Climate Change Policy is in Season: Complementarities in Global Climate Action

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Abstract

In canonical theories of international climate cooperation, free-riding incentives plague the provision of climate policy because countries' abatement efforts are strategic substitutes: the marginal impact of one state's efforts decreases when others are likely to contribute, which disincentivizes aggregate abatement. This paper is centered around two tasks: first, I present quantitative evidence to assess the empirical validity of the strategic substitutes assumption inherent to extant theories. I show descriptively that the adoption and stringency of climate policies is positively correlated with the policy choices of other countries, suggesting complementarities rather than substitutes in cross-national behavior. Second, I propose a formal model to show how such complementarities arise endogenously: countries learn from one another about the economic value and policy success of a green transition through the adoption of climate policy across borders. Since countries want to engage in costly climate policy investments only when the green transition will pay off, the adoption of climate measures by others is a signal of public optimism in a green economy and spurs subsequent climate action. The theoretical framework also characterizes conditions under which complementarity effects induced by observational learning are dominant relative to substitution effects. Learning effects that engender strategic complementarities are stronger precisely when incentives to free ride are smaller, or when countries are less averse to implementing policies with uncertain returns.

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How does the behavior of other nations influence climate policy adoption? Long-standing scholarly traditions emphasize the global threat inherent to environmental degradation, thereby conceptualizing a solution that warrants action across borders, and cast the issue as a problem of the underprovision of public goods (e.g., Ostrom 1990; Barrett 2003; Stern 2007; Bernauer 2013; Keohane and Victor 2016). On this view, climate action is stifled relative to a global optimum because the temptations to free ride—i.e., the marginal gains from refraining to engage in nationally costly abatement efforts because other countries could do so instead—outweigh the global benefits of environmental protection, so emissions reduction efforts should be negatively correlated across countries. Such thinking has been instrumental in developing the global climate change "regime complex" (Keohane and Victor 2011): international agreements like the Kyoto Protocol were designed with an eye toward mitigating free-riding concerns (Victor 2011).

This paper challenges the conventional wisdom that countries' decisions to enact climate policy are negatively correlated with the actions of other nations by engaging in two tasks. First, I present quantitative evidence to assess the empirical validity of this theoretical prediction. With descriptive analysis, I in fact show the opposite: on average, countries' actions are *positively* correlated with the adoption of previous climate measures by other nations, both in terms of the number of laws adopted and the stringency of environmental policies. I also establish that, when faced with a negative (positive) shock to the international climate regime, represented by the outcome of the 2016 (2020) United States presidential election, countries do not overcompensate (retreat) in their adoption of climate policies. These findings suggest *complementarities* across nations' climate policymaking behavior rather than substitutabilities, which underpin arguments about free-riding incentives.

Second, I develop a theoretical framework that allows for the endogenous generation of complementarities. In a formal model, countries engage in climate policymaking over time and observe the mitigation measures implemented by other nations. Similar to collective action models of climate policymaking, everyone is better off when more nations exert effort to abate the effects of climate change, but taking action is costly and there are diminishing marginal returns to subsequent countries' investments. But unlike traditional models, there is a fundamental uncertainty about the economic gains from the green transition, so countries want to make costly climate policy investments only if they are sufficiently sure that the green transition will be "successful." The adoption of climate policies by other countries is a signal of public optimism in a green economy, which spurs subsequent climate action. This learning effect elucidates a causal mechanism through which countries' actions are complementary (cf. Banerjee 1992; Bikhchandani, Hirshleifer and Welch 1992; Smith and Sørensen 2000).

When countries determine how much effort to contribute to global emissions reductions, they trade off the expected value of policy gains from the aforementioned learning effect—based upon their optimism or pessimism toward successful green policy—and the marginal costs of climate investments. While all countries are better off with increased aggregate abatement efforts, the prior adoption of climate policies by other nations diminishes each individual country's *marginal* contribution, which lessens the incentives for increased future mitigation investments (cf. Harrison and Lagunoff 2017; McAllister and Schnakenberg 2022; Kennard and Schnakenberg 2023). In addition, countries incur domestic implementation costs to enact climate reforms—climate policies create new redistributive fault lines (Breetz, Mildenberger and Stokes 2018; Colgan, Green and Hale 2021), and leaders may incur political costs (e.g., Stokes 2016; Voeten 2025) if domestic publics shoulder the burden of costs (e.g., Bechtel and Scheve 2013; Bernauer and Gampfer 2015; Stokes and Warshaw 2017; Gazmararian and Tingley 2023). A simple intuition arises: variation in policymaking outcomes across countries is the result of the interplay between countries' beliefs about a successful green transition and their willingness to shoulder the costs of implementing green policies with uncertain economic benefits.

Quite naturally, a country's level of mitigation efforts in equilibrium is increasing in the public optimism about a successful green transition, the learning effect that generates complementarities in nations' behavior, but is decreasing the effort already exerted by others, which induces substitution by discouraging future reforms. This fundamental tradeoff characterizes the tension in the model: if countries have previously observed climate action, their marginal contribution to global abatement efforts is smaller, which incentivizes free-riding and discourages action, but the prior implementation of climate reforms is informative about the value of green policy and thus motivates future investments. The theoretical framework adjudicates between two competing mechanisms that shape countries' incentives to enact climate policies, and characterizes conditions under which complementarity effects are dominant relative to substitution effects. I demonstrate that the learning effects that engender strategic complementarities are stronger precisely when the incentives to free ride are smaller or public optimism about green policy is larger.

What is more, I use the model to examine intertemporal climate policymaking dynamics across countries. As is evident from the learning effects in the model, countries are *always* more optimistic about the economic returns from green policy if they have observed others doing the same versus when other nations slack. Consistent with a mechanism of policy diffusion via learning (Elkins and Simmons 2005; Dobbin, Simmons and Garrett 2007), countries are more likely to "follow the leader" upon observing extant, more ambitious climate reforms. Moreover, reminiscent of herding results in the observational learning literature (Banerjee 1992; Bikhchandani, Hirshleifer and Welch 1992; Smith and Sørensen 2000), countries are all else equal willing to implement climate reforms with less optimistic private beliefs about the value of green policy if other nations have committed to costly mitigation efforts, which can drive strategic complementarities in international climate policymaking in the long run.

Contribution

A virtually hegemonic tradition of scholarship in international relations and political economy stresses that collective action challenges drive the underprovision of optimal environmental outcomes, creating a "tragedy of the commons" (Olson 1965; Hardin 1968; Keohane 1984; Ostrom 1990; Stavins 2011). This suboptimality arises because, while the benefits of climate policymaking are global, efforts to abate are nationally costly: countries are incentivized to allow others incur these costs, thereby reaping global benefits, without engaging in policy adjustment themselves (Barrett 2007; Hovi, Sprinz and Underdal 2009; Clapp and Dauvergne 2011).

The implications of this intellectual output are vast, as scholars and policymakers have viewed the free-rider problem as the dominant impediment to progress on climate policymaking (see Carattini, Levin and Tavoni 2017; Weitzman 2017). Policy solutions such as carbon taxes and cap-and-trade systems have been advanced to address free-riding's negative externalities.[1] Design features in international agreements, like the fines included in the Kyoto Protocol, aim to raise the costs of noncompliance with reduction targets (Barrett 2003; Victor 2011; Hovi, Ward and Grundig 2015). Other proposals such as "climate clubs" (Nordhaus 2015) seek to inspire climate action by ostensibly negating free-riding concerns through the engagement of a smaller number of participating nations.

More recently, debate launched by Aklin and Mildenberger (2020) eschews collective action concerns and instead emphasizes that heterogeneous preferences for climate reforms could be traced to domestic factors. This strand of literature points to the role of special interest lobbying (Meckling 2011; Mildenberger 2020; Stokes 2020), electoral institutions and electoral incentives (Lipscy 2018; Finnegan 2022; Melnick 2024; Finnegan et al. 2025), veto players (Madden 2014), and sectoral composition (Aklin and Urpelainen 2013; Cheon

[1] Ross (2025) notes that the policy bias toward carbon pricing instruments likely reflects that the effects of climate change had largely been studied by economists.

and Urpelainen 2013), among other subnational explanators, as determinants of climate policymaking. This literature, while correctly identifying an "over-emphasis" on free-riding concerns (Colgan, Green and Hale 2021, 586-587), sidesteps the question of how international factors affect climate policy decisionmaking by instead identifying domestic influences, and provide no countervailing theoretical expectations about international climate policymaking behavior. Indeed, heterogeneity of preferences may be compatible with a free-riding story at the international level (Kennard and Schnakenberg 2023).

This paper reconciles these ontological camps with empirical and theoretical contributions. It provides a direct empirical test of the fundamental assumption that free riding incentives induce a negative correlation between countries' climate actions, which underlies extant arguments, and rejects the premise that these concerns explain the international cooperative dynamic among countries in the climate policymaking realm. The descriptive facts affirm the idea posed by Aklin and Mildenberger (2020) that free-riding incentives are not empirically substantiated; however, these authors and their intellectual successors do not propose a theoretical alternative for how a country's climate policy might be affected by other nations. Thus, I offer a new theoretical framework that is consistent with the data at the international level and, while treating domestic political factors in reduced form, allows for a unification of international-level arguments with theories that rely on subnational institutions to explain variation in climate policymaking across nations.

To achieve this goal, I appeal to the literature on policy diffusion (Elkins and Simmons 2005; Simmons, Dobbin and Garrett 2006; Dobbin, Simmons and Garrett 2007) and learning in foreign policy decisionmaking (Levy 1994). I demonstrate that countries' policy actions are complementary through a mechanism of learning, where countries' beliefs about a successful green transition are influenced by the policy adoption decisions of previous movers. The observation of climate investments abroad inspires action at home because it signals optimism in a common global goal, the effort to abate the effects of climate change. Extant work in climate politics has advocated for greater experimentation to facilitate learning (Ostrom 2010; Jordan and Huitema 2014). Moreover, scholars have documented evidence for policy diffusion of policies such as 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); these studies point to several mechanisms to explain diffusion that include learning and emulation, technological innovation, and "peer pressure" (Savin, Mundt and Bellanca 2024).

