toward mitigating the effects of climate change, and would exert negative effort because $E[\theta|x_2, a_1] < 0$.

Quite naturally, country 2's optimal efforts increase when she is more optimistic about the economic returns to green policy. Formally, $\alpha_2(x_2, a_1)$ is increasing in x_2, country 2's private signal of the economic returns from climate policies.

Country 1's effort a_1 affects country's optimal mitigation investment $\alpha_2(x_2, a_1)$ through two channels. First, as seen in the first term of $\alpha_2(x_2, a_1)$ in Equation 1 above, country 1's effort has a direct effect of changing country 2's marginal contribution to global mitigation cooperation. That is, if country 1 has already committed to large emissions reductions, then country 2's policies have a smaller marginal impact on global abatement, thereby creating a temptation to free-ride. In this way, country 1's behavior engenders a substitutability across nations' mitigation actions, which is reminiscent of classical collective action pathologies.

Moreover, country 1's effort also affects country 2 through a second, informational channel—her expectations about the benefits from green policies—given by $\alpha_1^{-1}(a_1)$ in the second term of $\alpha_2(x_2, a_1)$. When country 1 exerts more effort, it leads country 2 to believe that country 1's signal x_1 was higher, and thus more optimistic about the economic returns from a green transition. Country 2 updates positively about the value of green policy, quantified by an increase in her posterior mean $E[\theta|x_2, a_1]$, which then motivates her to also exert greater effort. Having learned from country 1 by observing his remediation efforts, country 2 then also adopts more ambitious climate reforms.

Now consider the problem of country 1, who faces a similar decision but knows that his actions will influence the trajectory of global climate efforts. Given his signal x_1, country 1 has a posterior belief about the state $\theta|x_1 \sim N(\frac{\gamma\mu+\beta x_1}{\gamma+\beta}, \frac{1}{\gamma+\beta})$ as well as country 2's signal $x_2|x_1 \sim N(\frac{\gamma\mu+\beta x_1}{\gamma+\beta}, \frac{2\beta+\gamma}{\beta(\beta+\gamma)})$. Since he does not know x_2, country 1 does not know how much effort country 2 will commit to downstream, and thus has expected utility

$$u_1(a_1; x_1) = E_{x_2}\Big[E[\theta|x_1]g(a_1 + \lambda\alpha_2(x_2, a_1))\Big] - c(a_1),$$

and his optimal mitigation effort $\alpha_1(x_1)$ satisfies the following first-order condition:

$$E_{x_2}\Big[\underbrace{E[\theta|x_1]}_{\text{expected green benefits}} \cdot \underbrace{g'(a_1 + \lambda\alpha_2(x_2, a_1))}_{\text{marginal global contribution}} \underbrace{\left(1 + \lambda\frac{d\alpha_2(x_2, a_1)}{da_1}\right)}_{\text{expected impact on country 2}} \Big] - \underbrace{c'(a_1)}_{\text{marginal costs}} = 0.$$

Analogous to country 2, notice that if $x_1 < -\frac{\gamma\mu}{\beta}$ then $E[\theta|x_1] < 0$ and country 1's inference about the returns from climate investments are particularly dour. Given the functional form assumptions, a closed-form solution for country 1's effort can be found, so $\alpha_1(x_1)$ can be expressed as

$$\alpha_1(x_1) = \begin{cases} \frac{\beta\lambda x_1(2\gamma\mu+\beta x_1)+\lambda\gamma^2\mu^2}{4c_1c_2(2\beta^2+3\beta\gamma+\gamma^2)} & x_1 \geq -\frac{\gamma\mu}{\beta} \\ \frac{-\beta\lambda x_1(2\gamma\mu+\beta x_1)-\lambda\gamma^2\mu^2}{4c_1c_2(2\beta^2+3\beta\gamma+\gamma^2)} & x_1 < -\frac{\gamma\mu}{\beta}. \end{cases} \tag{2}$$

The following proposition summarizes the equilibrium (with formal proofs in Appendix A).

Proposition 1. *There exists a unique equilibrium characterized by the functions* $\alpha_1(x_1)$, $\alpha_2(x_2, a_1)$ *such that* $a_1^* = \alpha_1(x_1)$*, as defined in Equation 2, and* $a_2^* = \alpha_2(x_2, a_1^*)$*, as defined in Equation 1. Country 1 has beliefs* $\theta|x_1 \sim N(\frac{\gamma\mu+\beta x_1}{\gamma+\beta}, \frac{1}{\gamma+\beta})$ *and country 2 has beliefs* $\theta|x_2, a_1^* \sim N(\frac{\gamma\mu+\beta\alpha_1^{-1}(a_1^*)+\beta x_2}{\gamma+2\beta}, \frac{1}{\gamma+2\beta})$.

In equilibrium, country 1 balances the temptation to free-ride off of the possible climate implementation efforts of country 2 with the possibility that his own inaction could discourage subsequent reforms by sending a bad signal about the viability of a green transition. His actions are influential in determining the course of global climate investments because, on one hand, country 1 could jumpstart a sizable contribution to international climate cooperation; but on the other hand, he might wish to avoid the domestic costs of mitigation measures with the anticipation that country 2 will provide global benefits.[5] I now study how both nations optimally navigate this tradeoff.

The following corollary establishes the learning mechanism: country 1's effort is informative to country 2 about the value of green policy. When country 1 is more optimistic, he exerts greater effort. Having observed greater effort, country 2's expectations about the economic returns to climate policy increase, which further motivates downstream effort. Since countries only want to engage in costly climate investments if they are sufficiently optimistic

[5]While country 2 is clearly advantaged from an informational perspective, country 1's first-mover advantage can be seen in terms of effort. His marginal contribution to global mitigation investments is always weakly greater than country 2's, so for a strong enough signal x_1, he can guarantee some international effort in the event that country 2 takes minimal action.

that they will pay off, this information transmission is critical to calibrating country 2's equilibrium efforts.

