Learning and Free-Riding in International Climate Policymaking

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Motivation


Green Deal


The European Green Deal
Climate Pact and Climate Law
Promoting clean energy
Smarter, more sustainable transport
Striving for greener industry
Protecting nature
From farm to fork
Eliminating pollution
Leading the green change globally
Financing green projects
Making homes energy efficient
Ensuring a just transition for all

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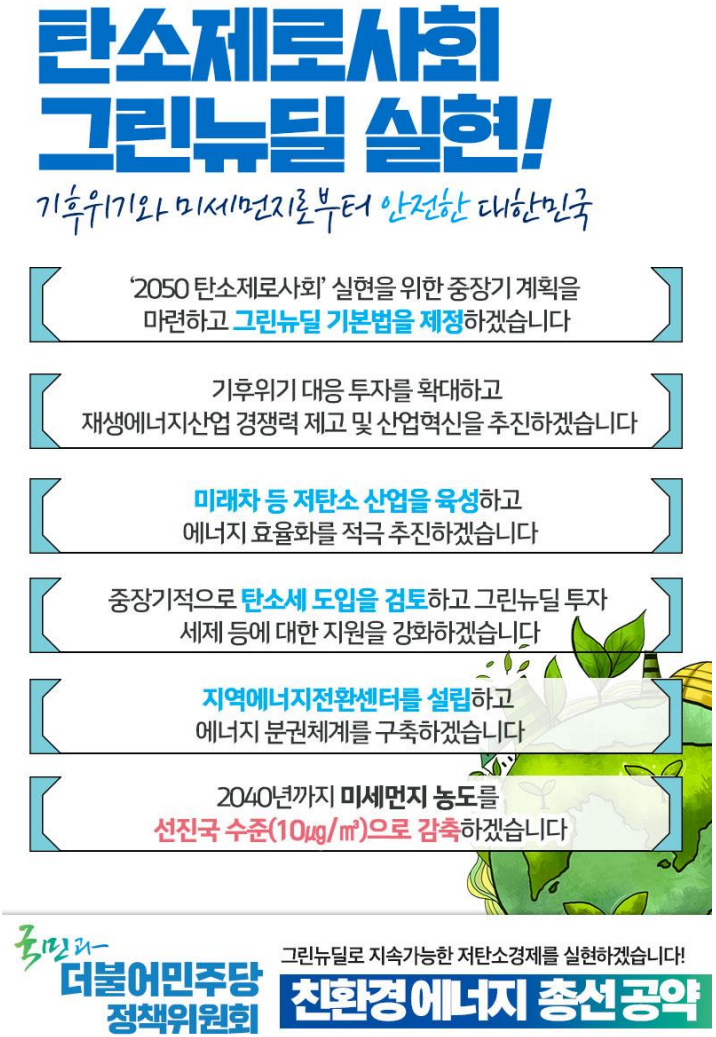
탄소제로사회
그린뉴딜 실현!
기후위기와 미세먼지로부터 안전한 대한민국
'2050 탄소제로사회' 실현을 위한 중장기 계획을 마련하고 그린뉴딜 기본법을 제정하겠습니다
기후위기 대응 투자를 확대하고 재생에너지산업 경쟁력 제고 및 산업혁신을 추진하겠습니다
미래차 등 저탄소 산업을 육성하고 에너지 효율화를 적극 추진하겠습니다
중장기적으로 탄소세 도입을 검토하고 그린뉴딜 투자 세제 등에 대한 지원을 강화하겠습니다
지역에너지전환센터를 설립하고 에너지 분권체계를 구축하겠습니다
2040년까지 미세먼지 농도를 선진국 수준(10㎍/㎥)으로 감축하겠습니다
국민과 더불어민주당 정책위원회
그린뉴딜로 지속가능한 저탄소경제를 실현하겠습니다!
친환경에너지 총선공약


Realizing the Green New
Deal, a Zero-Carbon Society!
A Republic of Korea safe from climate crisis and fine dust
We will establish a mid- to long-term plan to achieve a "zero-carbon society by 2050" and enact the Framework Act on the Green New Deal.
We will expand investment in responding to the climate crisis, enhance the competitiveness of the renewable energy industry, and promote industrial innovation.
We will foster low-carbon industries, including future vehicles, and actively promote energy efficiency.
In the mid- to long-term, we will consider introducing a carbon tax and strengthen support for Green New Deal investment tax systems.
We will establish a regional energy transition center and establish an energy decentralization system.
We will reduce fine dust concentration to the level of advanced countries (10μg/㎥) by 2040.
With the people
Democratic Party of Korea Policy Committee
We will realize a sustainable, low-carbon economy through the Green New Deal!
Eco-friendly energy general election pledge