Qualitative accounts of climate policymaking also highlight complementarity effects. Hochstetler (2020) notes that South African President Jacob Zuma committed to strong climate pledges in 2009 at the Copenhagen summit—despite resistance from pro-status quo actors like Eskom—perhaps in response to similarly ambitious commitments made by China, India, and Brazil. These complementarities might also work in the other direction, where (expected) retrenchment by one nation disincentivizes climate actions by all. For example, the looming prospect of Trump's return to the White House in 2024 hamstrung climate negotiations in Bonn, Germany earlier that year. According to diplomatic negotiators, the possibility of a negative shock to international climate policymaking prevented the talks from expected progress in negotiating a climate finance goal.[2] Similarly, backlash or reversal of climate policies might occur in sequence, reflecting these negative complementary effects. Shortly after the 2024 U.S. presidential election—which Donald Trump won while campaigning on anti-green transition policies—European Commission President Ursula von der Leyen announced a relaxing of the European Union's flagship green reporting laws. Simultaneously, the French government requested delays in new rules on sustainability reporting and the German government sought to delay new anti-deforestation laws.[3]

[2] https://www.politico.eu/article/donald-trump-global-climate-talks-white-house-us-election-cop29-climate-finance/

[3] https://www.politico.eu/article/europe-green-laws-economy-environment-red-tape-regul

Additionally, this paper contributes to the literature within the political economy of climate change that emphasizes the role of uncertainty. Melnick (2025) demonstrates how uncertainties about climate vulnerabilities can be exploited by special interest groups to stymie climate action at home and abroad. Gazmararian and Milner (2024) argue that natural disasters induce learning within countries about climate vulnerabilities which facilitates the adoption of climate laws. Uncertainty about climate change's effects can also interact with politician behavior to inspire political mobilization (Balcazar and Kennard 2025). Here, uncertainty is important insofar as it coordinates countries' expectations about whether costly climate investments will yield economic gains in the face of a green transition with unknown success.

Finally, this paper connects to survey experimental and public opinion evidence that domestic publics are "unconditional cooperators" or may support unilateral mitigation (Bechtel and Scheve 2013; Tingley and Tomz 2014; Bernauer and Gampfer 2015; Beiser-McGrath and Bernauer 2019). Although these empirical findings cannot falsify free-riding arguments (Kennard and Schnakenberg 2023), I demonstrate theoretically how such national beliefs may inform a country's optimism about the success of a green transition and may ultimately spur climate action.

The rest of this paper proceeds as follows. First I assess the empirical validity of extant theories by testing the theoretical assumptions associated with free-riding in the climate policymaking realm. The analysis rejects the assumption of pre-existing arguments that countries' propensities to adopt climate laws are decreasing in the actions of others, instead suggesting a complementary effect of policy across borders. Given these results, I then build a formal-theoretic framework to provide an explanation for the patterns observed in the data: countries' climate actions arise as complementarities endogenously through a process of learning about the success of a green transition.

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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—others could plausibly supply the global benefits from abatement—as the explanation for the underprovision of environmental protections.

Formally, this relies on the assumption that countries' actions are *strategic substitutes*. Consider the following simplified formalization of the climate collective action problem (cf. Harrison and Lagunoff 2017; McAllister and Schnakenberg 2022; Kennard and Schnakenberg 2023). There are two countries, i and j, that each choose carbon consumption (inverse abatement efforts) $k_i, k_j \in \mathbb{R}_+$. Their preferences over consumption are parameterized[4] as

$$u_i(k_i, k_j; \theta_i) = \theta_i \log(k_i) + (1 - \theta_i) \log(\omega - k_i - k_j),$$

where the first term captures the benefits of consumption (opportunity costs of abatement), the second term captures the benefits of global conservation, $\theta_i \in [0, 1]$ parameterizes the tradeoff between consumption and conservation, and $\omega > 0$ is a ceiling on the feasible amount of carbon consumption (potential abatement efforts). Denote $BR_i(k_j)$ as country i's best response to any action taken by country j. Importantly, each country's utility has the following feature:

$$\frac{\partial^2 u_i}{\partial k_i \partial k_j} = -\frac{1 - \theta_i}{(\omega - k_i - k_j)^2} < 0 \;\Leftrightarrow\; \frac{\partial BR_i(k_j)}{\partial k_j} < 0.$$

In this setup, actions are strategic substitutes: country i's marginal value of abatement is decreasing when country j exerts more effort. Simply put, when other nations do more, it is

[4]The logarithmic functional form is not necessary, sufficient for the relevant properties to hold is an increasing and concave function.

a best response to do less, and when other nations do less, it is a best response to do more. This premise lies at the core of extant theoretical approaches to global climate cooperation.

Empirical Assessment 1: Climate Law Adoption

To assess the strategic substitutes conjecture, I establish a series of empirical facts about the relationship between a country's climate policy decisionmaking as a function of the behavior of other nations. First, 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.[5] For each country i, I observe the number of climate laws adopted in year t and I also count the number of laws adopted by all other nations in year $t-1$. At the country-year level, I run the following fixed effects model with country-clustered standard errors:

$$\text{Adopt}_{it} = \beta \log(\text{Previous Laws}_{-it-1}) + X'_{it-1}\gamma + \alpha_i + \lambda_t + \varepsilon_{it},$$

where Adopt_{it} is either a binary indicator for whether country i adopted a climate law in year t, or is the total count of climate laws that country i adopted in year t. The independent variable $\text{Previous Laws}_{-it-1}$ captures the number of previous laws enacted by all other nations in the previous year $t-1$. The vector X_{it-1} contains country-level time-varying controls (population, GDP per capita, growth, net Polity score). I also include country fixed effects α_i and year fixed effects λ_t. Year fixed effects adjust for any global benefits that might incentivize climate policy, which includes any general equilibrium effects of increased mitigation benefits that could correlate with a contemporaneous rise in climate policies across countries.

The sign of the coefficient β is the estimand of interest; extant theoretical approaches

[5] The data covers laws adopted by the national governments of 196 countries plus the European Union. Laws passed by the EU are coded at the EU level. To be included as a law, a document must have full legal force or set out a current set of government policy objectives motivated by climate change.

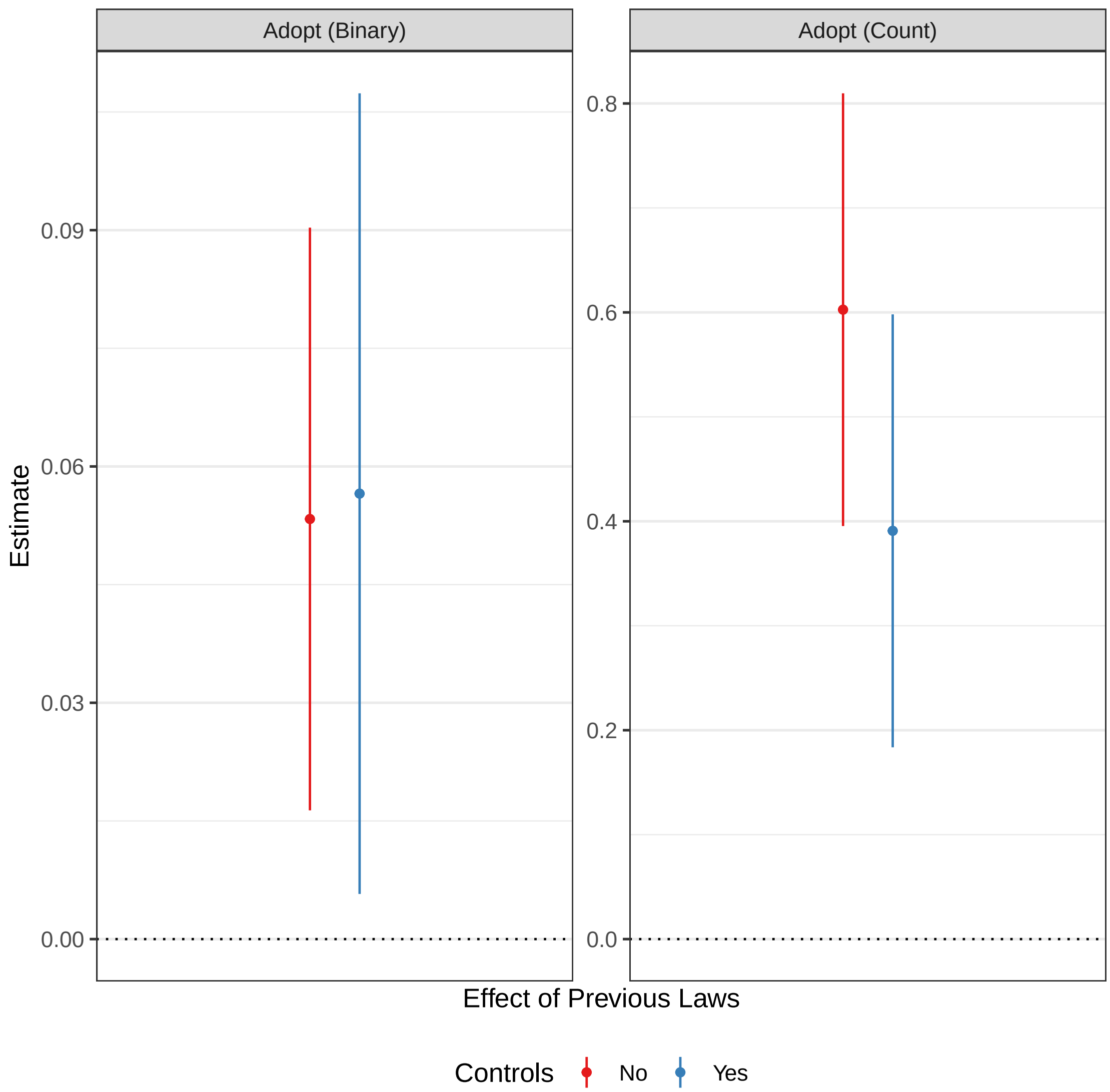

Figure 1: Effects of Previous Laws on Climate Law Adoption

would expect that $\beta < 0$, which would capture the presence of strategic substitutes in reduced form. Figure 1 displays the results. The adoption of climate laws by other nations in the past year is a positive and statistically significant predictor of climate law adoption. Since this correlation is positive, it suggests a complementarity rather than a substitutability in the adoption of climate laws across countries.

Empirical Assessment 2: Environmental Policy Stringency

While the first empirical assessment provides suggestive evidence against a free-riding story, one may be worried that the adoption of laws proxies quantity of action, but that conditional on a secular increase in climate action, countries' efforts are still strategic substitutes. Or, perhaps countries adopt climate laws but do not intend to fulfill their promises, allowing other nations to exert effort instead (Melnick and Smith 2024). From a measurement perspective, the discretized choice to adopt might mask substantial heterogeneity or information that a continuous measure could pick up. To probe these concerns, I turn to the OECD's Environmental Policy Stringency (EPS) Index (Botta and Koźluk 2014; Kruse et al. 2022). The EPS 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 data covers 40 countries between 1990 and 2020 and is measured at the country-year. For country i in year t, I run the following regression:

$$\text{Stringency}_{it} = \beta \text{ Average Stringency}_{-it} + X'_{it-1}\gamma + \alpha_i + \varepsilon_{it},$$

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. I also include country fixed effects α_i and time-varying controls (population, GDP per capita, growth, net Polity score), which includes time trends (linear, cubic, country $\times$ year) and cluster standard errors by country.