Corollary 1. *Country 1's climate policy is informative about θ:*

- *Country 1's equilibrium climate effort is increasing in its signal x_1, $\frac{da_1^*}{dx_1} > 0$;*
- *Country 2's posterior expectation of θ is increasing in country 1's effort, $\frac{dE[\theta|x_2,a_1^*]}{da_1} > 0$.*

Complements and Substitutes

I now characterize the fundamental tradeoff that countries face when determining mitigation investments: under what conditions are nations' climate actions positively or negatively correlated? Formally, when is $\frac{d\alpha_2(x_2,a_1)}{da_1}$ positive, and when is it negative? Fix two possible effort levels by country 1, $a_1' > a_1$, and recall that country 2's optimal effort level solves

$$\underbrace{E[\theta|x_2, a_1]}_{\text{expected green benefits}} \cdot \underbrace{g'(a_1 + \lambda\alpha_2(x_2, a_1))\lambda}_{\text{marginal global contribution}} = \underbrace{c'(\alpha_2(x_2, a_1))}_{\text{marginal costs}},$$

such that country 2 trades off the marginal domestic costs of implementation with her beliefs in a successful green transition and her marginal contribution to global abatement efforts.

The left-hand side of this equation has two components that are in tension with one another. Given country 1's efforts, country 2's marginal contribution to global abatement is smaller when country 1 has already invested large amounts of effort into providing the global benefit of mitigation, $g'(a_1' + \lambda a_2) < g'(a_1 + \lambda a_2)$. There are smaller marginal gains from additional costly remediation, which tempts country 2 to free-ride off of country 1's efforts. This force engenders substitution across countries' climate policies because the effort exerted by country 1 discourages reforms from country 2. However, country 1, having adopted costly climate reforms, signals belief in a successful green transition to country 2, $E[\theta|x_2, a_1'] >$

$E[\theta|x_2, a_1]$. Emboldening country 2 to take more ambitious climate action, country 1's efforts generate complementarities in countries' behavior. This also implies that by contrast, a smaller level of effort from country 1 makes country 2's marginal contribution more impactful and, from country 1's perspective, could provide greater global benefits; however, this also diminishes country 2's expectations about the economic returns to green policy because country 1's lack of climate action is a signal of his pessimism.

Countries' actions therefore influence each other through two channels. The temptation to free-ride, stemming from diminished marginal contributions, creates a strategic substitutability in countries' climate policies; however, the incentive to learn about a successful green transition by signaling information induces strategic complementarities. These two forces push in opposite directions when attempting to ascertain the marginal effect of country 1's effort on country 2's behavior. Corollary 2 formalizes this discussion by decomposing $\frac{d\alpha_2(x_2,a_1)}{da_1}$ into these two constituent effects, where a_1 represents the direct returns from country 1's effort and $\alpha_1^{-1}(a_1)$ represents the informational value.

Corollary 2. *Country 2's optimal mitigation effort is:*

- *Decreasing in the direct effect of country 1's effort,* $\frac{\partial\alpha_2(x_2,a_1)}{\partial a_1} \leq 0$*;*
- *Increasing in the informational effect of country 1's effort,* $\frac{\partial\alpha_2(x_2,a_1)}{\partial\alpha_1^{-1}(a_1)} \geq 0$.

Figure 2 illustrates the effects of the free-riding and learning mechanisms, plotting country 2's effort $\alpha_2(a_1, x_2)$ as a function of the behavior for country 1 a_1 given different possible signals x_2. The first panel depicts the direct effects increasing country 1's mitigation policies, holding constant the informational value of such effort. This begets less ambitious climate action from country 2 because her marginal contributions are diminished, generating free-riding temptations, indicated by the negative slope of the lines in the panel. The second panel shows that, holding constant the direct effect from country 1's effort, country 2 is incentivized to exert greater effort when she receives a stronger signal from country 1 about the success of the green transition. The positive slope of the lines in this panel reflect this value of learning. Finally, the third panel demonstrates the total effect: countries' actions, depending on which mechanism dominates, can either be substitutes or complements. Whether nations' actions are complements or substitutes in equilibrium determines the sign of the correlation between their efforts. Here, when the slope of the line is positive, then the learning channel dominates the free-riding channel; when it is negative, the free-riding channel dominates the learning channel. Then in the former case countries' climate actions are positively correlated, while in the latter case they are negatively correlated.

