Appendix: Learning and Free-Riding in International Climate Policymaking

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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 $x_2|x_1 \sim N(\frac{\gamma\mu+\beta x_1}{\gamma+\beta}, \frac{2\beta+\gamma}{\beta(\beta+\gamma)})$. Let $m = \frac{\gamma\mu+\beta x_1}{\gamma+\beta}$ and $z = \sqrt{\frac{\beta(\beta+\gamma)}{2\beta+\gamma}}$. 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

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

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

It is clear that since q is increasing in $\alpha_1^{-1}(a_1)$, country 1's optimal strategy does not contain any "flat spots" as it is always optimal for him to induce greater effort from country 2. 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,

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

$\square$

B Additional Tables and Figures

B.1 Climate Law Adoption and Environmental Policy Stringency

The main results employ country × year time trends. Table A.1 shows robustness of the findings without any temporal controls.

	Laws (Count)		Laws (Binary)		EPS		CAPMF	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(Other Laws)	0.530***	0.819***	0.526***	0.867***				
	(0.012)	(0.049)	(0.011)	(0.053)				
Avg. Other Stringency					0.918***	0.706***	0.972***	0.818***
					(0.013)	(0.143)	(0.003)	(0.051)
Observations	7,000	7,000	7,000	7,000	1,200	1,200	1,650	1,650
R^2	0.302	0.331	0.314	0.344	0.900	0.904	0.960	0.962
Within R^2	0.277	0.307	0.273	0.305	0.845	0.852	0.958	0.960
DV Mean	0.348	0.348	0.713	0.713	2.04	2.04	1.25	1.25
Number of Countries	200	200	200	200	40	40	50	50
Country fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
Country × Year trends		✓		✓		✓		✓

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

Table A.1: Effects of Previous Law Adoption and Policy Stringency on Climate Policymaking (with and without Time Trends)

The main results include a country fixed effect to parse out any time-invariant factors that lead countries to adopt laws or pursue environmental policies in a heterogeneous fashion. However, in so doing, the regression coefficient β thus targets the within-country correlation of the effect of other nations' climate actions on the adoption of climate laws. Table A.2 removes country fixed effects and shows that the results still hold.

	Laws (Count)		Laws (Binary)		EPS		CAPMF	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
log(Other Laws)	0.530***	0.803***	0.525***	0.849***				
	(0.012)	(0.048)	(0.012)	(0.052)				
Avg. Other Stringency					0.904***	0.409**	0.971***	0.801***
					(0.013)	(0.152)	(0.003)	(0.051)
Observations	7,000	7,000	7,000	7,000	1,200	1,200	1,650	1,650
R^2	0.267	0.270	0.257	0.262	0.529	0.536	0.909	0.911
Adjusted R^2	0.267	0.270	0.257	0.262	0.528	0.536	0.909	0.910
DV Mean	0.348	0.348	0.713	0.713	2.04	2.04	1.25	1.25
Year trends		✓		✓		✓		✓

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

Table A.2: Effects of Previous Law and Policy Stringency on Climate Policymaking (without Country Fixed Effects)

Climate Laws

In the main text, I employ country × year time trends to capture the effects of potential secular increases in the demand for climate policy. Table A.3 shows that results are robust to different types of time trends. Specifically, I estimate linear, quadratic, and cubic yearly time trends. I also estimate year random effects.

	Laws (Count)			Laws (Binary)		
	(1)	(2)	(3)	(4)	(5)	(6)
log(Other Laws)	0.819***	0.968***	0.388***	0.867***	0.911***	0.315***
	(0.048)	(0.047)	(0.064)	(0.052)	(0.052)	(0.064)
Observations	7,000	7,000	7,000	7,000	7,000	7,000
R^2	0.305	0.310	0.330	0.319	0.319	0.340
Within R^2	0.280	0.285	0.306	0.278	0.279	0.301
Country fixed effects	✓	✓	✓	✓	✓	✓
Time trends	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic

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

Table A.3: Effects of Climate Laws with Alternate Time Trends

	Laws (Count)	Laws (Binary)
	(1)	(2)
(Intercept)	−1.019***	−0.963***
	(0.213)	(0.192)
log(Other Laws)	0.530***	0.526***
	(0.050)	(0.040)
Country fixed effects	✓	✓
AIC	17652.524	17938.139
BIC	19043.818	19329.433
Log Likelihood	−8623.262	−8766.069
Num. obs.	7000	7000
Num. groups: year	35	35
Var: year (Intercept)	0.082	0.052
Var: Residual	0.655	0.685

$^{***}p < 0.001$; $^{**}p < 0.01$; $^{*}p < 0.05$

Table A.4: Effects of Climate Laws with Year Random Effects

While the results between other nations' laws and the tendency to adopt laws should be treated as descriptive or correlational, I also estimate these models with the inclusion of some time-varying controls. These control variables are meant to parse time-varying variation away from nations' climate policymaking behavior. Specifically, I estimate the revised model

$$\text{Laws}_{i,t} = \beta \ \log(\text{Other Laws}_{-i,t-1}) + X'_{i,t-1}\gamma + \alpha_i + \lambda_{i,t} + \varepsilon_{i,t},$$

where the term $X'_{it-1}\gamma$ captures these controls. I include a lagged dependent variable, GDP per capita, population, and a country's growth rate (all from the World Bank), and the size of a country's winning coalition to proxy for regime type (Bueno de Mesquita and Smith 2022). Results are shown in Table A.5.