Figure 2 illustrates the results. The top panel of the figure plots the raw data of each country's environmental policy stringency index (solid colored line) as well as the average global stringency (excluding country i) for each year (black dashed line). It is evident from the graphs that policy stringency is secularly increasing in almost all countries, and

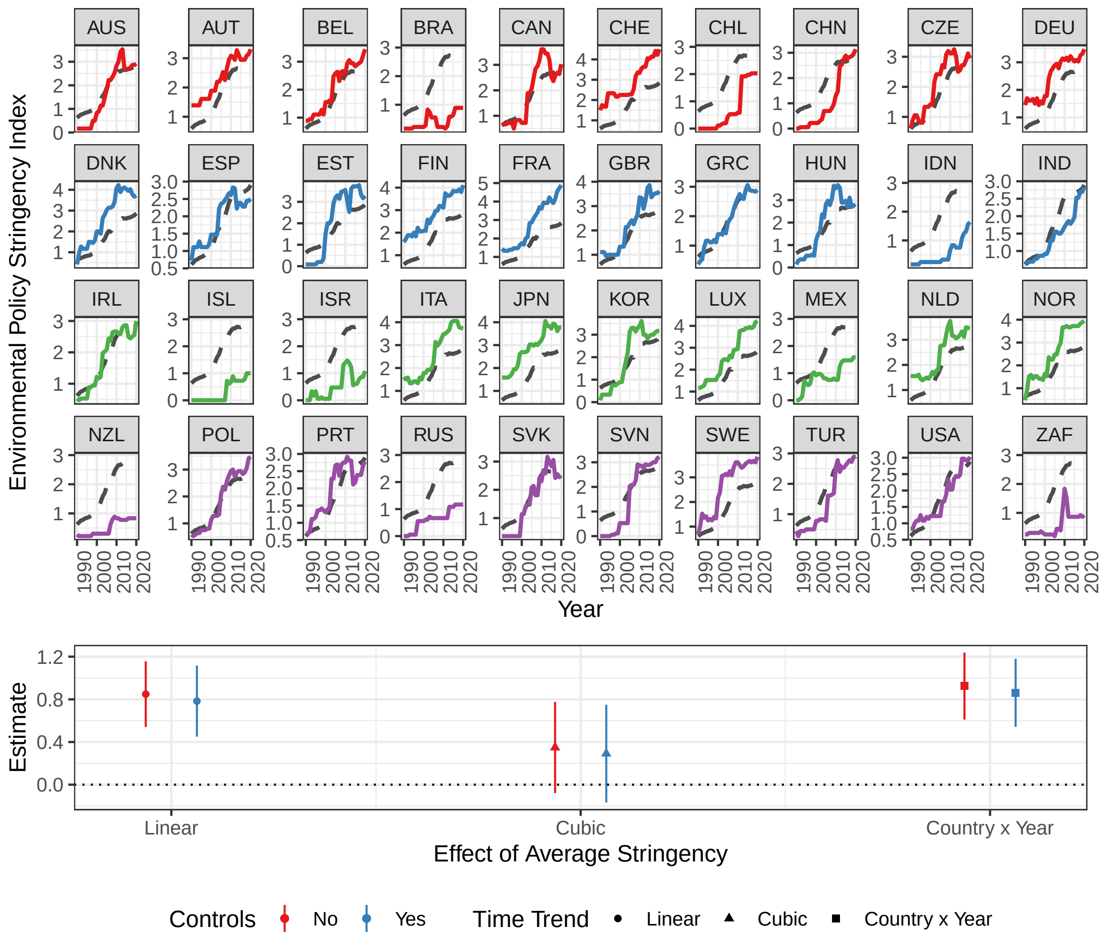

Figure 2: Effects of Average Global Policy Stringency on Environmental Policy Stringency

also correlates positively with average global stringency. The bottom half of the figure confirms this by estimating the regression models. In a similar fashion to the first test, the sign of β determines whether other countries' average stringency induces more or less stringent climate policy from a given nation. A 1 point (out of 6) increase in the average policy stringency of other nations is associated with approximately at 0.8 point *increase* in country i's environmental policy stringency score.[6] This effect again contradicts pre-existing theoretical arguments. Moreover, given the sample, this empirical test demonstrates

[6]Results are also robust if we take the weighted average of a country's EPS score weighted by GDP per capita, which would capture the idea that wealthier countries' climate policy actions are more important than less developed nations' policy actions. See Appendix B for tables with these additional results.

a positive correlation in climate actions among large countries with substantial impact on the climate, which bolsters the claim that countries are learning from pivotal emitters.

Empirical Assessment 3: U.S. Presidential Elections

As a third piece of evidence, I examine the effects of United States presidential elections on the adoption of climate laws. American election outcomes in 2016 and 2020 were relatively unexpected and thus quasi-random. Moreover, 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 countries' best responses and subsequently informs their optimal decisionmaking in light of expected American behavior following the election. The classical logic predicts that, outlined by the formalization above, 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:

$$\text{Adopt}_{im} = \beta \mathbb{1}(t > t_k) + \varphi f(t - t_k) + \alpha_i + \lambda_m + \varepsilon_{im},$$

where the outcome is either 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, t_k is the calendar date of the election (either 2016 or 2020), and $f(\cdot)$ is a smooth function of time. Fixed effects at the country and month level are also included to capture country-specific idiosyncrasies in law adoption as well as common temporal shocks. I report conventional as well as bias-corrected and optimal bandwidth selected estimates (Calonico, Cattaneo and

Titiunik 2014), and cluster standard errors by country.

The sign of β identifies the local average treatment effect of the U.S. election on other nations' adoption of climate laws right at the date of the election. A free-riding argument would expect β to be positive (negative) in 2016 (2020). In this account, Trump's apathy toward climate policies would increase the marginal value of policymaking for other nations to compensate, while Biden's willingness to enact climate policy would decrease the incentives for others to exert costly effort.

The threat to identification of the LATE would be countries strategically adopting climate laws around the time of the election. Specifically, in the 2016 election, the relevant bias in favor of the free-riding argument is if countries were to delay adoption of climate laws until after the election, which would bias the LATE downward. 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. Analogously, in 2020, countries would have to pass all of their laws right before the election and then strategically withhold effort once Biden won the election.

Figure 3 displays point estimates as well as graphical depictions of the evolution of climate laws over time as a function of U.S. presidential elections.[7] In the top-left panel of the figure, it is clear that Trump's 2016 election victory is associated with about a 1-2 percentage point reduction in climate laws but is not statistically significant. Conversely, the top-right panel demonstrates that Biden's win in 2020 did meaningfully increase the adoption of climate laws, by approximately 7 percentage points. In both cases, the sign of the RD estimates refute a story of strategic substitutes. 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.

[7]RD plots are for the binary adoption outcome; logged counts display similar results.

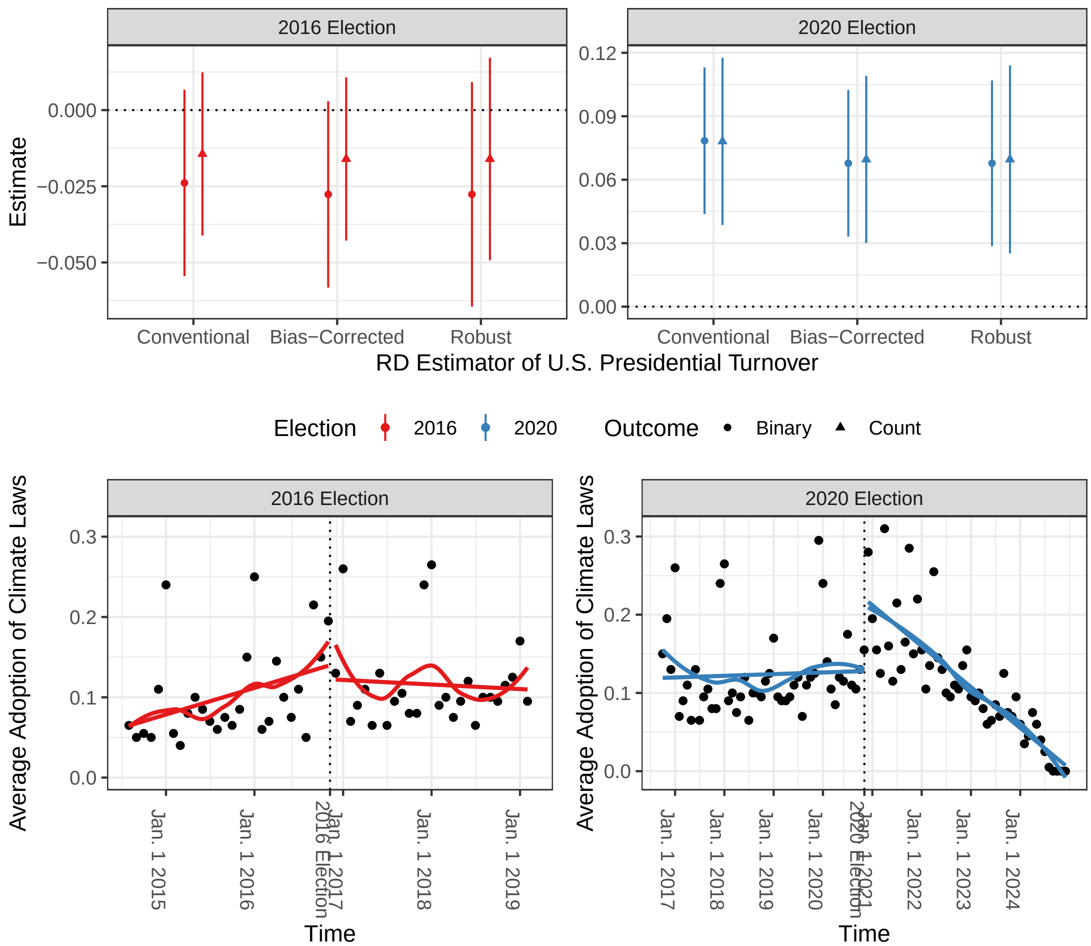

Figure 3: Effects of U.S. Presidential Turnover on Climate Law Adoption (RD)

Taking Stock

These empirical findings cast significant doubt on traditional theoretical accounts of global climate policymaking in which an increase in the effort of other nations decreases the likelihood of effort by a given country. By contrast, the evidence posited suggests the opposite: the accumulation of effort by other nations *increases* the likelihood that nations take climate action. Hence, rather than capturing behavior consistent with a story of strategic substitutes, the data offers instead a picture of strategic complements.

If countries' climate policy actions are strategic complements—as the data suggests they are, at least on average—what is the theoretical mechanism that generates this behavior? How do these complementarities arise? The rest of the paper introduces a theoretical framework that characterizes the conditions under which these complementary effects dominate nations' climate policy decisionmaking.

Theoretical Framework

Consider sequential climate policymaking by $n = 2$ countries indexed by i. Each country determine 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 efforts to reduce carbon emissions, while negative effort $a_i < 0$ can be thought of as anti-climate measures like deforestation or other means of increasing carbon consumption. The order in which each country takes action is fixed and exogenous; country 2 ("she") observes country 1's choice ("he") prior to taking an action.