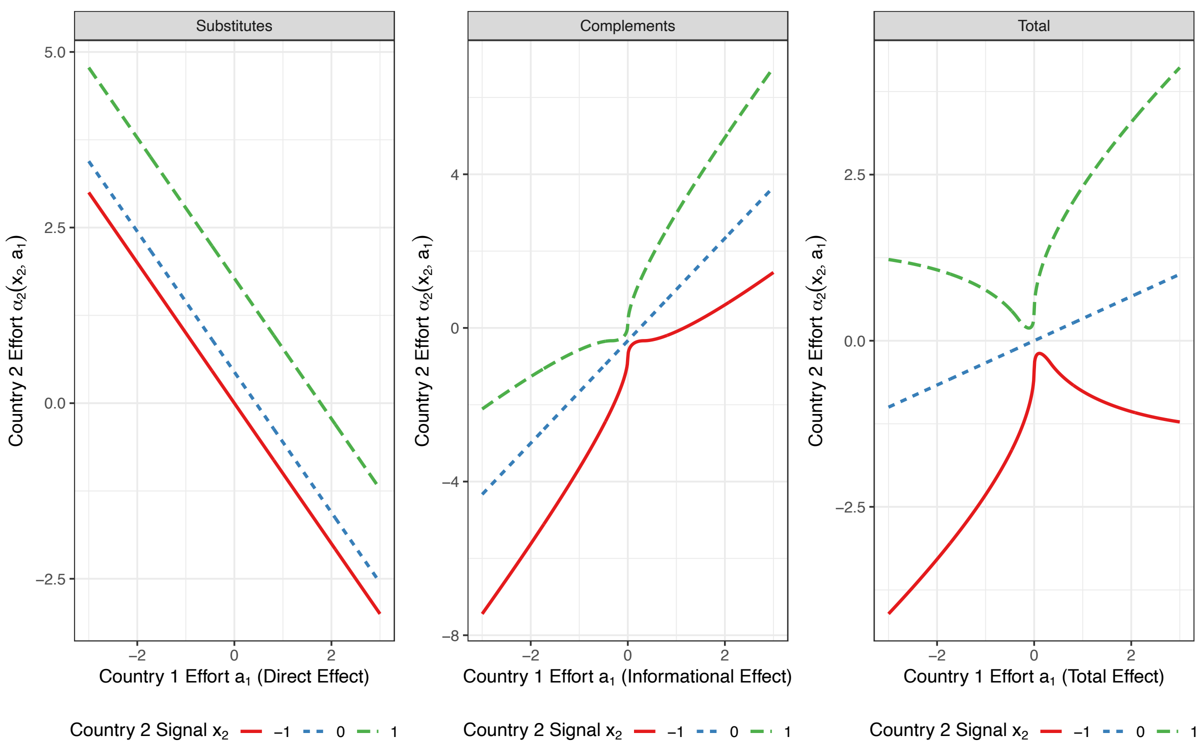

Figure 2: Substitutes and Complements Mechanisms on Climate Mitigation Efforts
$\mu = 0.5,\ \gamma = 1,\ \beta = 1,\ \lambda = 1,\ c_1 = 0.5,\ c_2 = 0.25$

Which factor dominates? I now consider the conditions under which the effects of changing country 1's information outweigh the direct effects of his effort on country 2's decisionmaking. The result is simple: when country 2's posterior update about the success of a green transition, the public optimism from country 1 along with her private signal x_2, dominates her aversion toward exerting costly effort into policies with unknown return, then the learning channel that engenders strategic complementarities is stronger than the free-riding channel that generates strategic substitutes. Alternatively, when the risk involved in implementing green policies is large—the returns to such investments are unknown and their implementation is domestically politically costly—then substitution effects dominate learning incentives.

Proposition 2. *Complementarity effects dominate substitution effects when public optimism is large relative to the risks of green policy investment,*

$$\underbrace{\left(-\frac{g''(A)}{g'(A)}\right)^{-1}}_{\substack{\textit{risk aversion from}\\ \textit{costly climate investment}}} < \underbrace{\frac{|\gamma\mu + \beta\alpha_1^{-1}(a_1) + \beta x_2|}{\beta}}_{\textit{posterior optimism}}.$$

Proposition 2 determines the dominant mechanism, either the substitution effect or the learning effect, on country 2's climate policy decisionmaking. These two mechanisms are both always operant, but the proposition determines which outweighs the other. That is, it tells us the sign of the correlation between countries' climate efforts. Moreover, the proposition states that we can assess the dual effects of complementarity and substitutability based on the interplay between public assessments of optimism toward green policy and the induced risk that comes with implementing costly mitigation policies with unknown economic returns.

The right-hand side of the inequality approximates country 2's expectations about θ, the informational returns from country 1's costly climate investments, while the left-hand side is a measure of country 2's Arrow-Pratt "risk aversion." Since the economic value of the green transition is unknown, the value of country 1's effort on country 2's posterior update must outweigh her tolerance for implementing policies with uncertain returns in order for the total effect of country 1's effort on her own effort to be positive. The result also underscores that uncertainty exacerbates the temptation to free-ride (McAllister and Schnakenberg 2022): if country 2 becomes less willing to tolerate the uncertainties of the green transition's benefits, thereby decreasing the right-hand side of the inequality, country 2's incentive to free-ride becomes stronger relative to her incentive to learn.

Implications of the Learning Mechanism

The theory identifies a learning mechanism that connects the proliferation of climate action to optimistic beliefs about the success of the green transition. In particular, the model generates two implications connecting beliefs and actions within and across countries. First, a country's beliefs about the success of a green transition should correlate positively with its effort, $cor(x_i, a_i) > 0$. Moreover, learning is dominant over free-riding, a country's beliefs should also positively correlate with the effort of others in reduced form, $cor(x_i, a_j) > 0$. This section teases out these implications of the learning mechanism by studying the relationship between beliefs and subsequent climate policy stringency.

Since the model's information structure is sparse, I empirically enrich the context by examining both mass-level and elite-level beliefs. We might think of the private beliefs that countries hold in the model as a function of public opinion sentiments. Citizen beliefs about the importance of climate change can facilitate action (Melnick 2025), and empirical studies of public opinion have concluded that climate policy is fairly responsive to mass beliefs (Bromley-Trujillo and Poe 2020; Schaffer, Oehl and Bernauer 2022). I employ repeated cross-sectional data from Eurobarometer and AmericasBarometer (LAPOP), which have asked whether respondents think climate change is a serious problem (1-4 scale) to measure mass beliefs. In total, data is available for 31 countries across Europe and Latin America between 2011 and 2023. This data is valuable because it allows for measurement of beliefs within countries over time to assess learning dynamics, and helps to uncover how citizens' beliefs covary with the policy stringency of their countries.