	Laws (Count)		Laws (Binary)	
	(1)	(2)	(3)	(4)
log(Other Laws)	0.557***	0.005	0.544***	0.224***
	(0.033)	(0.076)	(0.035)	(0.079)
Lagged DV	0.071***	0.023	0.041**	0.003
	(0.019)	(0.019)	(0.016)	(0.017)
log(GDP per capita)	0.148	-0.097	0.168	0.027
	(0.101)	(0.196)	(0.104)	(0.227)
log(Population)	0.089	-0.246	0.141	0.154
	(0.092)	(0.655)	(0.105)	(0.552)
Growth	0.004	0.002	0.005*	0.003
	(0.003)	(0.003)	(0.003)	(0.004)
Winning Coalition Size	-0.419**	-0.766***	-0.242	-0.447*
	(0.174)	(0.249)	(0.183)	(0.244)
Observations	5,075	5,075	5,075	5,075
R^2	0.366	0.396	0.366	0.389
Within R^2	0.345	0.376	0.331	0.355
Country fixed effects	✓	✓	✓	✓
Country × Year trends		✓		✓
Controls	✓	✓	✓	✓

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

Table A.5: Effects of Climate Laws with Controls

We may be worried that only richer countries or only countries that are emissions-intensive need to pass laws. Tables A.6 and A.7 weight results by countries' GDP per capita and emissions per capita.

	Laws (Count)		Laws (Binary)	
	(1)	(2)	(3)	(4)
log(Other Laws)	0.613***	0.004	0.597***	0.248***
	(0.011)	(0.076)	(0.011)	(0.077)
Observations	5,863	5,863	5,863	5,863
R^2	0.350	0.381	0.355	0.379
Within R^2	0.327	0.360	0.318	0.343
Country fixed effects	✓	✓	✓	✓
Country × Year trends		✓		✓
Weights	GDP per capita	GDP per capita	GDP per capita	GDP per capita

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

Table A.6: Effects of Climate Laws (Weighted by GDP per capita)

	Laws (Count)		Laws (Binary)	
	(1)	(2)	(3)	(4)
log(Other Laws)	0.506***	0.677***	0.498***	0.752***
	(0.031)	(0.100)	(0.031)	(0.097)
Observations	6,545	6,545	6,545	6,545
R^2	0.293	0.329	0.301	0.335
Within R^2	0.257	0.295	0.245	0.282
Country fixed effects	✓	✓	✓	✓
Country × Year trends		✓		✓
Weights	GHG per capita	GHG per capita	GHG per capita	GHG per capita

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

Table A.7: Effects of Climate Laws (Weighted by Emissions per capita)

Policy Stringency

Figures A.1 and A.2 plot the raw data of each country's EPS and CAPMF score (solid line) as well as the average stringency of all other countries (dashed line) over time. It is evident that for almost all countries, stringency is increasing over time and is positively correlated with the actions of others.