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 pays off or will be "successful" 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 $\varepsilon_i \sim N(0, \frac{1}{\beta})$, which is private information to country i. Denote $\Phi(\cdot)$ and $\phi(\cdot)$ as the distribution and density functions of the standard normal distribution respectively. Higher signals are on average more likely to indicate that θ is larger, so a country with a higher signal is more optimistic about the success of a green transition. Country i's returns to its 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.

In traditional 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 future efforts on the global mitigation goal. Countries receive a global benefit of $g(A)$ given total global policy implementation where $g(A)$ is an increasing and concave function with $g(0) = 0$. Additionally, adopting climate friendly policies is costly, 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 $c(a_i) = c_i|a_i|$. We might think that the costs associated with mitigation efforts incorporate both a common cost representing technological requirements to undertake environmental reforms, and a heterogeneous cost for any domestic political consequences from imposing costs on citizens or large domestic polluters to implement reforms (Aklin and Mildenberger 2020; Colgan, Green and Hale 2021).

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

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

In a departure from extant collective action approaches to modeling international climate policymaking (e.g., Kennard and Schnakenberg 2023), this model introduces uncertainty about the benefits accrued from climate abatement efforts and sequential moves. Both of these elements are necessary in order to highlight the mechanism that countries may be learning from one another through the implementation of climate reforms and thereby engender strategic complementarities. That said, this utility function captures 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. As the empirical results in the previous section show, countries' climate actions are not, at least on average, decreasing in the actions of others. Characterizing the conditions under which countries' climate policies are complementary or substitutes is thus an important goal of the present theoretical analysis.

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 are formed via Bayes's rule.

Comments on the Model

The model's assumptions are reminiscent of canonical theories of observational learning (for a review, see Bikhchandani et al. 2024); I discuss some of their implications here. In particular, two assumptions require further comment: the limit of $n = 2$ countries and the exogeneity of the sequence of moves among them. In contrast to traditional observational learning models which allow the number of agents n to grow arbitrarily large, I fix the number of countries at $n = 2$.[8] Increasing the number of countries would add mathematical complexity without developing further theoretical nuance; to the extent that we believe other, unmodeled countries' climate policy adoption behaviors might affect the countries in the model, they could be accommodated either by changing the prior expected economic gains from green investments μ or the concavity of the global abatement value function $g(\cdot)$. Moreover, agents' payoffs in most observational learning models are backward-looking as their behavior is only linked through the information conveyed by prior movers. See Appendix C for a model with

[8]The literature on tensor complementarity in games with multiple players (e.g., Huang and Qi 2017; Guan and Li 2020) demonstrates that an $n > 2$ player interaction can be broken into many $n = 2$ subproblems, which converge on the solution of the $n > 2$ player game. We can consider the results of the $n = 2$ case described herein as converging to a more general $n > 2$ model and when taking the model to data, consider the exogenous ordering of the $n = 2$ countries as arbitrary.

more than 2 countries that resembles this setup.

The endogenous timing of countries' climate actions could stem from heterogeneously precise signals, meaning that some countries have better information about the possibility of a successful green transition than others, or from heterogeneity in countries' vulnerabilities to climate change's effects; better informed countries would then have incentives to act first (Zhang 1997).

Analysis

First I derive each country's optimal climate effort decision given their expectations about the economic returns to a green transition and the pre-existing international climate policy regime (Proposition 1). I then demonstrate how climate efforts increase in public optimism generated by investments from other nations, but decrease in the level of those efforts by diminishing further marginal contributions. The former effect generates policy complementarities across countries, while the latter engenders substitution effects. I then characterize the conditions under which either of these two factors dominates countries' climate policy decisionmaking process (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 invert to obtain 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:

$$E[\theta|x_2, a_1]g'(a_1 + \lambda\alpha_2(x_2, a_1))\lambda - c'(\alpha_2(x_2, a_1)) = 0.$$

Country 2 balances her expectations about returns from costly climate investments $E[\theta|x_2, a_1]$ and her marginal value to global climate efforts $\lambda g'(A)$, with the marginal costs of climate policy implementation c_2. 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 $E[\theta|x_2, a_1] < 0$. Given the functional form specifications, a closed-form solution for country 2's optimal effort is obtained:

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

Country 2's mitigation efforts are commensurate with her expectations about a green transition, quantified by her posterior mean $E[\theta|x_2, a_1]$. As her belief in a successful green transition grows, so too does her level of climate investments. Unsurprisingly, $\alpha_2(x_2, a_1)$ is increasing in x_2, country 2's private signal of the economic returns from climate policies. In addition to her own information, country 2's optimal effort depends on the relationship between country 1's effort a_1, which affects $\alpha_2(x_2, a_1)$ through two channels. First, country 1's effort changes country 2's marginal contribution to global mitigation efforts, as seen in the first term of $\alpha_2(x_2, a_1)$. That is, if country 1 has already committed to large emissions reductions, then country 2's policies have a smaller marginal impact on global efforts, 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. However, country 1's effort also affects country 2 through a second channel—her expectations about the benefits from green policies—as seen in the second term of $\alpha_2(x_2, a_1)$ by $\alpha_1^{-1}(a_1)$. When country 1 exerts more effort, it leads country 2 to believe that country 1's signal x_1 was higher, and thus also more optimistic about the economic returns from a green transition, which behooves country 2 to also exert more effort. This latter effect, on the other hand, encourages country 2 to adopt more ambitious climate reforms because it induces a learning effect across countries and thereby generates complementarities in actions.

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 $\theta|x_1 \sim N(\frac{\gamma\mu+\beta x_1}{\gamma+\beta}, \frac{1}{\gamma+\beta})$ and country 2's signal $x_2|x_1 \sim N(\frac{\gamma\mu+\beta x_1}{\gamma+\beta}, \frac{2\beta+\gamma}{\beta(1+\gamma)})$. 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 (rearranged and simplified) first-order condition:

$$E_{x_2}\Big[E[\theta|x_1]g'(a_1 + \lambda\alpha_2(x_2, a_1))\Big(1 + \lambda\frac{d\alpha_2(x_2, a_1)}{da_1}\Big)\Big] - c'(a_1) = 0,$$

which given functional forms simplifies to

$$\alpha_1'(x_1) = \frac{(\gamma\mu + \beta x_1)\beta\lambda}{2c_2c_1(2\beta + \gamma)(\gamma + \beta)}.$$

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 sour. 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

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

As demonstrated in the formal analysis, country 1's optimal behavior is also determined by the interplay between his own private signal x_1 and subsequent expectations about the economic value of a green transition $E[\theta|x_1]$, the marginal political costs to implementing climate reforms c_1, and his marginal contribution to abatement efforts $g'(A)$. Importantly, country 1's ultimate contribution is decided by country 2's behavior downstream, which is affected by his own choices via the two channels described above. In equilibrium, country 1 balances the temptation to free-ride off of the possible future climate implementation efforts of country 2 with the knowledge that his own inaction could discourage future reforms by sending a bad signal about the viability of a green transition. The following proposition thus summarizes the equilibrium (with formal proofs in the appendix).

Proposition 1. *There exists a unique equilibrium characterized by the functions* $\alpha_1(x_1)$, $\alpha_2(x_2, a_1)$ *such* $a_1^* = \alpha_1(x_1)$ *and* $a_2^* = \alpha_2(x_2, a_1^*)$.

Since countries only want to engage in costly climate investments if they are sufficiently optimistic that they will pay off, country 1's implementation of climate policy conveys information to country 2 about country 1's belief in a successful green transition. The following corollary demonstrates that country 1's action is informative of the state of the world: the implementation of climate policy is itself a signal to country 2.

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,* $\frac{dE[\theta|x_2,a_1^*]}{da_1} > 0$.

An important implication of this corollary is reminiscent of herding results in the observational learning literature (Banerjee 1992; Bikhchandani, Hirshleifer and Welch 1992; Smith and Sørensen 2000) in which country 2's expectations about θ are higher upon observing greater mitigation investments from country 1, thereby generating a path in which country 2 "follows" the behavior of country 1. In particular, because country 2's posterior assessment of the economic value of green policy is higher, she becomes more willing to implement costlier climate reforms. This also means that, all else equal, country 2 will engage in more ambitious climate action for lesser quality private signals x_2 upon observing climate investments of increasing ambition from country 1. In this way, country 1's implementation of climate policy initiates a chain of policy diffusion (Elkins and Simmons 2005) through which country 2 observes country 1's apparent optimism in the green transition and inspires similar policy adoption.

Complements and Substitutes

We can now consider the fundamental tradeoff between countries' climate mitigation effort investments. Fix two possible effort levels by country 1, $a_1' > a_1$, and recall that country 2's optimal effort level solves

$$E[\theta|x_2, a_1]g'(a_1 + \lambda a_2)\lambda = c'(a_2).$$

In other words, 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 is smaller when country 1 has already invested large amounts of effort into providing the global benefit of mitigation, $g'(a_1' + \lambda a_2) < g'(a_1 + \lambda a_2)$, so there are smaller marginal gains from additional costly abatement, 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 to country 2 that a green transition would be successful $E[\theta|x_2, a_1'] > E[\theta|x_2, a_1]$, which emboldens country 2 to take climate action, which generates complementarities in countries' behavior. By contrast, if country 1's climate investments are small, country 2's marginal contribution is larger, and thus could provide a greater global benefit with its mitigation efforts, but the expected economic returns of such reforms is diminished because country 1's lack of climate action is a signal of his pessimism about the value of climate policy.

From the vantage point of country 1, his actions are influential in determining the course of global climate investments. On one hand, country 1 could undertake costly mitigation measures, jumpstarting a sizable contribution to international climate cooperation, hoping that its decision to implement reforms will have sufficient informational value to deter country 2 from free-riding. Alternatively, country 1 might wish to avoid the domestic costs of climate policy adoption with the anticipation that country 2 will provide global benefits, although such a move is risky as country 2 could interpret country 1's inaction as a signal that green investments are not worth the costs. Given this tradeoff, it might appear that country 2 is always advantaged, as she has more information about the state of the world when choosing how much effort to exert. What is the advantage of moving first? Country 1's first-mover advantage is thus that, since his marginal contribution to global mitigation investments is always weakly greater than country 2's, for a strong enough signal x_1, he can guarantee some international effort in the event that country 2 takes minimal action. Even net of its signaling value, a sufficiently optimistic country 1 finds it advantageous to implement climate reforms.

To summarize, countries' actions influence each other through two channels. The temptation to free-ride because of 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. Corollary 2 formalizes this discussion and Figure 4 illustrates these comparative statics.[9] The left panel depicts the effects of increasing the effort value of country 1's mitigation policies, holding constant the informational value of such effort, which begets less ambitious climate action from country 2 because her marginal contributions are diminished. The right panel shows that increasing the informational value of country 1's effort, thereby engendering greater optimism about the economic returns from green investments, also inspires more ambitious efforts from country 2, thus documenting complementarities.