Another interpretation of the model is that beliefs come from policy elites who advise leaders in climate policy implementation. Consistent with this notion, I make use of a survey of approximately 900 climate negotiators and climate scientists compiled between September 2020 and January 2021, which constitutes one of the largest samples of climate policy elites ever systematically polled (Victor, Lumkowsky and Dannenberg 2022). Respondents were asked to assess the ambition (relative to the country's economic strength) of nationally determined contributions (NDCs) for 10 different countries as well as their confidence that each country would fulfill their NDC (both on a 1-5 scale). These survey items assist in examining the second implication of the model—whether respondent beliefs ultimately predict the policy stringency of other nations given the climate commitments that each country had set prior—as we could imagine countries making further remediation efforts after their stating their climate commitments with belief updating in between (cf. Melnick and Smith 2025). Unfortunately, each respondent was only surveyed once, so we cannot assess the dynamics of negotiators' beliefs, but I leverage within-respondent variation in negotiators' assessments of multiple countries' climate commitments to study the relationship between beliefs and policy stringency.

I first establish empirical evidence consistent with the model's implication that beliefs and effort within countries should be positively correlated using the Eurobarometer and AmericasBarometer data. To do so, I estimate the following regression for respondent r living in country i surveyed in year t:

$$\text{Stringency}_{i,t} = \beta \text{ CC Serious}_{i[r],t} + \alpha_i + \lambda_t + \varepsilon_{i[r],t},$$

where stringency is measured using the CAPMF from above. The independent variable is the extent to which respondent r in country i judged climate change to be a serious problem, where higher values indicate greater seriousness. I estimate country and year fixed effects and cluster standard errors by country. This design targets variation across individuals' beliefs within countries, and maps this onto the stringency of subsequent environmental policies. However, since the dependent variable is measured at the country level I also report pooled results at the country-year level by averaging respondents' beliefs,

$$\text{Stringency}_{i,t} = \beta \text{ Average CC Serious}_{i,t} + \alpha_i + \lambda_t + \varepsilon_{i,t}.$$

	CAPMF			
	(1)	(2)	(3)	(4)
CC Serious Problem	0.024***	0.003**	0.803***	0.199**
	(0.005)	(0.001)	(0.099)	(0.082)
Observations	172,946	172,946	168	168
R^2	0.709	0.968	0.755	0.965
Within R^2	0.009	0.002	0.304	0.090
DV Mean	4.38	4.38	2.19	2.19
Number of Countries	31	31	31	31
Country fixed effects	✓	✓	✓	✓
Year fixed effects		✓		✓

p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Robust standard errors clustered at the country level

Table 3: Mass Beliefs and Climate Policy Stringency

Table 3 displays the results and demonstrates a positive relationship between a respondent's assessment of the seriousness of climate change and the stringency of policy that the country's government has undertaken. This relationship is stronger when pooling up to the country level. Consistent with the model, within countries, respondents' private beliefs positively covary with policy stringency. Furthermore, as shown in Appendix B.3, there is suggestive evidence that the average assessment of the seriousness of climate change is increasing over time, and the variance in respondents' answers is decreasing over time. Taken together with the findings in Table 3, the results suggest that over time, publics update their beliefs about the seriousness of climate change, which then induces further action.

Turning to elite beliefs, I consider how climate negotiators and scientists assess the nationally determined contributions of other nations and correlate these beliefs with the subsequent behavior of those nations. Respondents were asked to assess pledges made by Australia, Brazil, China, the European Union, India, Russia, Saudi Arabia, South Africa, the United States, and their own country. For respondent r assessing the commitment of country i, I estimate the following regression:

$$\text{Stringency}_{i,t} = \beta \text{ Beliefs}_{r,i} + \alpha_i + \eta_r + \varepsilon_{r,i}.$$

Since the elites' beliefs were elicited at the end of 2020, I examine downstream policy stringency in 2021, 2022, and 2023. Hence the dependent variable is country i's CAPMF score in either 2021, 2022, or 2023, and respondent r's beliefs are either their assessment of country i's ambition or respondent r's confidence that country i will fulfill its nationally determined contribution. I estimate respondent fixed effects η_r to control for any expert-specific biases in assessments across countries as well as country fixed effects α_i to capture baseline levels of variation in the ambition in countries' climate commitments. Standard errors are clustered at the respondent level.

Table 4 displays the results. Expert respondents' beliefs about the ambition of countries' climate commitments are positively correlated, at statistically significant levels, with more stringent policy measures that countries ultimately undertake. These results bolster confidence in the learning mechanism by lending credence to the second empirical implication: as countries' private beliefs increase, other nations are also on average more likely to exert more

	Stringency$_{2021}$		Stringency$_{2022}$		Stringency$_{2023}$	
	(1)	(2)	(3)	(4)	(5)	(6)
Belief NDC Ambitious	0.024***		0.021***		0.025***	
	(0.008)		(0.008)		(0.008)	
Belief NDC Fulfilled		0.013**		0.011**		0.017***
		(0.006)		(0.005)		(0.006)
Observations	4,068	4,293	4,068	4,293	4,068	4,293
R^2	0.929	0.937	0.930	0.937	0.928	0.935
Within R^2	0.005	0.002	0.004	0.001	0.005	0.003
DV Mean	4.26	4.18	4.23	4.26	4.18	4.23
Respondent fixed effects	✓	✓	✓	✓	✓	✓
Belief Country fixed effects	✓	✓	✓	✓	✓	✓

p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Robust standard errors clustered at the respondent level

Table 4: Elite Beliefs and Climate Policy Stringency

effort. This reduced-form relationship works because survey respondents have updated posterior beliefs about the success of the green transition given nations' climate commitments, which then correlate with sustained climate efforts downstream.

Consistent with the theory, there is a positive correlation between beliefs, elicited and both mass and elite levels, and climate policy stringency. These results provide evidence of a learning mechanism connecting private beliefs to climate mitigation efforts. Specifically, they are useful in distinguishing or isolating the empirical implications between temptations to free-ride and learning, as the former mechanism produces no expectations about the relationship between beliefs and effort. Moreover, as there may be many theoretical explanations consistent with a story of strategic complementarities—which underlies the positive correlations documented at the beginning of the paper—these findings bolster confidence in the specific learning mechanism identified by the theory.