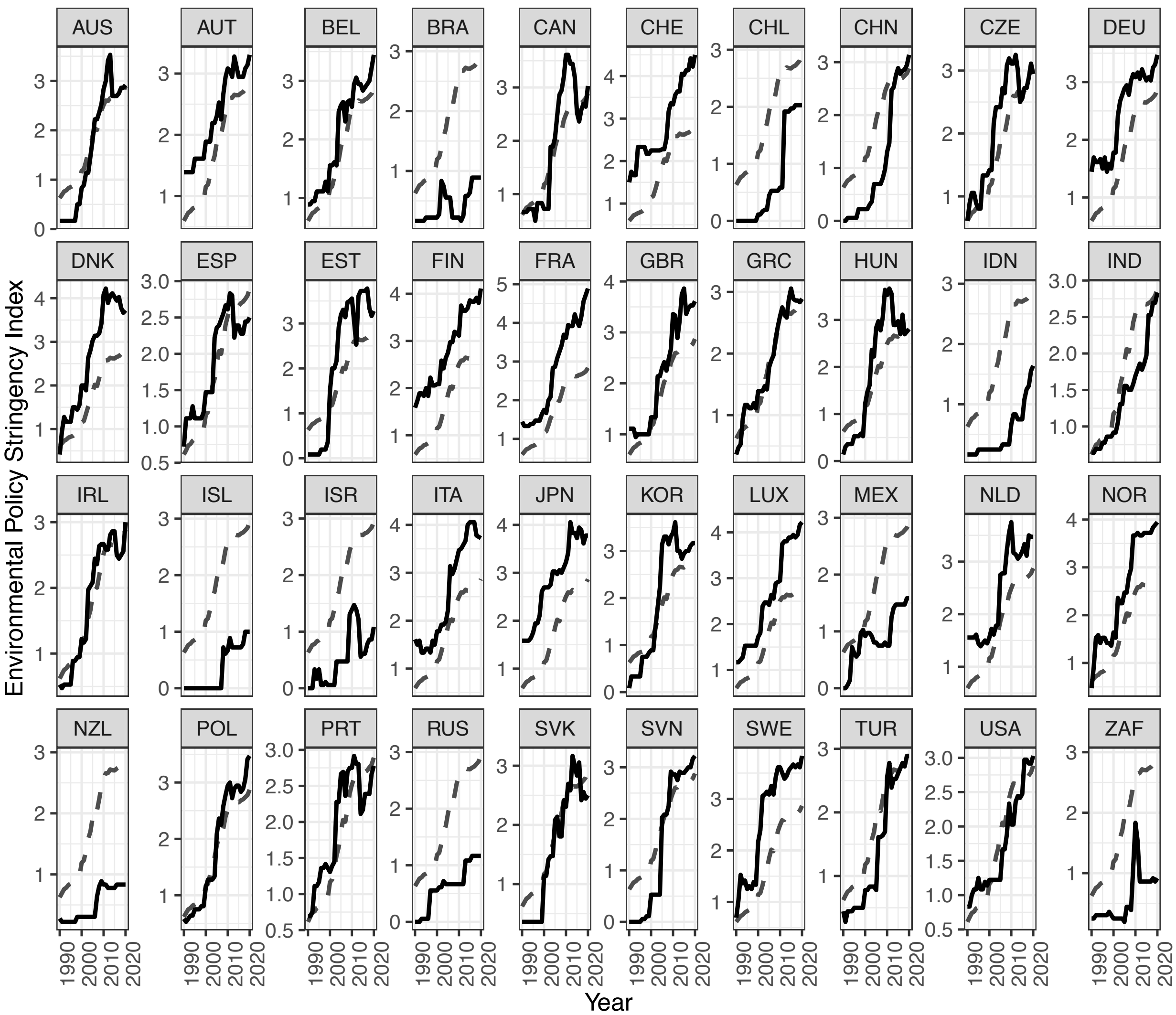

Figure A.1: Environmental Policy Stringency 1990-2020

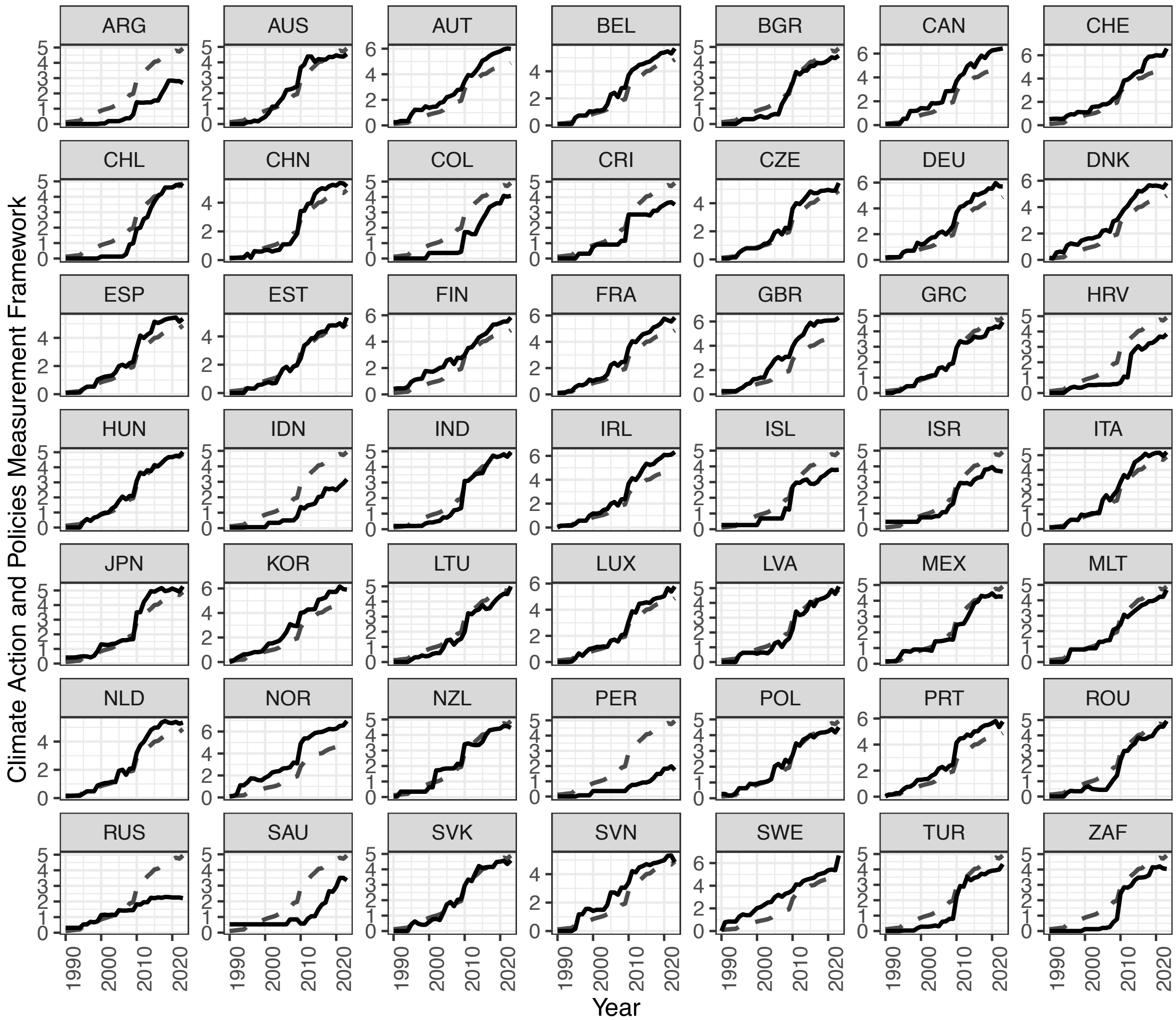

Figure A.2: Climate Action Policy Mitigation Framework 1990-2023

In the main text, I employ country × year time trends to capture the effects of potential secular increases in the demand for climate policy. Table A.8 shows that results are robust to different types of time trends. Specifically, I estimate linear, quadratic, and cubic yearly time trends. I also estimate year random effects.

	EPS			CAPMF		
	(1)	(2)	(3)	(4)	(5)	(6)
Average Other Stringency	0.705***	0.698***	0.339	0.818***	0.823***	0.646***
	(0.141)	(0.137)	(0.224)	(0.051)	(0.055)	(0.047)
Observations	1,200	1,200	1,200	1,650	1,650	1,650
R^2	0.901	0.901	0.902	0.962	0.962	0.963
Within R^2	0.847	0.847	0.848	0.960	0.960	0.961
Country fixed effects	✓	✓	✓	✓	✓	✓
Time trends	Linear	Quadratic	Cubic	Linear	Quadratic	Cubic

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

Table A.8: Effects of Policy Stringency with Alternate Time Trends

	EPS	CAPMF
	(1)	(2)
(Intercept)	−0.546***	−0.327***
	(0.078)	(0.041)
Average Other Stringency	0.916***	0.966***
	(0.015)	(0.017)
Country fixed effects	✓	✓
AIC	1320.345	−540.609
BIC	1539.218	−253.957
Log Likelihood	−617.172	323.305
Num. obs.	1200	1650
Num. groups: year	30	33
Var: year (Intercept)	0.003	0.008
Var: Residual	0.148	0.033

***$p < 0.001$; **$p < 0.01$; *$p < 0.05$

Table A.9: Effects of Policy Stringency with Year Random Effects