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

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

Which factor dominates? Under what conditions are countries' actions strategic complements or strategic substitutes in equilibrium? To conceptualize this, I consider the conditions under which the effects of changing country 1's informational value outweigh the effects of changing his effort value 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, outweighs 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

[9] Formal results are expressed for country 2 as it makes most sense to consider the effects on her effort a_2 changing as a function of what country 1 has already done.

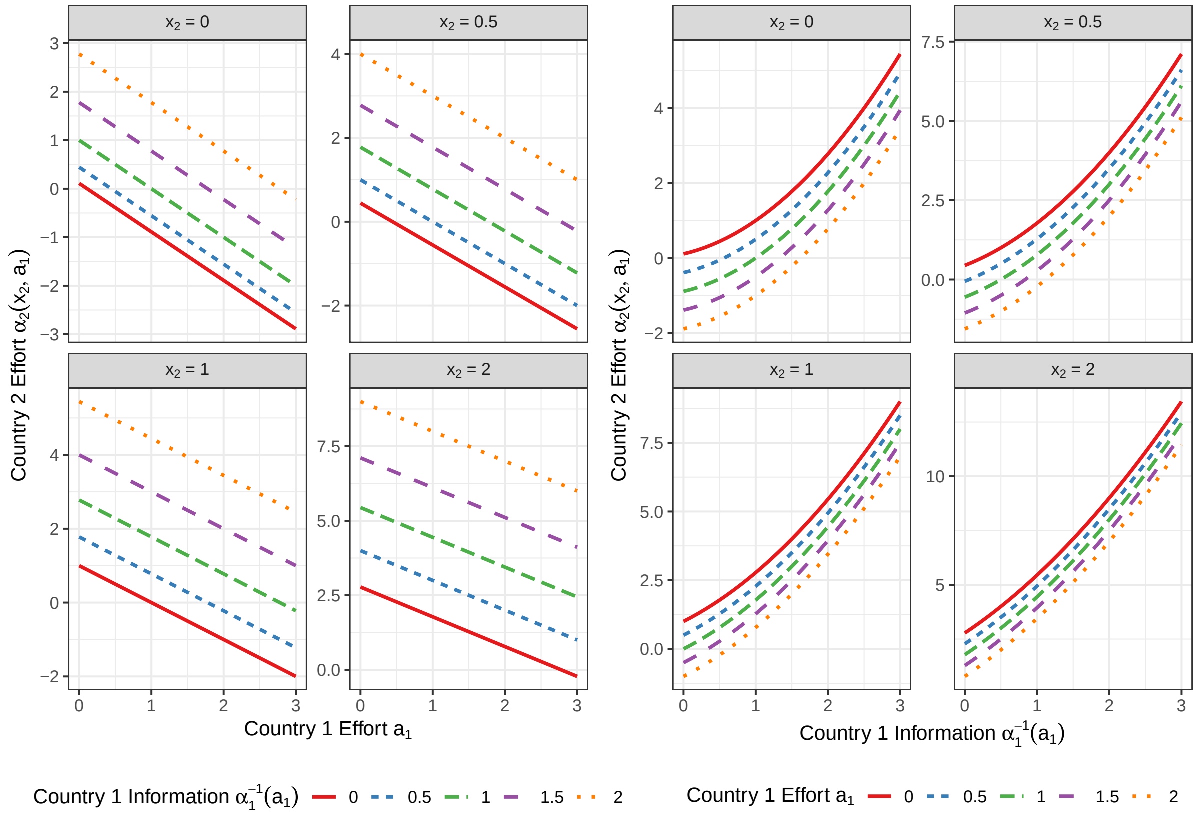

Figure 4: Substitutes and Complements Mechanisms on Climate Mitigation Efforts
$\mu = 0.5$, $\gamma = 1$, $\beta = 1$, $\lambda = 1$, $c_1 = 0.5$, $c_2 = 0.25$

such investments are unknown and their implementation is domestically politically costly—then substitution effects are likely to dominate learning incentives.

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

$$\frac{\beta}{\gamma\mu + \beta\alpha_1^{-1}(a_1) + \beta x_2} < -\frac{g''(A)}{g'(A)}.$$

Proposition 2 states that we can assess the competing 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 left-hand side of the inequality approximates the inverse of country 2's expectations about θ, which is her informational value of making costly climate investments, while the right-hand side is a measure of country 2's "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 actions to be complementary. 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.

In reduced form, the proposition characterizes which mechanism—the temptation to free-ride inducing substitution or the informational returns from learning generating complementarities—is operant in country 2's climate policy decisionmaking. Of course, these two ingredients are intertwined in equilibrium, but in reduced form they represent the core features of the model that determine the impact of country 1's actions on country 2's incentives to pursue further climate reforms. Notably, these quantities are path dependent and fluctuate depending on past behavior by country 1 and any prior information held by the two countries about the success of a green transition.

Model Summary

Equilibrium climate actions are determined by the tradeoff between a country's belief that the green transition will be prosperous and their marginal contributions to global abatement efforts. This simple theoretical framework posits two strategic channels through which other countries' actions affect the implementation of climate policy. On one hand, countries want to invest greater effort into climate measures if they believe that the green transition will be successful; the adoption of climate reforms by others signals optimism in this regard and generates strategic complementarities across nations. By contrast, increased efforts to abate emissions and transition toward a green economy renders a single state's marginal contributions to the global effort smaller, and induces strategic substitutes across countries' climate actions. The theory demonstrates that the former channel dominates the latter in countries' decisionmaking when public optimism is large relative to the risk of investing in policies with unknown returns.

The model therefore explains the empirical facts presented at the beginning of the paper which extant theories cannot. The results summarized in Figure 1 and 2 document that, on average, countries' propensities to enact climate laws and to pursue more stringent environmental policies are increasing in the number of laws adopted and the ambition of other nations. The theory demonstrates that this positive correlation is due to incentives to signal and learn information about the likelihood of a successful global green transition; increased adoption of climate policies signals greater public optimism for a green economy, which spurs more reforms. Figure 3 zooms into particular moments in time, American elections, to isolate a potential change in countries' beliefs about a successful green transition. The results demonstrate how complementary effects in countries' climate actions shape future incentives.

References

Aklin, Michaël and Johannes Urpelainen. 2013. "Political Competition, Path Dependence, and the Strategy of Sustainable Energy Transitions." *American Journal of Political Science* 57(3):643–658.

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.

Balcazar, Carlos Felipe and Amanda Kennard. 2025. "Climate Change and Political Mobilization: Theory and Evidence from India." *https://drive.google.com/file/d/14yiR15XTWylc8-xE3RosKL03i2_Ta989/view* .

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.

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

Barrett, Scott. 2007. *Why cooperate? : the incentive to supply global public goods*. 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.

Beiser-McGrath, Liam F. and Thomas Bernauer. 2019. "Commitment failures are unlikely to undermine public support for the Paris agreement." *Nature Climate Change* 9(3):248–252.

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

Bernauer, Thomas and Robert Gampfer. 2015. "How robust is public support for unilateral climate policy?" *Environmental Science & Policy* 54:316–330.

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.

Breetz, Hanna, Matto Mildenberger and Leah Stokes. 2018. "The political logics of clean energy transitions." *Business and Politics* 20(4):492–522.

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

Carattini, Stefano, Simon Levin and Alessandro Tavoni. 2017. Cooperation in the climate commons. GRI Working Paper 259 Grantham Research Institute on Climate Change and the Environment.

Cheon, Andrew and Johannes Urpelainen. 2013. "How do Competing Interest Groups Influence Environmental Policy? The Case of Renewable Electricity in Industrialized Democracies, 1989–2007." *Political Studies* 61(4):874–897.

Clapp, Jennifer and Peter Dauvergne. 2011. *Paths to a Green World: The Political Economy of the Global Environment*. The MIT 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.

Dobbin, Frank, Beth A. Simmons and Geoffrey Garrett. 2007. "The Global Diffusion of Public Policies: Social Construction, Coercion, Competition, or Learning?" *Annual Review of Sociology* 33(1):449–472.

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.

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

Finnegan, Jared J. 2022. "Institutions, Climate Change, and the Foundations of Long-Term Policymaking." *Comparative Political Studies* 55(7):1198–1235.

Finnegan, Jared, Phillip Lipscy, Jonas Meckling and Florence Metz. 2025. "The Institutional Sources of Economic Transformation: Explaining Variation in Energy Transitions." *The Journal of Politics* .

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

Gazmararian, Alexander F. and Helen V. Milner. 2024. "Political Cleavages and Changing Exposure to Global Warming." *Comparative Political Studies* .

Goeree, Jacob K., Thomas R. Palfrey and Brian W. Rogers. 2006. "Social learning with private and common values." *Economic Theory* 28(2):245–264.

Guan, Hong-Bo and Dong-Hui Li. 2020. "Linearized Methods for Tensor Complementarity Problems." *Journal of Optimization Theory and Applications* 184(3):972–987.

Hardin, Garrett. 1968. "The Tragedy of the Commons." *Science* 162(3859):1243–1248.

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.

Hovi, Jon, Detlef F. Sprinz and Arild Underdal. 2009. "Implementing Long-Term Climate Policy: Time Inconsistency, Domestic Politics, International Anarchy." *Global Environmental Politics* 9(3):20–39.

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

Huang, Zheng-Hai and Liqun Qi. 2017. "Formulating an n-person noncooperative game as a tensor complementarity problem." *Computational Optimization and Applications* 66(3):557–576.

Jordan, Andrew and Dave Huitema. 2014. "Innovations in climate policy: the politics of invention, diffusion, and evaluation." *Environmental Politics* 23(5):715–734.

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

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. 2011. "The Regime Complex for Climate Change." *Perspectives on Politics* 9(1):7–23.

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.

Levy, Jack S. 1994. "Learning and foreign policy: sweeping a conceptual minefield." *International Organization* 48(2):279–312.

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.

Lipscy, Phillip Y. 2018. *The Institutional Politics of Energy and Climate Change*.

Madden, Nathan J. 2014. "Green means stop: veto players and their impact on climate-change policy outputs." *Environmental Politics* 23(4):570–589.

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

Meckling, Jonas. 2011. *Carbon Coalitions: Business, Climate Politics, and the Rise of Emissions Trading*. Cambridge: The MIT Press.

Melnick, Justin. 2024. "Domestic Politics in the European Union's Emissions Trading System: Evidence from Free Allowance Allocation." *Journal of Political Institutions and Political Economy* 5(4):627–657.

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

Melnick, Justin and Alastair Smith. 2024. "Shaming Paris: A Political Economy of Climate Commitments." *https://justinmelnick.github.io/papers/paris/paper.pdf* .

Mildenberger, Matto. 2020. *Carbon Captured: How Business and Labor Control Climate Politics*. Cambridge: The MIT Press.

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

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.