Qualitative Accounts of Learning

In addition to the quantitative evidence presented in the previous section, qualitative evidence also corroborates the notion that countries are learning from other nations when implementing climate policies. Numerous studies document diffusion effects in climate policy implementation (e.g., Harrison 2010; Thisted and Thisted 2020; Linsenmeier, Mohommad and Schwerhoff 2023). This section documents several cases that are illustrative of the learning mechanism.

Following then-President Joe Biden's U.S. presidential victory in 2020, the United States had proposed the Build Back Better Act—an act that Biden personally championed and expended large amounts of political capital to realize, ultimately becoming the Inflation Reduction Act, the largest investment in clean energy in the world—as its cornerstone legislative program. Meetings with international leaders further inspired action around the globe based on Biden's beliefs in the economic value of the green transition. Indeed, in talks with then-Canadian Prime Minister Justin Trudeau in February 2021, the two leaders "expressed their shared commitment to taking real action to fighting climate change while growing the economy and creating good jobs," and announced a formal diplomatic project to "align [their] policies and [their] goals to increase ambition to tackle the climate crisis."[6] Two months later, the Canadian government announced several new, expanded climate policies to enhance their NDC in early 2021. Trudeau initiated programs to incentivize Canadian businesses to achieve net-zero emissions and develop cleaner industry.[7] Importantly, Trudeau emphasized cooperation on climate issues with the United States, as both countries recognized the economic value in ambitious climate investments,[8] and affirmed a common belief

[6] https://www.pm.gc.ca/en/news/news-releases/2021/02/23/prime-minister-canada-welcomes-plan-revitalize-and-expand-ties-united

[7] https://www.pm.gc.ca/en/news/news-releases/2021/04/22/prime-minister-trudeau-announces-increased-climate-ambition

[8] https://www.canada.ca/en/environment-climate-change/news/2021/02/canada-us-high-level-climate-ministerial.html

that greater ambition would realize greater policy success.

Another example of learning across borders comes from South Korea's 2020 legislative elections. The incumbent Democratic Party won in a landslide victory, in part due to the party's emphasis on ambitious climate spending. Then-President Moon Jae-in campaigned on a European Union-style Green Deal, explicitly referring to the E.U.'s climate plan as a template for Korean policy.[9] In its own Green New Deal, South Korea committed to carbon neutrality by 2050, and the plan includes large-scale investments in renewable energy, the introduction of a carbon tax, the phaseout of coal financing by public institutions, and the creation of a jobs transition programs to support workers who relocate into green jobs.[10] This was facilitated by the formation of a working group between the Koreans and the Europeans, initiated to share ideas and harmonize policy solutions[11]—allowing the Koreans to learn from the Europeans' optimism—and, in 2021, the two countries compared policy proposals. The two countries highlighted their commonalities and complementarities in their approaches to tackling climate change, confirming that "climate, energy and environment policies have to be addressed holistically, in the light of the interdependence of challenges."[12]

Finally, consider the climate commitment pledged by then-South African President Jacob Zuma at the Copenhagen climate summit in 2009. The summit's final document, the Copenhagen Accord, was largely panned as incomplete. However, Zuma, who initially considered ditching the summit,[13] was considered "one of the stars" of the negotiations by committing to reduce emissions by 34% below current expected levels by 2020 and by about 42% by 2025.[14] The target was particularly unexpected because it was the first time the

[9] https://www.forbes.com/sites/davidrvetter/2020/04/16/south-korea-embraces-eu-style-green-deal-for-covid-19-recovery/

[10] https://www.climatechangenews.com/2020/04/16/south-korea-implement-green-new-deal-ruling-party-election-win/

[11] https://www.mofa.go.kr/eng/brd/m_5658/view.do?seq=318785

[12] https://www.eeas.europa.eu/eeas/eu-republic-korea-joint-press-release-following-working-group-energy-environment-and-climate-change_en

[13] https://unfccc.int/sites/default/files/cop15_mw_091211_sa.pdf

[14] http://news.bbc.co.uk/2/hi/africa/8398775.stm

country had ever made such a pledge, and because of the resistance from influential, pro-status quo actors like Eskom, the country's public utility company. Observers note that, while Zuma never justified his sudden commitment—which transformed national dialogue inside of South Africa toward building a green economy—it may have been due to similarly ambitious pledges from peer countries like China, India, and Brazil (Hochstetler 2020, 40), suggestive of complementarities in climate commitments across developing nations.

Consequences for International Institutions

Conventional wisdom, underscoring free-riding concerns, has proposed a set of institutional solutions in an attempt to facilitate international climate cooperation. For example, the fines included in the Kyoto Protocol aimed to deter potential free-riding by raising the costs of noncompliance with reduction targets (Barrett 2003; Victor 2011; Hovi, Ward and Grundig 2015). Other proposals like "climate clubs" seek to minimize free-riding by restricting abatement efforts to a smaller number of participating nations while levying tariffs on those not in the club (Nordhaus 2015). However, temptations to free-ride, while certainly present, may not be the dominant concern when states enact climate policy and consider possible investments by others. Institutions with intentions to maximize global mitigation investments should therefore be designed to exploit the complementarity effects of nations' climate policymaking behavior rather than solely to punish potential free-riders. This means managing the dual effects—the direct effect associated with free-riding as well as the informational effect from learning—of the impacts of countries' mitigation actions on subsequent effort.