While the results between other nations' stringency and the country i's policy stringency should be treated as descriptive or correlational, I also estimate these models with the inclusion of some time-varying controls. These control variables are meant to parse time-varying variation away from nations' climate policymaking behavior. Specifically, I estimate the revised model

$$\text{Stringency}_{i,t} = \beta \text{ Average Stringency}_{-i,t-1} + X'_{i,t-1}\gamma + \alpha_i + \lambda_{i,t} + \varepsilon_{i,t},$$

where the term $X'_{it-1}\gamma$ captures these controls. I include a lagged dependent variable, GDP per capita, population, and a country's growth rate (all from the World Bank), and the size of a country's winning coalition to proxy for regime type (Bueno de Mesquita and Smith 2022). Results are shown in Table A.10.

	EPS		CAPMF	
	(1)	(2)	(3)	(4)
Average Other Stringency	0.184***	0.134**	0.213***	0.080***
	(0.031)	(0.056)	(0.034)	(0.028)
Lagged DV	0.745***	0.738***	0.767***	0.753***
	(0.024)	(0.024)	(0.034)	(0.036)
log(GDP per capita)	0.158***	0.529*	0.107***	-0.097
	(0.053)	(0.262)	(0.025)	(0.090)
log(Population)	0.238*	-0.389	0.143***	-0.873*
	(0.125)	(0.924)	(0.037)	(0.438)
Growth	-0.006*	-0.005	0.002	-0.0002
	(0.003)	(0.003)	(0.001)	(0.001)
Winning Coalition Size	0.057	0.116	0.045	-0.234
	(0.242)	(0.510)	(0.091)	(0.145)
Observations	1,165	1,165	1,469	1,469
R^2	0.952	0.954	0.977	0.978
Within R^2	0.927	0.930	0.975	0.977
Country fixed effects	✓	✓	✓	✓
Country × Year trends		✓		✓
Controls	✓	✓	✓	✓

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

Table A.10: Effects of Policy Stringency with Controls

We may be worried that only richer countries or only countries that are emissions-intensive have greater policy stringency. Tables A.11 and A.12 weight results by countries' GDP per capita and emissions per capita.