Ostrom, Elinor. 2010. "Polycentric systems for coping with collective action and global environmental change." *Global Environmental Change* 20(4):550–557.

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

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.

Savin, Ivan, Philipp Mundt and Margherita Bellanca. 2024. "The Paradox of Climate Policy Diffusion.".

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.

Stavins, Robert N. 2011. "The Problem of the Commons: Still Unsettled after 100 Years." *American Economic Review* 101(1):81–108.

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.

Stokes, Leah C. 2020. *Short Circuiting Policy: Interest Groups and the Battle Over Clean Energy and Climate Policy in the American States*. New York: Oxford University Press.

Stokes, Leah C. and Christopher Warshaw. 2017. "Renewable energy policy design and framing influence public support in the United States." *Nature Energy* 2(8):1–6.

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.

Tingley, Dustin and Michael Tomz. 2014. "Conditional Cooperation and Climate Change." *Comparative Political Studies* 47(3):344–368.

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

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.

Appendix: Climate Change Policy is in Season: Complementarities in Global Climate Action

Contents

A Formal Proofs

Proof of Proposition 1. To solve for the equilibrium, I conjecture the existence of a strategy for country 1 $a_1 = \alpha_1(x_1)$ and assume that $\alpha_1(x_1)$ is one-to-one. Proceeding by backward induction first consider country 2's effort investment given her signal x_2 and country 1's effort a_1. Given that $\alpha_1(x_1)$ is one-to-one, we have $x_1 = \alpha_1^{-1}(a_1)$ and so country 2's posterior update about θ is $\theta|x_2, a_1 \sim N(\frac{\gamma\mu+\beta\alpha_1^{-1}(a_1)+\beta x_2}{\gamma+2\beta}, \frac{1}{\gamma+2\beta})$. Country 2 therefore solves

$$\max_{a_2}\ E[\theta|x_2, a_1]g(a_1 + \lambda a_2) - c(a_2).$$

Differentiating with respect to a_2, country 2's first-order condition is

$$E[\theta|x_2, a_1]g'(a_1 + \lambda a_2)\lambda - c'(a_2) = 0.$$

Note that if $E[\theta|x_2, a_1] < 0$, which occurs when $x_2 < -\frac{\gamma\mu}{\beta} - \alpha_1^{-1}(a_1)$ then $E[\theta|x_2, a_1] < 0$ and country 2 exerts effort in the opposite direction. Given the functional form specifications and solving the above first-order condition, we have the following piecewise function:

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

It is clear from the second-order condition that for any x_2 and any a_1, $\alpha_2(x_2, a_1)$ is unique as the second-order condition as always negative:

$$E[\theta|x_2, a_1]g''(a_1 + \lambda a_2)\lambda^2 - c''(a_2) < 0.$$

Now consider country 1's effort choice. Given his own signal x_1, he believes that $\theta|x_1 \sim N(\frac{\gamma\mu+\beta x_1}{\gamma+\beta}, \frac{1}{\gamma+\beta})$ and that country 2's signal $x_2|x_1 \sim N(\frac{\gamma\mu+\beta x_1}{\gamma+\beta}, \frac{2\beta+\gamma}{\beta(1+\gamma)})$. Let $m = \frac{\gamma\mu+\beta x_1}{\gamma+\beta}$ and $z = \sqrt{\frac{\beta(1+\gamma)}{2\beta+\gamma}}$. Further, denote $q = \frac{\lambda(\gamma\mu+\beta\alpha_1^{-1}(a_1)+\beta x_2)^2}{4c_2^2(2\beta+\gamma)^2}$ and $t = -\frac{\gamma\mu}{\beta} - \alpha_1^{-1}(a_1)$. By backward induction, country 1's problem is to maximize

$$\max_{a_1} \int_{-\infty}^{t} \Big[mg(-q)z\phi(z(x_2 - m))\Big]\ dx_2 + \int_{t}^{\infty} \Big[mg(q)z\phi(z(x_2 - m))\Big]\ dx_2 - c(a_1).$$

Differentiating with respect to a_1, country 1's first-order condition is

$$\begin{aligned} FOC = {} & mg(0)z\phi(z(t-m))\frac{dt}{da_1} + \int_{-\infty}^{t} -mg'(-q)\frac{dq}{da_1}z\phi(z(x_2 - m))\ dx_2 \\ & - mg(0)z\phi(z(t-m))\frac{dt}{da_1} + \int_{t}^{\infty} mg'(q)\frac{dq}{da_1}z\phi(z(x_2 - m))\ dx_2 - c_1 = 0 \\ = {} & \int_{-\infty}^{t} \frac{m\beta\lambda}{2c_2(2\beta+\gamma)}\frac{1}{\alpha_1'(\alpha_1^{-1}(a_1))}z\phi(z(x_2 - m))\ dx_2 \end{aligned}$$

$$+\int_t^\infty \frac{m\beta\lambda}{2c_2(2\beta+\gamma)}\frac{1}{\alpha_1'(\alpha_1^{-1}(a_1))} z\phi(z(x_2-m))\, dx_2 - c_1 = 0$$
$$\Leftrightarrow\ \alpha_1'(\alpha_1^{-1}(a_1)) = \frac{(\gamma\mu+\beta x_1)\beta\lambda}{2c_2c_1(2\beta+\gamma)(\gamma+\beta)}.$$

Observe that for $x_1 < -\frac{\mu\gamma}{\beta}$, $m < 0$ and so country 1 would then exert effort in the negative direction. By equilibrium conjecture, $a_1 = \alpha_1(x_1)$ so $\alpha_1^{-1}(a_1) = x_1$ and integrating with respect to x_1 yields

$$\alpha_1(x_1) = \frac{\beta\lambda x_1(2\gamma\mu+\beta x_1)}{4c_1c_2(2\beta^2+3\beta\gamma+\gamma^2)} + C.$$

The constant of integration is pinned down by the boundary condition that, at $x_1 = -\frac{\gamma\mu}{\beta}$, we have $E[\theta|x_1] = 0$. The equilibrium effort is thus

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

Note that this is one-to-one in x_1, confirming that $\alpha_1(x_1)$ is one-to-one in equilibrium. This means that $\alpha_1^{*^{-1}}(\cdot)$ is well-defined so country 2 knows $x_1 = \alpha_1^{*^{-1}}(a_1)$ in equilibrium.

Finally, observe that the second order condition is

$$-\frac{m\beta\lambda}{2c_2(2\beta+\gamma)}\frac{\alpha_1''(\alpha_1^{-1}(a_1))}{(\alpha_1'(\alpha_1^{-1}(a_1)))^3} < 0,$$

so the solution $\alpha_1(x_1)$ is the unique maximizer of country 1's utility. □

Proof of Corollary 1. Immediate given the equilibrium strategy of country 1:

$$\frac{d\alpha_1(x_1)}{dx_1} = \frac{2\beta\lambda(\gamma\mu+\beta x_1)}{4c_1c_2(2\beta^2+3\beta\gamma+\gamma^2)} \geq 0.$$
$$\frac{dE[\theta|x_2,a_1]}{da_1} = \frac{\beta}{\beta+\gamma}\frac{1}{\frac{d\alpha_1(x_1)}{dx_1}} \geq 0.$$

□

Proof of Corollary 2. Given country 2's first-order condition,

$$\frac{\partial^2 u_2}{\partial a_2 \partial\alpha_1^{-1}(a_1)} = \frac{\beta}{\gamma+2\beta} g'(a_1+\lambda a_2)\lambda > 0 \ \Leftrightarrow\ \frac{\partial\alpha_2(x_2,a_1)}{\partial\alpha_1^{-1}(a_1)} \geq 0.$$
$$\frac{\partial^2 u_2}{\partial a_2\partial a_1} = E[\theta|x_2,a_1]g''(a_1+\lambda a_2)\lambda < 0 \ \Leftrightarrow\ \frac{\partial\alpha_2(x_2,a_1)}{\partial a_1} \leq 0.$$

$\square$

Proof of Proposition 2. From Corollary 2,

$$
\begin{aligned}
& \Big|\frac{\partial \alpha_2(x_2, a_1)}{\partial \alpha_1^{-1}(a_1)}\Big| > \Big|\frac{\partial \alpha_2(x_2, a_1)}{\partial a_1}\Big| \\
\Leftrightarrow\ & \frac{\beta}{\gamma + 2\beta} g'(a_1 + \lambda a_2)\lambda < -E[\theta | x_2, a_1] g''(a_1 + \lambda a_2)\lambda \\
\Leftrightarrow\ & \frac{\beta}{\gamma\mu + \beta\alpha_1^{-1}(a_1) + \beta x_2} < -\frac{g''(A)}{g'(A)}.
\end{aligned}
$$

$\square$

B Additional Tables and Figures

	Adopt (Binary)		Adopt (Count)	
	(1)	(2)	(3)	(4)
Log(Previous Laws)	0.053***	0.057**	0.603***	0.391***
	(0.019)	(0.026)	(0.105)	(0.105)
Controls	No	Yes	No	Yes
Observations	6,449	4,254	6,449	4,254
R^2	0.424	0.367	0.375	0.362
Within R^2	0.002	0.004	0.010	0.013
Country fixed effects	✓	✓	✓	✓
Year fixed effects	✓	✓	✓	✓

Table A.1: Effect of Previous Laws on Climate Law Adoption

(a) Standard errors clustered by country-year in parentheses

	Adopt (Binary)	
	(1)	(2)
Log(Previous Laws)	0.073**	-0.178
	(0.028)	(0.194)
Log(Previous Laws) × Post-Paris	-0.033	
	(0.036)	
Log(Previous Laws) × Post-Kyoto		0.232
		(0.194)
Observations	6,449	6,449
R^2	0.424	0.424
Within R^2	0.002	0.002
Country fixed effects	✓	✓
Year fixed effects	✓	✓

Table A.2: Effect of Previous Laws on Climate Law Adoption by Agreement Timing

(a) Standard errors clustered by country-year in parentheses

	Environmental Policy Stringency					
	(1)	(2)	(3)	(4)	(5)	(6)
Average Stringency	0.838***	0.787***	0.337	0.274	0.919***	0.869***
	(0.157)	(0.167)	(0.218)	(0.229)	(0.158)	(0.157)
Observations	1,209	1,071	1,209	1,071	1,209	1,071
R^2	0.874	0.888	0.876	0.890	0.937	0.934
Within R^2	0.780	0.803	0.783	0.805	0.891	0.885
Country fixed effects	✓	✓	✓	✓	✓	✓
Controls	No	Yes	No	Yes	No	Yes
Time Trend	Linear	Linear	Cubic	Cubic	Country × Year	Country × Year

Table A.3: Effect of Average Global Policy Stringency on Environmental Policy Stringency (Unweighted)

(a) Standard errors clustered by country in parentheses

	Environmental Policy Stringency					
	(1)	(2)	(3)	(4)	(5)	(6)
Average Stringency (W)	0.077***	0.072***	0.035*	0.026	0.084***	0.079***
	(0.013)	(0.014)	(0.018)	(0.019)	(0.013)	(0.014)
Observations	1,209	1,071	1,209	1,071	1,209	1,071
R^2	0.874	0.886	0.876	0.888	0.937	0.934
Within R^2	0.780	0.799	0.783	0.802	0.890	0.884
Country fixed effects	✓	✓	✓	✓	✓	✓
Controls	No	Yes	No	Yes	No	Yes
Time Trend	Linear	Linear	Cubic	Cubic	Country × Year	Country × Year

Table A.4: Effect of Average Global Policy Stringency on Environmental Policy Stringency (Weighted)

(a) Standard errors clustered by country in parentheses

C Alternative Model with $n > 2$ Countries

The model in the main text assumes a two-country interaction. The theoretical purchase of this approach was that it allowed for a parsimonious study of forward-looking incentives to exert effort or not. In this section, I describe a model that features $n > 2$ countries but remove this strategic interdependence. Similar to observational learning models (Banerjee 1992; Bikhchandani, Hirshleifer and Welch 1992; Smith and Sørensen 2000), countries are only backward-looking in their valuation of contributions to global effort.