Per this paper's theoretical takeaways, institutional designers may wish to adopt an alternative set of principles that foreground the roles of information and expectations in shaping international climate cooperation. The importance of international institutions in reducing uncertainty is well-established (Keohane 1982; 1984), as institutions can generate and disseminate information via review processes (Abbott 2017; Aldy 2018), which allow for the transmission of knowledge about how best to structure policies and approach the problem of climate change mitigation (Chayes and Chayes 1995). As the theoretical analysis illustrates, when expectations about the success of a green transition outweigh risk aversion from uncertain climate investments, then international efforts to address climate change are complementary.

Institutions, therefore, have a natural role in shaping prior beliefs about the returns to climate investments by transmitting information about policy effectiveness (captured by μ and γ in the model). This is reminiscent of arguments that international organizations can be used to disseminate information bolstered by policy domain expertise (Johns 2007; Fang 2008; Johnson and Urpelainen 2014). In terms of engendering complementarities, it is always better for countries to have more optimistic prior expectations, and more precise information is beneficial to accompany this optimism.

Institutions can also influence countries' risk perceptions, counteracting aversions that discourage remediation and enable free-riding. The tradeoff between free-riding effects and learning effects is dampened if marginal contributions to global output are high (the shape of $g(\cdot)$), so institutions could facilitate the dissemination of technology that raises the benefits from potential mitigation investments. By modifying how the benefits and costs of mitigation are perceived, institutions can generate "increasing returns" (Pierson 2000; Hale 2020).

The information dissemination provisions in the Paris Agreement demonstrate the possibility of institutional infrastructure to facilitate learning dynamics that the model highlights. Articles 13, 14, and 15 of the Paris Agreement outline the review process of individual country progress toward climate commitments, a worldwide discussion of aggregate performance, as well as nonpunitive troubleshooting of obstacles to policy implementation (UNFCCC 2015). While this "global stocktake" process is not intended to single out any individual country for its failure to comply with targets—as any "naming and shaming" is supposed to flow from the global stocktake by other public actors (Milkoreit and Haapala 2017)—this institutional framework could be used to disseminate information about countries' policy successes, which could bolster common, public expectations about the value of green investments.

Beyond Paris's pledge-and-review structure, institutions may also assist in expectations management by providing a platform for nations to pool common information. For example, the World Bank launched the Partnership for Market Readiness (PMR) in 2011, which "supports countries to assess, prepare, and implement carbon pricing instruments [and] serves as a platform for countries to share knowledge and work together to shape the future of cost-effective climate change mitigation" (World Bank Partnership for Market Readiness 2017). This institution has been accredited with transforming global familiarity with, understanding of, and comfort with carbon pricing instruments, leading to a larger uptake of carbon pricing (Dickman and Larkin 2017). By dispersing knowledge on carbon pricing and supporting its implementation, institutions like the PMR have promoted carbon pricing and have succeeded in making it a more accessible policy tool, thereby facilitating learning among nations about policies that can assist in the green transition (Thisted and Thisted 2020, 816).

Conclusion

This article reassesses the conventional wisdom of international climate policymaking that countries' efforts to mitigate the effects of climate change are solely substitutable and proposes an alternative theoretical framework in which they may also be complementary. While free-riding concerns may entice nations to shirk in their mitigation investments, I argue that the implementation of environmental policies is also a signal about the expected policy success of costly climate investments. Hence, the strength of positive or negative incentives to take climate action upon observing action by other countries is not *ex ante* clear. With theoretical analysis, I show that when nations' optimism about the expected economic returns from climate investment outweigh their aversion toward investing in a risky policy such as climate mitigation, then the positive effects from learning dominate free-rider temptations.

The theory provides several implications for international climate cooperation and the design of international climate institutions. As discussed above, the model suggests a departure from institutional mechanisms that punish free-riders and toward a design that centers around shaping expectations about successful policy implementation. Future research could consider the optimal design of institutions that are explicitly geared toward maximizing countries' expectations about the success of climate policy implementation. Additionally, other work expanding on this article might also consider how best to maximize cross-country learning in terms of factors such as policy instrument choice or geographic concentration.

Beyond climate cooperation, the theoretical framework advanced in this paper might assist in studying global public goods problems in other realms of international politics. The core tension of the model boils down to when countries should invest in global public goods as a function of their collective beliefs about the success of these investments and the temptations to free-ride off of others; when the former dominates the latter, then global public goods contributions are complementary. For example, in the realm of collective security, countries often face the dilemma of whether to arm in the face of a potential adversary, whose strength may be unknown, or whether to free-ride on the security provided by other nations. Contributing to collective defense is costly, but observing greater investments may be a signal that a contributing state believes the adversary is particularly strong, and therefore greater investment is worthwhile. The model helps us understand, in broadest terms, the incentives nations face to cooperate in an environment of common values uncertainty.

References

Abbott, Kenneth W. 2017. "Orchestrating experimentation in non-state environmental commitments." *Environmental Politics* 26(4):738–763.

Aklin, Michaël and Matto Mildenberger. 2020. "Prisoners of the Wrong Dilemma: Why Distributive Conflict, Not Collective Action, Characterizes the Politics of Climate Change." *Global Environmental Politics* 20(4):4–27.

Aldy, Joseph E. 2018. Policy Surveillance: Its Role in Monitoring, Reporting, Evaluating and Learning. In *Governing Climate Change: Polycentricity in Action?*, ed. Andrew Jordan, Dave Huitema, Harro van Asselt and Johanna Forster. Cambridge: Cambridge University Press pp. 210–228.

Baldwin, Elizabeth, Sanya Carley and Sean Nicholson-Crotty. 2019. "Why do countries emulate each others' policies? A global study of renewable energy policy diffusion." *World Development* 120(C):29–45.

Banerjee, Abhijit. 1992. "A Simple Model of Herd Behavior." *The Quarterly Journal of Economics* 107(3):797–817.