	EPS		CAPMF	
	(1)	(2)	(3)	(4)
Average Other Stringency	0.923***	0.732***	0.968***	0.796***
	(0.013)	(0.137)	(0.005)	(0.052)
Observations	1,170	1,170	1,523	1,523
R^2	0.898	0.902	0.958	0.961
Within R^2	0.845	0.852	0.956	0.959
Country fixed effects	✓	✓	✓	✓
Country × Year trends		✓		✓
Weights	GDP per capita	GDP per capita	GDP per capita	GDP per capita

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

Table A.11: Effects of Policy Stringency (Weighted by GDP per capita)

	EPS		CAPMF	
	(1)	(2)	(3)	(4)
Average Other Stringency	0.927***	0.785***	0.972***	0.782***
	(0.011)	(0.131)	(0.004)	(0.052)
Observations	1,200	1,200	1,617	1,617
R^2	0.903	0.907	0.958	0.960
Within R^2	0.854	0.859	0.956	0.959
Country fixed effects	✓	✓	✓	✓
Country × Year trends		✓		✓
Weights	GHG per capita	GHG per capita	GHG per capita	GHG per capita

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

Table A.12: Effects of Policy Stringency (Weighted by Emissions per capita)

Table A.13 shows robustness to measuring the behavior of other nations at the median rather than the average policy stringency, which eases concerns about extreme values.

	EPS		CAPMF	
	(1)	(2)	(3)	(4)
Median Stringency	0.919***	0.746***	0.972***	0.877***
	(0.013)	(0.168)	(0.003)	(0.051)
Observations	1,200	1,200	1,650	1,650
R^2	0.900	0.904	0.962	0.963
Within R^2	0.844	0.850	0.960	0.961
Country fixed effects	✓	✓	✓	✓
Country × Year trends		✓		✓

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

Table A.13: Effects of Median Policy Stringency

Table A.14 re-estimates the results in the main text but excludes the influences of China.

	EPS		CAPMF	
	(1)	(2)	(3)	(4)
Average Other Stringency	0.920***	0.749***	0.971***	0.801***
	(0.013)	(0.165)	(0.003)	(0.053)
Observations	1,170	1,170	1,617	1,617
R^2	0.898	0.902	0.959	0.961
Within R^2	0.843	0.849	0.957	0.959
Country fixed effects	✓	✓	✓	✓
Country × Year trends		✓		✓

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

Table A.14: Effects of Policy Stringency Excluding China

B.2 U.S. Presidential Elections

Table A.15 estimates the RD effect of U.S. elections without country fixed effects.

	Trump (2016)		Biden (2020)	
	(1)	(2)	(3)	(4)
RD Election Effect	-0.009	-0.020	0.067***	0.070***
	(0.017)	(0.019)	(0.022)	(0.020)
DV	Count	Binary	Count	Binary
Bandwidth (days)	810.142	782.037	1616.285	1504.298
Effective Observations	10547	10149	20497	19701

Table A.15: RD Estimates without Country Fixed Effects

The RD specification in the main text does not adjust for any other temporal shocks. Tables A.16 and A.17 control for country-month time trends and month fixed effects, respectively. These terms capture factors like signing of international agreements, the onset of global pandemic, or other time shocks that correlated with the adoption of climate laws around the election.

	Trump (2016)		Biden (2020)	
	(1)	(2)	(3)	(4)
RD Election Effect	-0.014	-0.025	0.065***	0.066***
	(0.017)	(0.019)	(0.022)	(0.020)
DV	Count	Binary	Count	Binary
Country fixed effects	✓	✓	✓	✓
Country $\times$ Month time trends	✓	✓	✓	✓
Bandwidth (days)	829.619	824.242	1610.132	1510.144
Effective Observations	10746	10746	20298	19701

Table A.16: RD Estimates with Country-Month Time Trends

	Trump (2016)		Biden (2020)	
	(1)	(2)	(3)	(4)
RD Election Effect	-0.014	-0.025	0.065***	0.066***
	(0.017)	(0.019)	(0.022)	(0.020)
DV	Count	Binary	Count	Binary
Country fixed effects	✓	✓	✓	✓
Month fixed effects	✓	✓	✓	✓
Bandwidth (days)	829.619	824.242	1610.132	1510.144
Effective Observations	10746	10746	20298	19701

Table A.17: RD Estimates with Month Fixed Effects

Figures A.3 and A.4 serve as placebo tests for the RD effects that vary the cutoff in the running variable. I look at the 90 day period around each election. The estimate highlighted in red is the actual estimate.