Model Setup

Consider sequential climate policymaking between n countries indexed by $i = 1, \ldots, n$ who decide whether to pursue climate reforms $a_i = 1$ or not $a_i = 0$. The action $a_i = 1$ represents climate reforms or policies instituted to facilitate a green transition in country i, while $a_i = 0$ represents maintaining the status quo. These countries take actions in a fixed order and can observe the choices of all countries before them.

Countries' payoffs to climate reform depend on two uncertain elements: the global benefit to a green transition and the private domestic cost of implementing reforms. The global benefit to a green transition is a binary state variable $\theta \in \{0, 1\}$. No country knows the true realization of θ—whether or not the green transition pays off or will be "successful" is unknown—but share the common prior $P(\theta = 1) = \pi \in (0, 1)$. If a country does not take climate action, it receives a payoff of zero. By taking climate action, country i receives a benefit normalized to 1 only if $\theta = 1$: this captures the idea that countries only want to pursue climate reforms if it is appropriate to do so or if the green transition is sufficiently likely to be successful.

While the benefits of a green transition are state dependent, their costs are not: implementing climate friendly policies is domestically costly—political opportunity costs may arise, perhaps because of redistributive frictions that drive new societal cleavages (Aklin and Mildenberger 2020; Colgan, Green and Hale 2021) or because large polluters face greater costs to adjust their mitigation burdens—and choosing $a_i = 1$ comes at a cost $c_i \sim U[0, 1]$. These costs represent the domestic political feasibility of the green transition. Formally, these costs create heterogeneity in preferences for climate policy across countries (Goeree, Palfrey and Rogers 2006). Country i's costs of implementation are privately known, drawn independently for each country, and are independent of θ.

There are two information sources that countries have at their disposal when determining whether to implement climate policy. The first is the history of observed actions, $h_i = (a_1, \ldots a_{i-1})$. Countries learn about the suitability of green policy θ through the behavior of others. They also receive conditionally independent private signals, which, along with the prior, generate private beliefs $p_i \in [0, 1]$. I work with these beliefs rather than signals and the prior π directly (p_i is a sufficient statistic). These beliefs are not publicly known, but insofar as they translate into actions they may partially inferred. Let the cumulative distribution function of a private belief p in state θ be $F(p|\theta)$ with density $f(p|\theta)$ such that

$F(p|1) < F(p|0)$.[1]

Given some history of countries' climate policies h_i, define the public belief $P(\theta = 1|h_i)$ as the informational content about the suitability of the green transition. There is an associated public likelihood ratio $\ell_i = \frac{1-P(\theta=1|h_i)}{P(\theta=1|h_i)}$ such that lower values of ℓ_i imply a greater likelihood that $\theta = 1$, or that a green transition would be successful.

The climate problem is often described as one of strategic substitutes because it is nationally costly to exert effort to address climate change despite that this effort provides a global benefit. To capture this tension, I introduce *collective action penalties*, which are action-specific, history-dependent costs (Eyster et al. 2014). It becomes more costly to pursue climate reform if many other countries have done so already. In reduced form, these penalties capture the strategic substitutability of climate actions across countries present in other models. Denote collective actions penalties as $z(h_i)$ (and suppress dependence on h_i where it is not confusing). This function is increasing in the number of countries who have already taken climate action, or $\sum h_i$. For simplicity, assume the penalty is bounded, $z_i \in [0, 1]$; since the domestic costs c_i are on the same scale, there is no explicit assumption as to whether implementation costs are greater than collective action penalties. As an example, consider a linearly proportional cost function for any country $i \geq 2$ (with $z_1 = 0$),

$$z_i = \frac{\sum h_i}{i-1}.$$

In countries' payoffs I scale these externalities by $k > 0$ in order to parameterize the extent to which countries weigh potential complementarities (generated by information about θ) and potential substitutes (generated by collective action penalties). This parameter can be thought of as scaling the extent to which countries internalize free-riding concerns; larger k implies stronger free-riding incentives as collective action penalties are weighted more heavily.

Given this setup, country i's payoff can be written as

$$u_i(a_i, h_i, \theta; c_i) = a_i(\theta - c_i - kz(h_i)).$$

A strategy for country i is a choice to implement climate reforms or not, $a_i \in \{0, 1\}$, given the choices of other prior-moving countries contained in history h_i, and its type (p_i, c_i), comprised of its private belief about θ and its domestic costs of implementing green policy. I examine weak perfect Bayesian equilibria and derive all posterior beliefs via Bayes's Rule.

Results and Proofs

Fix a history $h_i = (a_1, \ldots, a_{i-1})$ of past climate policy adoption decisions that induce a public likelihood ratio ℓ_i and potential collective action penalties z_i. Given ℓ_i and the private belief

[1] By Bayes's Rule, the state-conditional densities $f(p|\theta)$ satisfy $p = \frac{\pi f(p|1)}{f(p)}$ and $1 - p = \frac{(1-\pi)f(p|0)}{f(p)}$ with $f(p) = \pi f(p|1) + (1-\pi)f(p|0)$. Then $\frac{f(p|1)}{f(p|0)} = \frac{p}{1-p}\frac{1-\pi}{\pi}$; this stochastic ordering implies that the conditional distributions are mutually absolutely continuous, share the same support, and that $F(p|1) < F(p|0)$ for all private beliefs strictly inside the support.

p_i, country i can make an assessment about the appropriateness of climate policy, i's posterior belief that $\theta = 1$ is defined as

$$\mu_i = P(\theta = 1 | p_i, \ell_i) = \frac{p_i}{p_i + (1 - p_i)\ell_i}.$$

Then, country i prefers to implement climate reforms if and only if

$$\begin{aligned} \mu_i - c_i - kz_i &\geq 0 \\ \Leftrightarrow \ \mu_i &\geq c_i + kz_i \\ \Leftrightarrow \ p_i &\geq \frac{\ell_i(c_i + kz_i)}{1 - (c_i + kz_i) + \ell_i(c_i + kz_i)} \ \equiv \ \tilde{p}(c_i, \ell_i). \end{aligned}$$

Country i pursues climate action if and only if their private belief about a successful green transition is sufficiently high, given the domestic political costs of implementing climate reforms and the potential collective action penalties. If $\tilde{p}(c_i, \ell_i) > 1$, then i never takes climate action regardless of the value of p_i, which occurs whenever $c_i > 1 - kz_i \ \equiv \ \bar{c}_i$. Intuitively, if the domestic costs of implementing climate policy are prohibitively high, it does not matter how optimistic i is about the green transition, implementing green policy is not domestically feasible. Then, for any $c_i \in [0, \ \bar{c}_i]$, i pursues climate action if and only if $p_i > \tilde{p}(c_i, \ell_i)$, which occurs with probability $1 - F(\tilde{p}(c_i, \ell_i)|\theta)$.

Proposition A.1. *Let $\alpha^*(a_i|\ell_i, \theta)$ be the probability that country i takes climate action a_i in state θ. Then*

$$\alpha^*(1|\ell_i, \theta) = \int_0^{\bar{c}_i} 1 - F(\tilde{p}(c_i, \ell_i)|\theta) \ dc_i \ = \ 1 - \alpha^*(0|\ell_i, \theta).$$

Lemma A.1. *The threshold $\tilde{p}(c_i, \ell_i)$ is:*

- *increasing in the public likelihood ratio ℓ_i;*
- *increasing in domestic implementation costs c_i;*
- *increasing in collective action penalties z_i;*
- *increasing in the strength of free-riding incentives k.*

Proof of Lemma A.1.

$$\begin{aligned} \frac{\partial \tilde{p}(c_i, \ell_i)}{\partial \ell_i} &= \frac{(1 - c_i - kz_i)(c_i + kz_i)}{(1 - (c_i + kz_i) + \ell_i(c_i + kz_i))^2} \ \geq \ 0. \\ \frac{\partial \tilde{p}(c_i, \ell_i)}{\partial c_i} &= \frac{\ell_i}{(1 - (c_i + kz_i) + \ell_i(c_i + kz_i))^2} \ \geq \ 0. \end{aligned}$$

$$\frac{\partial \tilde{p}(c_i,\ell_i)}{\partial z_i} = \frac{k\ell_i}{(1-(c_i+kz_i)+\ell_i(c_i+kz_i))^2} \;\geq\; 0.$$
$$\frac{\partial \tilde{p}(c_i,\ell_i)}{\partial k} = \frac{\ell_i z_i}{(1-(c_i+kz_i)+\ell_i(c_i+kz_i))^2} \;\geq\; 0.$$

□

Proof of Proposition A.1. Immediate from text. □

Corollary A.1. *Climate policy is informative about θ. The probability of climate action is greater when $\theta = 1$ versus $\theta = 0$: $\alpha^*(1,\ell_i,1) > \alpha^*(1,\ell_i,0)$. The probability of climate inaction is greater when $\theta = 0$ versus $\theta = 1$: $\alpha^*(0,\ell_i,1) < \alpha^*(0,\ell_i,0)$.*

Proof of Corollary A.1.

$$\begin{aligned}\alpha^*(1|\ell_i,1) - \alpha^*(1|\ell_i,0) &= \Big(\int_0^{\bar{c}_i} 1 - F(\tilde{p}(c_i,\ell_i)|1)\;dc_i\Big) - \Big(\int_0^{\bar{c}_i} 1 - F(\tilde{p}(c_i,\ell_i)|0)\;dc_i\Big)\\ &= \int_0^{\bar{c}_i} F(\tilde{p}(c_i,\ell_i)|0) - F(\tilde{p}(c_i,\ell_i)|1)\;dc_i > 0,\end{aligned}$$

where the result follows from the stochastic ordering of private beliefs. □

Corollary A.2. *The probability of climate action is increasing in the public optimism about a successful green transition, $\frac{d\alpha^*(1|\ell_i,\theta)}{d\ell_i} \leq 0$.*