Bank, World. 2017. Partnership for Market Readiness: Supporting Action for Climate Change Mitigation. Technical report The World Bank.

Barrett, Scott. 2003. *Environment and Statecraft: The Strategy of Environmental Treaty-Making*. Oxford: Oxford University Press.

Bechtel, Michael M. and Kenneth F. Scheve. 2013. "Mass support for global climate agreements depends on institutional design." *Proceedings of the National Academy of Sciences* 110(34):13763–13768.

Bernauer, Thomas. 2013. "Climate Change Politics." *Annual Review of Political Science* 16:421–448.

Bikhchandani, Sushil, David Hirshleifer and Ivo Welch. 1992. "A Theory of Fads, Fashion, Custom, and Cultural Change as Informational Cascades." *Journal of Political Economy* 100(5):992–1026.

Bikhchandani, Sushil, David Hirshleifer, Omer Tamuz and Ivo Welch. 2024. "Information Cascades and Social Learning." *Journal of Economic Literature* 62(3):1040–1093.

Botta, Enrico and Tomasz Koźluk. 2014. Measuring Environmental Policy Stringency in OECD Countries: A Composite Index Approach. OECD Economics Department Working Paper 1177 OECD Publishing.

Bromley-Trujillo, Rebecca and John Poe. 2020. "The importance of salience: public opinion and state policy action on climate change." *Journal of Public Policy* 40(2):280–304.

Bueno de Mesquita, Bruce and Alastair Smith. 2022. "A new indicator of coalition size: Tests against standard regime-type indicators." *Social Science Quarterly* 103(2):365–379.

Busby, Joshua W. and Johannes Urpelainen. 2020. "Following the Leaders? How to Restore Progress in Global Climate Governance." *Global Environmental Politics* 20(4):99–121.

Calonico, Sebastian, Matias D. Cattaneo and Rocio Titiunik. 2014. "Robust Nonparametric Confidence Intervals for Regression-Discontinuity Designs." *Econometrica* 82(6):2295–2326.

Carattini, Stefano, Greer Gosnell and Alessandro Tavoni. 2020. "How developed countries can learn from developing countries to tackle climate change." *World Development* 127:104829.

Carattini, Stefano, Simon Levin and Alessandro Tavoni. 2019. "Cooperation in the Climate Commons." *Review of Environmental Economics and Policy* 13(2):227–247.

Chayes, Abram and Antonia Handler Chayes. 1995. *The New Sovereignty: Compliance with International Regulatory Agreements*. Cambridge: Harvard University Press.

Colgan, Jeff D., Jessica F. Green and Thomas N. Hale. 2021. "Asset Revaluation and the Existential Politics of Climate Change." *International Organization* 75(2):586–610.

Dickman, Antonia and Julia Larkin. 2017. Second Independent Evaluation of the PMR: Inception Report. Technical report Ipsos MORI Social Research Institute London: .

Doob, Joseph L. 1953. *Stochastic Processes*. Wiley.

Elkins, Zachary and Beth A. Simmons. 2005. "On Waves, Clusters, and Diffusion: A Conceptual Framework." *The Annals of the American Academy of Political and Social Science* 598(1):33–51.

Eyster, Erik, Andrea Galeotti, Navin Kartik and Matthew Rabin. 2014. "Congested observational learning." *Games and Economic Behavior* 87(C):519–538.

Fang, Songying. 2008. "The Informational Role of International Institutions and Domestic Politics." *American Journal of Political Science* 52(2):304–321.

Fang, Songying and Randall W. Stone. 2012. "International Organizations as Policy Advisors." *International Organization* 66(4):537–569.

Fankhauser, Samuel, Caterina Gennaioli and Murray Collins. 2016. "Do international factors influence the passage of climate change legislation?" *Climate Policy* 16(3):318–331.

Gazmararian, Alexander F. and Dustin Tingley. 2023. *Uncertain Futures: How to Unlock the Climate Impasse*. New York: Cambridge University Press.

Hale, Thomas. 2020. "Catalytic Cooperation." *Global Environmental Politics* 20(4):73–98.

Harrison, Kathryn. 2010. "The Comparative Politics of Carbon Taxation." *Annual Review of Law and Social Science* 6(Volume 6, 2010):507–529.

Harrison, Rodrigo and Roger Lagunoff. 2017. "Dynamic Mechanism Design for a Global Commons." *International Economic Review* 58(3):751–782.

Hochstetler, Kathryn. 2020. *Political Economies of Energy Transition: Wind and Solar Power in Brazil and South Africa*. Business and Public Policy Cambridge: Cambridge University Press.

Hoffmann, Matthew J. 2011. *Climate Governance at the Crossroads: Experimenting with a Global Response after Kyoto*. Oxford: Oxford University Press.

Hovi, Jon, Hugh Ward and Frank Grundig. 2015. "Hope or Despair? Formal Models of Climate Cooperation." *Environmental & Resource Economics* 62(4):665–688.

Johns, Leslie. 2007. "A Servant of Two Masters: Communication and the Selection of International Bureaucrats." *International Organization* 61(2):245–275.

Johnson, Tana and Johannes Urpelainen. 2014. "International Bureaucrats and the Formation of Intergovernmental Organizations: Institutional Design Discretion Sweetens the Pot." *International Organization* 68(1):177–209.

Kennard, Amanda and Keith E. Schnakenberg. 2023. "Comment: Global Climate Policy and Collective Action." *Global Environmental Politics* 23(1):133–144.

Keohane, Robert O. 1982. "The demand for international regimes." *International Organization* 36(2):325–355.

Keohane, Robert O. 1984. *After Hegemony: Cooperation and Discord in the World Political Economy*. Princeton: Princeton University Press.

Keohane, Robert O. and David G. Victor. 2016. "Cooperation and discord in global climate policy." *Nature Climate Change* 6:570–575.