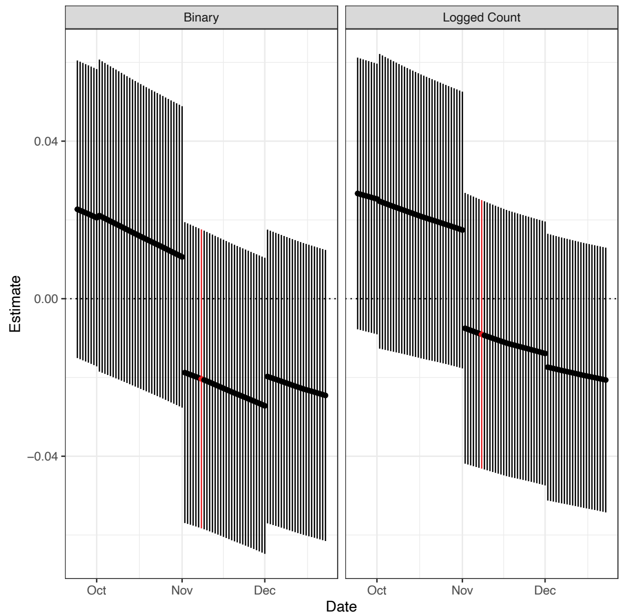

Figure A.3: RD Placebo Test (Trump)

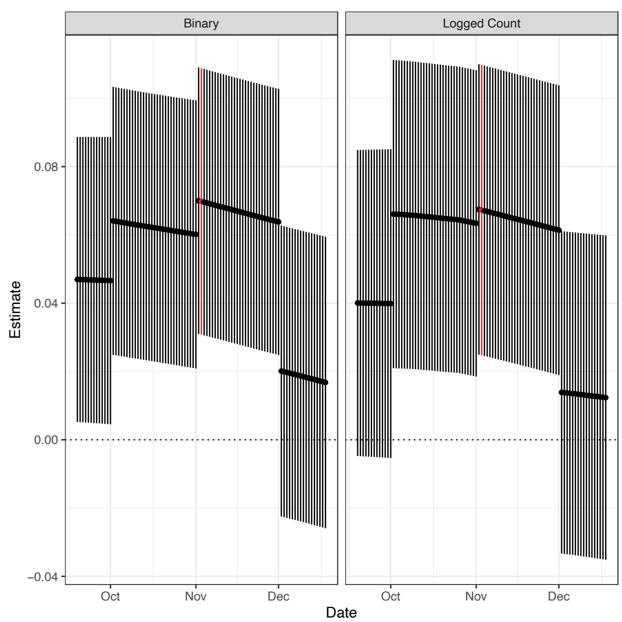

Figure A.4: RD Placebo Test (Biden)

The elections of 2008 and 2012 in which Barack Obama was elected and reelected to the U.S. presidency also provide evidence of complementarities in climate policy adoption. Figure A.5 shows the RD plots and Table A.18 confirms the positive local treatment effect of climate policy adoption around Obama's elections.