Motivation

❑ 이에 따라 국제적인 대응 움직임도 빨라지고 있습니다. **EU**는 '**그린딜(Green Deal)**' 전략 발표를 통해 **매년 330조원(EU 전체 GDP의 15%)**을 기후위기대응 및 탈탄소 인프라 구축, 녹색산업 전환 등에 투자하겠다고 밝혔고, 현재 진행 중인 **미국 대선**에서 역시 '**그린뉴딜(Green NewDeal)**'은 핵심의제로 다뤄지고 있습니다.

❑ 우리 또한 기후변화에 서둘러 대응해야 할 상황입니다. 한국은 **연간 온실가스 배출 세계 7위**이자 대표적인 화력발전 국가입니다. 조속히 기후위기 대응 체계를 갖추지 않을 경우 **연간 GDP**의 **5.2%**가 **감소**할 것이라는 전망(한국환경정책평가연구원, 2017)도 존재합니다.

❑ 이 때문에 문재인 정부는 **석탄화력발전소 신규 건설 중단** 및 **재생에너지 중심의 에너지 전환 정책** 등을 강력히 추진하고 있습니다.

❑ 더불어민주당 역시 기후위기 대응에 적극 앞장서겠습니다. '**2050 그린뉴딜**'을 통해 **저탄소 · 고효율**의 **산업구조**를 실현하고, **재생에너지 중심**의 **지속가능한 경제 성장 기반**을 마련하겠습니다.

❑ Accordingly, international response efforts are accelerating. The EU announced its "Green Deal" strategy, declaring that it would invest 330 trillion won (15% of the EU's total GDP) annually in responding to the climate crisis, building decarbonized infrastructure, and transitioning to green industries. The "Green New Deal" is also a key agenda item in the ongoing US presidential election.

❑ We too are in a situation where we must urgently respond to climate change. Korea is the world's seventh-largest emitter of greenhouse gases and a major producer of thermal power. There are projections that if we don't quickly establish a climate crisis response system, our annual GDP will decline by 5.2% (Korea Environment Institute, 2017).

❑ For this reason, the Moon Jae-in administration is strongly pursuing policies such as halting the construction of new coal-fired power plants and transitioning to an energy transition centered on renewable energy.

❑ The Democratic Party of Korea will also actively lead the way in responding to the climate crisis. Through the "2050 Green New Deal," we will achieve a low-carbon, high-efficiency industrial structure and establish a foundation for sustainable economic growth centered on renewable energy.

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- Two things happen when nations observe previous climate efforts
  - marginal contribution to public good diminishes
  - but also provides information about green policy success

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3. Empirical implications: how does the learning mechanism work?
   - survey data on mass/elite beliefs and climate policy stringency
   - optimism diffuses across borders and predicts more stringent mitigation

Formal Model

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- Payoff for country i:

$$u_i(a_i, A; \theta) = \underbrace{\theta}_{\substack{\text{uncertain} \\ \text{benefits}}} \cdot \underbrace{g(A)}_{\text{global value}} - \underbrace{c(a_i)}_{\text{local costs}}$$

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- PBE: strategies $a_1 = \alpha_1(x_1)$, $a_2 = \alpha_2(x_2, a_1)$, Bayesian updates on θ, x_i

Equilibrium Effort

Proposition

There exists a unique equilibrium such that $a_1^* = \alpha_1(x_1)$ *and* $a_2^* = \alpha_2(x_2, a_1^*)$.

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- Equilibrium effort pinned down by

$$\underset{\text{benefits}}{\text{expected green}} \cdot \underset{\text{contribution}}{\text{marginal global}} = \underset{\text{costs}}{\text{marginal}}$$

Equilibrium Learning

- Country 2's update:

$$E[\theta|x_2, a_1] = \frac{\gamma\mu + \beta\alpha_1^{-1}(a_1) + \beta x_2}{\gamma + 2\beta}$$