Kruse, Tobias, Antoine Dechezleprêtre, Rudy Saffar and Léo Robert. 2022. Measuring environmental policy stringency in OECD countries: An update of the OECD composite EPS indicator. Technical Report 1703 OECD.

Levin, Kelly, Benjamin Cashore, Steven Bernstein and Graeme Auld. 2012. "Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change." *Policy Sciences* 45(2):123–152.

Linsenmeier, Manuel, Adil Mohommad and Gregor Schwerhoff. 2023. "Global benefits of the international diffusion of carbon pricing policies." *Nature Climate Change* 13(7):679–684.

McAllister, Jordan H. and Keith E. Schnakenberg. 2022. "Designing the Optimal International Climate Agreement with Variability in Commitments." *International Organization* 76(2):469–486.

Melnick, Justin. 2025. "Information and Climate (In)action.".

Melnick, Justin and Alastair Smith. 2025. "Shaming Paris: A Political Economy of Climate Commitments." *International Organization* 79(2):281–305.

Milkoreit, Manjana and Kate Haapala. 2017. Designing the Global Stocktake: A Global Governance Innovation. Technical report Center for Climate and Energy Solutions.

Morris, Stephen and Hyun Song Shin. 2003. Global games: Theory and applications. In *Advances in Economics and Econometrics (Proceedings of the Eighth World Congress of* *the Econometric Society)*, ed. Mathias Dewatripont, Lars Peter Hansen and Stephen J. Turnovsky. Cambridge: Cambridge University Press.

Nachmany, Michal, Sam Fankhauser, Joana Setzer and Alina Averchenkova. 2017. Global trends in climate change legislation and litigation. Technical report Grantham Institute.

Nachtigall, Daniel, Luisa Lutz, Miguel Cárdenas Rodríguez, Filippo Maria D'Arcangelo, Ivan Haščič, Tobias Kruse and Rodrigo Pizarro. 2024. "The Climate Actions and Policies Measurement Framework: A Database to Monitor and Assess Countries' Mitigation Action." *Environmental and Resource Economics* 87(1):191–217.

Nordhaus, William. 2015. "Climate Clubs: Overcoming Free-Riding in International Climate Policy." *American Economic Review* 105(4):1339–1370.

Olson, Mancur. 1965. *The Logic of Collective Action: Public Goods and the Theory of Groups*. Cambridge: Harvard University Press.

Ostrom, Elinor. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Dallas, TX: Cambridge University Press.

Pierson, Paul. 2000. "Increasing Returns, Path Dependence, and the Study of Politics." *The American Political Science Review* 94(2):251–267.

Ross, Michael L. 2025. "The New Political Economy of Climate Change." *World Politics* 77(1):155–194.

Rowan, Sam S. 2025. "From Gridlock to Ratchet: Conditional Cooperation on Climate Change." *International Organization* 79(2):257–280.

Sabel, Charles F. and David G. Victor. 2017. "Governing global problems under uncertainty: making bottom-up climate policy work." *Climatic Change* 144(1):15–27.

Sauquet, Alexandre. 2014. "Exploring the nature of inter-country interactions in the process of ratifying international environmental agreements: the case of the Kyoto Protocol." *Public Choice* 159(1/2):141–158.

Schaffer, Lena Maria, Bianca Oehl and Thomas Bernauer. 2022. "Are policymakers responsive to public demand in climate politics?" *Journal of Public Policy* 42(1):136–164.

Simmons, Beth A., Frank Dobbin and Geoffrey Garrett. 2006. "Introduction: The International Diffusion of Liberalism." *International Organization* 60(4):781–810.

Smith, Lones and Peter Sørensen. 2000. "Pathological Outcomes of Observational Learning." *Econometrica* 68(2):371–398.

Stern, Nicholas. 2007. *The Economics of Climate Change: The Stern Review*. Cambridge: Cambridge University Press.

Stokes, Leah C. 2016. "Electoral Backlash against Climate Policy: A Natural Experiment on Retrospective Voting and Local Resistance to Public Policy." *American Journal of Political Science* 60(4):958–974.

Thisted, Ebbe V. and Rune V. Thisted. 2020. "The diffusion of carbon taxes and emission trading schemes: the emerging norm of carbon pricing." *Environmental Politics* 29(5):804–824.

Torney, Diarmuid. 2019. "Follow the leader? Conceptualising the relationship between leaders and followers in polycentric climate governance." *Environmental Politics* 28(1):167–186.

UNFCCC. 2015. "Paris Agreement.".

Urpelainen, Johannes. 2011. "A California Effect for International Environmental Externalities?" *International Interactions* 37(2):170–189.

Urpelainen, Johannes and Thijs Van de Graaf. 2018. "United States non-cooperation and the Paris agreement." *Climate Policy* 18(7):839–851.

van der Ven, Hamish, Steven Bernstein and Matthew Hoffmann. 2017. "Valuing the Contributions of Nonstate and Subnational Actors to Climate Governance." *Global Environmental Politics* 17(1):1–20.

Victor, David G. 2011. *Global Warming Gridlock: Creating More Effective Strategies for Protecting the Planet*. Cambridge: Cambridge University Press.

Victor, David G., Marcel Lumkowsky and Astrid Dannenberg. 2022. "Determining the credibility of commitments in international climate policy." *Nature Climate Change* 12(9):793–800.

Voeten, Erik. 2025. "The Energy Transition and Support for the Radical Right: Evidence from the Netherlands." *Comparative Political Studies* 58(2):394–428.

Weitzman, Martin L. 2017. "On a World Climate Assembly and the Social Cost of Carbon." *Economica* 84(336):559–586.

Zhang, Jianbo. 1997. "Strategic Delay and the Onset of Investment Cascades." *The RAND Journal of Economics* 28(1):188–205.