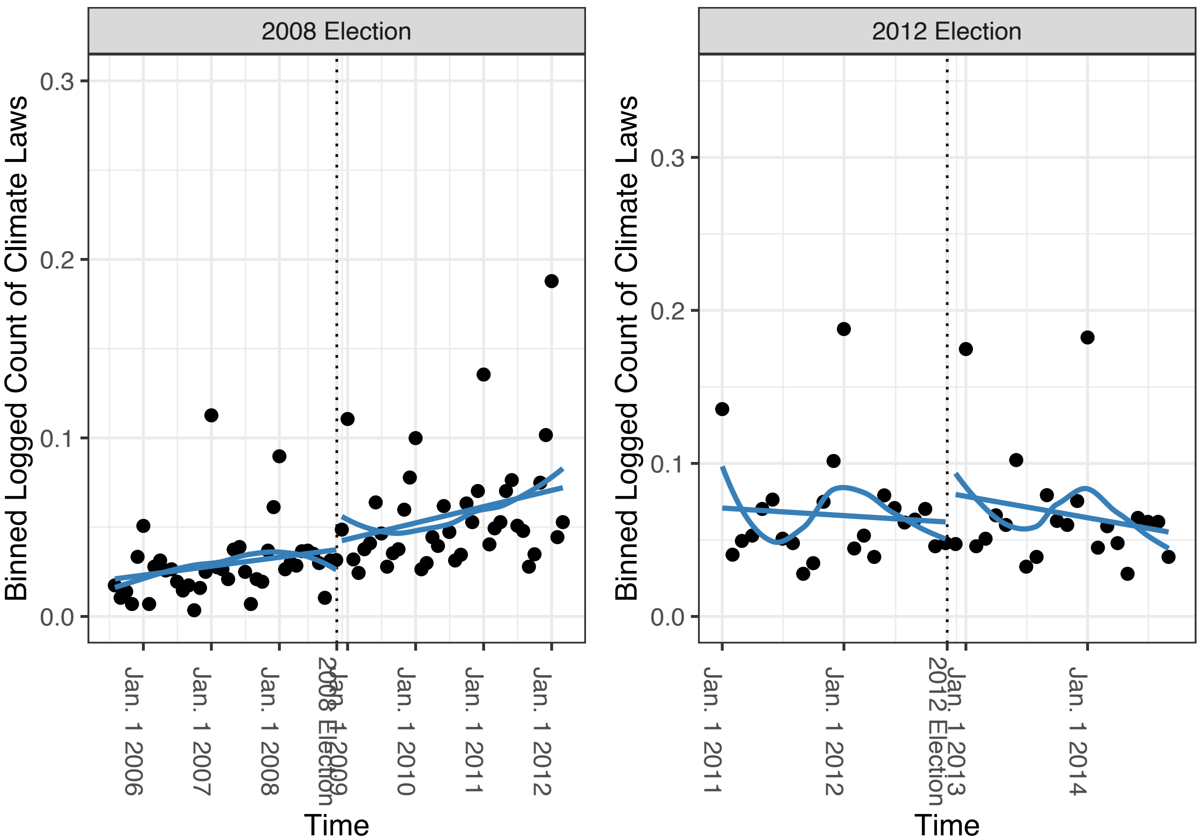

Figure A.5: RD Plots for 2008 and 2012 Elections

	Obama (2008)		Obama (2012)	
	(1)	(2)	(3)	(4)
RD Election Effect	0.015	0.015	0.025*	0.034**
	(0.009)	(0.010)	(0.013)	(0.015)
DV	Count	Binary	Count	Binary
DV Mean	0.043	0.053	0.067	0.081
Bandwidth	1214.288	1297.451	678.854	699.373
Effective Observations	15920	16915	8955	9154

Table A.18: RD Estimates for 2008 and 2012 Elections

B.3 Implications of the Learning Mechanism

Using the mass beliefs, I examine the mean and variance over time on how respondents assess the seriousness of climate change. This exercise allows us to examine belief dynamics: if countries are learning, then the variance in respondents' beliefs should decrease, and the average seriousness of climate change should converge to the truth.[1] In Figure A.6, pooled means and variances over time are in red while country-specific trends are in grey. The left panel of the figure show that over time, there is a slight increase in the average seriousness rating that respondents assign to the problem of climate change. In the right panel of the figure, the variances across respondents are fairly constant in Europe.

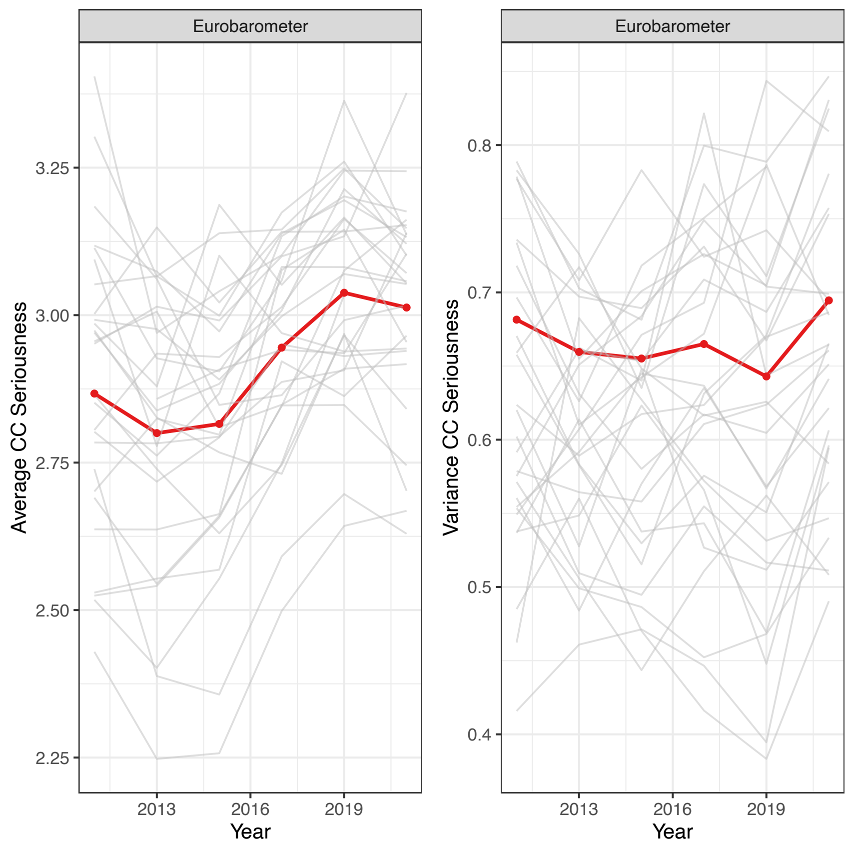

Figure A.6: Mass Belief Means and Variances of Climate Change Seriousness

[1]This extrapolates slightly from the model since the theory does not generate results about convergence—although the model does imply full information transition from country 1 to country 2, so if this game were repeated across more countries then beliefs should converge on the true value of θ—but over time we should observe a convergence of average seriousness to the truth as well as a decline in variance of beliefs. The dynamic model developed in Appendix C does however produce results about belief convergence that are consistent with the results in Figure A.6.