Proof of Corollary A.2. Differentiating with respect to ℓ_i yields

$$\frac{d\alpha^*(1|\ell_i,\theta)}{d\ell_i} = -\int_0^{\bar{c}_i} f(\tilde{p}(c_i,\ell_i)|\theta)\frac{\partial \tilde{p}_i}{\partial \ell_i}\;dc_i \leq 0.$$

□

Corollary A.3. *The probability of climate action is decreasing in collective action penalties, $\frac{d\alpha^*(1|\ell_i,\theta)}{dz_i} \leq 0$.*

Proof of Corollary A.3. By the Leibniz integral rule, differentiating with respect to z_i yields

$$\begin{aligned}\frac{d\alpha^*(1|\ell_i,\theta)}{dz_i} &= \frac{\partial \bar{c}_i}{\partial z_i} - F(\tilde{p}(\bar{c}_i,\ell_i)|\theta)\frac{\partial \bar{c}_i}{\partial z_i} - \int_0^{\bar{c}_i} f(\tilde{p}(c_i,\ell_i)|\theta)\frac{\partial \tilde{p}(c_i,\ell_i)}{\partial z_i}\;dc_i\\ &= -\int_0^{\bar{c}_i} f(\tilde{p}(c_i,\ell_i)|\theta)\frac{\partial \tilde{p}(c_i,\ell_i)}{\partial z_i}\;dc_i \leq 0.\end{aligned}$$

where the first two terms simplify because $\tilde{p}(\bar{c}_i,\ell_i) = 1$. □

Corollary A.2 states that more optimistic public beliefs about a successful green transition begets more climate action. That is, these beliefs endogenously generate *complementarities* in countries' climate actions. Conversely, increased collective action penalties—which arise because more countries have already pursued climate policies—depress subsequent climate action, as stated in Corollary A.3. The actions of prior movers induce *substitution* in the behavior of later policymakers.

Which factor dominates? Under what conditions are countries' actions strategic complements or strategic substitutes in equilibrium? To conceptualize this, I consider the ratio of the marginal effects of public beliefs and collective action penalties. Define $\rho(\ell_i, z_i|\theta)$ as

$$\rho(\ell_i, z_i|\theta) = \frac{d\alpha^*(1|\ell_i,\theta)}{d\ell_i} \Big/ \frac{d\alpha^*(1|\ell_i,\theta)}{dz_i}.$$

The magnitude of $\rho(\ell_i, z_i|\theta)$ is always positive, but we can think about which factor dominates—strategic complementarities that stem from increased public beliefs or strategic substitutes from collective action penalties—based on where it is greater than or less than 1. If $\rho(\ell_i, z_i|\theta) > 1$, then, all else equal, varying public beliefs has a larger effect on the equilibrium probability of climate action than does varying collective action penalties. In this case, we can say that the net effect of other countries' behavior generates complementarities for country i. By contrast, when $\rho(\ell_i, z_i|\theta) < 1$, then the incentives to free ride swamp the potential benefits from climate policy investment.

Proposition A.2. *Complementarity effects dominate when free-riding incentives are small, and substitution effects dominate when free-riding incentives are large: there exists a threshold $\overline{k}_i$ such that if $k < \overline{k}_i$ then $\rho(\ell_i, z_i|\theta) > 1$.*

Proof of Proposition A.2. It follows that

$$\rho(\ell_i, z_i|\theta) > 1 \;\Leftrightarrow\; \int_0^{\bar{c}_i} f(\tilde{p}(c_i,\ell_i)|\theta)\frac{\partial \tilde{p}_i}{\partial \ell_i}\, dc_i > \int_0^{\bar{c}_i} f(\tilde{p}(c_i,\ell_i)|\theta)\frac{\partial \tilde{p}(c_i,\ell_i)}{\partial z_i}\, dc_i.$$

Define $Q(k) = (1-(c_i+kz_i)+\ell_i(c_i+kz_i))^2 \geq 0$, which is the denominator of the comparative statics on $\tilde{p}(c_i,\ell_i)$. Simplifying yields

$$\int_0^{\bar{c}_i} \frac{f(\tilde{p}(c_i,\ell_i)|\theta)}{Q(k)}\Big((1-c_i-k_i)(c_i+kz_i) - k\ell_i\Big)\, dc_i > 0.$$

Now note that for any $k < \frac{1}{z_i}$, the integral is well-defined (otherwise $\bar{c}_i = 0$). Furthermore, for any $k < \frac{1}{z_i}$, $\frac{f(\tilde{p}(c_i,\ell_i)|\theta)}{Q(k)} \geq 0$ and we are integrating over a positive interval of the c_i space. So the integrand is negative if and only if

$$(1-c_i-k_i)(c_i+kz_i) - k\ell_i < 0,$$

which simplifies to $k > \frac{z_i - 2c_i z_i - \ell_i + \sqrt{\ell_i^2 - 2\ell_i z_i + 4c_i \ell_i z_i + z_i^2}}{2z_i^2} \equiv \overline{k}_i$. Hence a sufficient condition for the integrand to be negative is if $k > \overline{k}_i$ which implies that $\rho(\ell_i, z_i|\theta) < 1$. □

We can now use the model to think about the long-run dynamics of climate policy across countries based on the analysis in the previous subsection. We have shown that the decision problem facing each country at the time of climate adoption is static, meaning history-relevant parameters such as ℓ_i and z_i can be treated in reduced form, but now wish to trace the evolution of actions and beliefs across countries.

Since private signals are conditionally independent, the likelihood ratio updates such that

$$\ell_{i+1} = \varphi(a_i, \ell_i) = \ell_i \frac{\alpha^*(a_i|\ell_i, 0)}{\alpha^*(a_i|\ell_i, 1)}.$$

Observe that by Corollary A.1, relative to ℓ_i, ℓ_{i+1} shrinks if $a_i = 1$ but ℓ_{i+1} grows if $a_i = 0$. The public belief becomes more or less optimistic depending on the previous action a_i, which in turn informs the decision to enact climate policy in the subsequent period. Then, given the updated public belief and any additional collective action penalties, country $i+1$ considers the tradeoff between implementing climate reforms and incurring domestic implementation costs and collective action penalties or free-riding, where climate policy occurs with probability $\alpha^*(1|\ell_{i+1}, \theta)$.

As is standard in the informational cascades and herding literature (e.g., Smith and Sørensen 2000), convergence results are stated conditioning on $\theta = 1$. This is also the more interesting case from a substantive perspective anyway, as this is where the tradeoff between the two mechanisms is present.

Lemma A.2. *Conditional on $\theta = 1$, the public likelihood ratio $< \ell_i >$ is a martingale.*

Proof of Lemma A.2. Recall that the public likelihood ratio updates according to

$$\ell_{i+1} = \ell_i \frac{\alpha^*(a_i|\ell_i, 0)}{\alpha^*(a_i|\ell_i, 1)},$$

by the conditional independence of signals. Taking expectations yields

$$\begin{aligned} E[\ell_{i+1}|\ell_1, \ldots, \ell_i, \theta = 1] &= \sum_{a \in \{0,1\}} \alpha^*(a|\ell_i, 1)\ell_i \frac{\alpha^*(a|\ell_i, 0)}{\alpha^*(a|\ell_i, 1)} \\ &= \ell_i \sum_{a \in \{0,1\}} \alpha^*(a|\ell_i, 0) \\ &= \ell_i. \end{aligned}$$

□

Proposition A.3. *In the limit, countries learn whether the green transition will be successful: public beliefs converge to the true state of the world almost surely.*

Proof of Proposition A.3. Without loss of generality condition on state $\theta = 1$. Since $< \ell_i >$ is a martingale and all values are nonnegative, it converges almost surely to a random variable $\ell_\infty = \lim_{i\to\infty} \ell_i$ with support $[0, \infty)$ by the Martingale Convergence Theorem (Doob 1953). This rules out nonstationary limit beliefs. Since private beliefs p_i are unbounded within $[0, 1]$, then the only stationary finite likelihood ratio in state $\theta = 1$ is 0, so $\ell_\infty \to 0$ almost surely (Smith and Sørensen 2000, Theorem 1). □

Proposition A.4. *In the limit, countries take the correct action $a_i = \theta$ if and only if $c_i \leq \bar{c}_i$.*

Proof of Proposition A.4. Recall that i chooses $a_i = 0$ if $c_i > \bar{c}_i$ for any private belief p_i, which occurs with probability $P(c_i > \bar{c}_i) = kz_i$. This probability is increasing in z_i, which increases in the number of countries that choose $a_i = 1$. Now suppose that $\theta = 1$ and $c_i \leq \bar{c}_i$ so i chooses $a_i = 1$ iff $p_i \geq \tilde{p}(c_i, \ell_i)$. By Proposition A.3, the likelihood ratio converges almost surely to $\ell_i \to 0$. Then we have $\lim_{\ell_i\to 0} \tilde{p}(c_i, \ell_i) = 0$. Hence conditional on $c_i < \bar{c}_i$, i chooses $a_i = 1 = \theta$ for any private belief.

If countries are taking action on a measure zero subset, $\bar{c}_j \to 0$ or $k > \frac{1}{z_j}$ for some $j \leq n$, then countries pool on $a_j = 0\ \forall j, \ldots, n$. □

Corollary A.4. *Let $z_i(h_i) = \frac{\sum h_i}{i-1}$. The probability of climate action converges to $\frac{1}{1+k}$.*

Proof of Corollary A.4. Conditional on state $\theta = 1$, climate action occurs with probability $\bar{c}_i$, as $\tilde{p}(c_i, \ell_i) \to 0$ as $\ell_i \to 0$. Moreover, given that $z_i = \frac{\sum h_i}{i-1}$, it is a linear proportional function of previous actions, so in the limit, $z_i \to \alpha^*(1|\ell_i, \theta)$. Then we have

$$\begin{aligned}
\alpha^*(1|\ell_i, \theta) &= \bar{c}_i = 1 - kz_i \\
&= 1 - k\alpha^*(1|\ell_i, \theta) \\
\Leftrightarrow \quad \alpha^*(1|\ell_i, \theta) &= \frac{1}{1+k}.
\end{aligned}$$

□

Corollary A.5. *In the limit, $\rho(\ell_i, z_i|\theta) > 1$ if $k < 1 - c_i$.*

Proof of Corollary A.5. Per Proposition A.2, a sufficient condition for $\rho(\ell_i, z_i|\theta) > 1$ is $k < \bar{k}_i$ where $\bar{k}_i = \frac{z_i - 2c_iz_i - \ell_i + \sqrt{\ell_i^2 - 2\ell_iz_i + 4c_i\ell_iz_i + z_i^2}}{2z_i^2}$. Then in the long run, $\lim_{\ell_i\to 0} \bar{k}_i = 1 - c_i$. □