The results in Table 3 are robust (although some results lose statistical significance) to the inclusion of lagged dependent variables, shown below in Table A.19.

Panel A: $cor(x_i, x_j)$	CC Serious (1)	CC Serious (2)
Avg. Other CC Serious	0.233***	0.098
	(0.038)	(0.078)
Observations	322	322
R^2	0.997	0.997
Within R^2	0.518	0.579
Country fixed effects	✓	✓
Lagged DV	✓	✓
Country × Year trends		✓

Panel B: $cor(x_i, a_i)$	Stringency (1)	Stringency (2)
CC Serious	0.001	-0.016
	(0.018)	(0.017)
Observations	322	322
R^2	0.967	0.984
Within R^2	0.835	0.182
Country fixed effects	✓	✓
Year fixed effects		✓
Lagged DV	✓	✓

Panel c: $cor(a_i, x_j)$	CC Serious (1)	CC Serious (2)
Avg. Other Stringency	0.351***	0.317
	(0.047)	(0.227)
Observations	322	322
R^2	0.997	0.997
Within R^2	0.551	0.580
Country fixed effects	✓	✓
Lagged DV	✓	✓
Country × Year trends		✓

Panel D: $cor(x_i, a_j)$	Stringency (1)	Stringency (2)
Avg. Other CC Serious	0.047**	-0.119***
	(0.019)	(0.024)
Observations	324	324
R^2	0.968	0.978
Within R^2	0.834	0.886
Country fixed effects	✓	✓
Lagged DV	✓	✓
Country × Year trends		✓

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

Table A.19: Mass Beliefs with Lagged DV

The panels in Table A.20 disaggregate the elite belief results by climate negotiators and climate scientists. Both groups are optimistic about the ambition of countries' climate commitments although scientists' beliefs are more strongly correlated with nations' future mitigation measures. Turning to confidence in NDC fulfillment, this relationship appears to be driven by climate negotiators rather than scientists; scientist confidence in commitment fulfillment is still positively correlated with policy stringency although weakly so, and this correlation fails to reach conventional levels of statistical significance.

Panel A: Negotiators

	Stringency_{2021}		Stringency_{2022}		Stringency_{2023}	
	(1)	(2)	(3)	(4)	(5)	(6)
Belief NDC Ambitious	0.020**		0.018*		0.020**	
	(0.010)		(0.009)		(0.010)	
Belief NDC Fulfilled		0.016**		0.015**		0.021***
		(0.007)		(0.007)		(0.007)
Observations	3,008	3,069	3,008	3,069	3,008	3,069
R^2	0.922	0.932	0.925	0.934	0.924	0.933
Within R^2	0.003	0.002	0.003	0.002	0.003	0.004
Respondent fixed effects	✓	✓	✓	✓	✓	✓
Belief Country fixed effects	✓	✓	✓	✓	✓	✓

Panel B: Scientists

	Stringency_{2021}		Stringency_{2022}		Stringency_{2023}	
	(1)	(2)	(3)	(4)	(5)	(6)
Belief NDC Ambitious	0.042***		0.037**		0.045***	
	(0.015)		(0.014)		(0.016)	
Belief NDC Fulfilled		0.009		0.007		0.011
		(0.010)		(0.009)		(0.010)
Observations	1,060	1,224	1,060	1,224	1,060	1,224
R^2	0.950	0.950	0.947	0.947	0.941	0.941
Within R^2	0.019	0.0009	0.015	0.0006	0.018	0.001
Respondent fixed effects	✓	✓	✓	✓	✓	✓
Belief Country fixed effects	✓	✓	✓	✓	✓	✓

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

Table A.20: Elite Beliefs and Climate Policy Stringency: Negotiators and Scientists

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.

C.1 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: 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. 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 $F(p|1) < F(p|0)$.[2]

[2]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.

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.

C.2 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 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 $1 - F(\tilde{p}(c_i, \ell_i)|\theta)$.

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.

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

□

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*

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

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 $k > \frac{z_i - 2c_iz_i - \ell_i + \sqrt{\ell_i^2 - 2\ell_iz_i + 4c_i\ell_iz_i + z_i^2}}{2z_i^2} \equiv \overline{k}_i$. 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 $k < \overline{k}_i$ where $\overline{k}_i = \frac{z_i - 2c_i z_i - \ell_i + \sqrt{\ell_i^2 - 2\ell_i z_i + 4c_i \ell_i z_i + z_i^2}}{2z_i^2}$. Then in the long run, $\lim_{\ell_i \to 0} \overline{k}_i = 1 - c_i$. □