$\Longrightarrow$ $E[\theta|x_2, a_1]$ increasing in x_2, a_1

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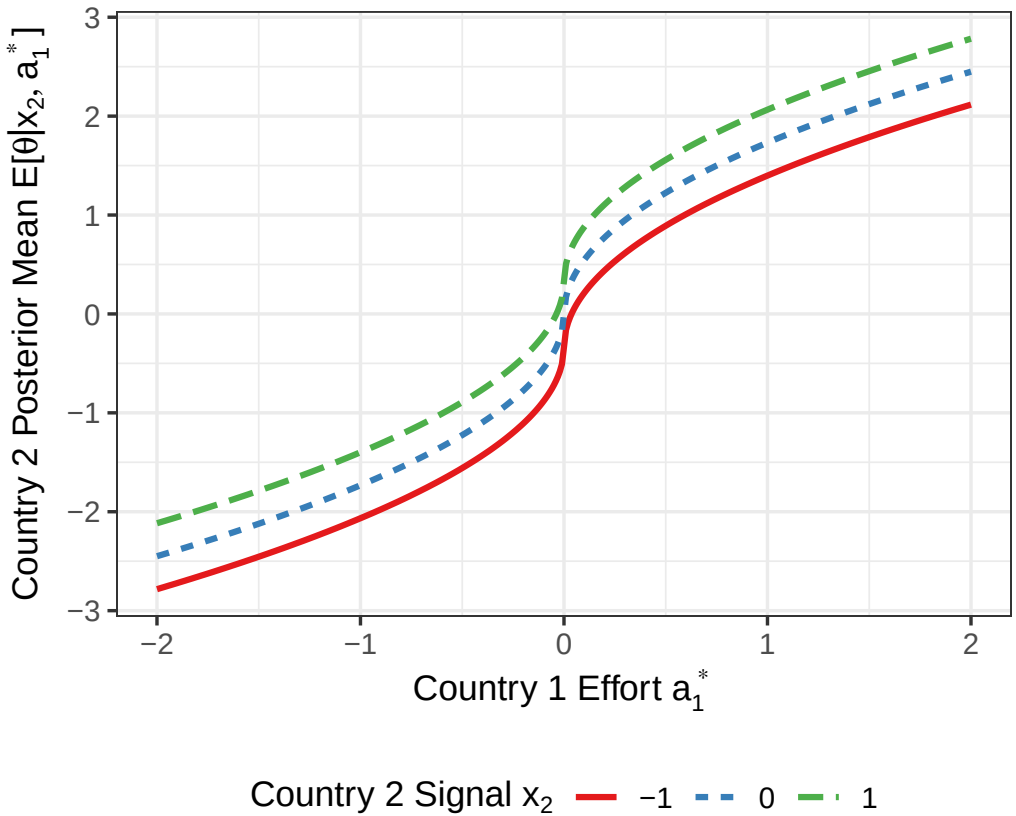

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Actions can be complements or substitutes, positively or negatively correlated

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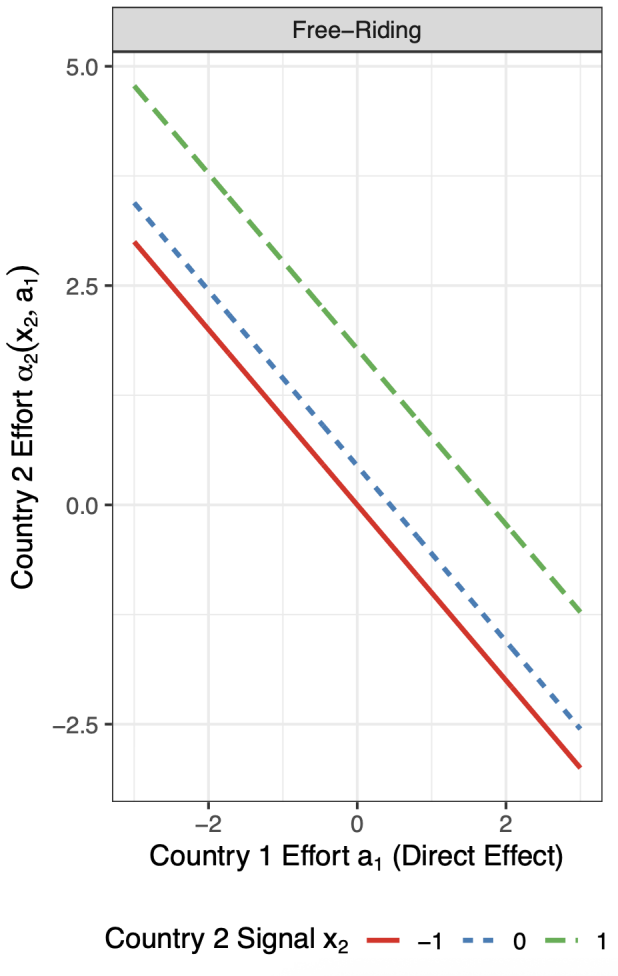

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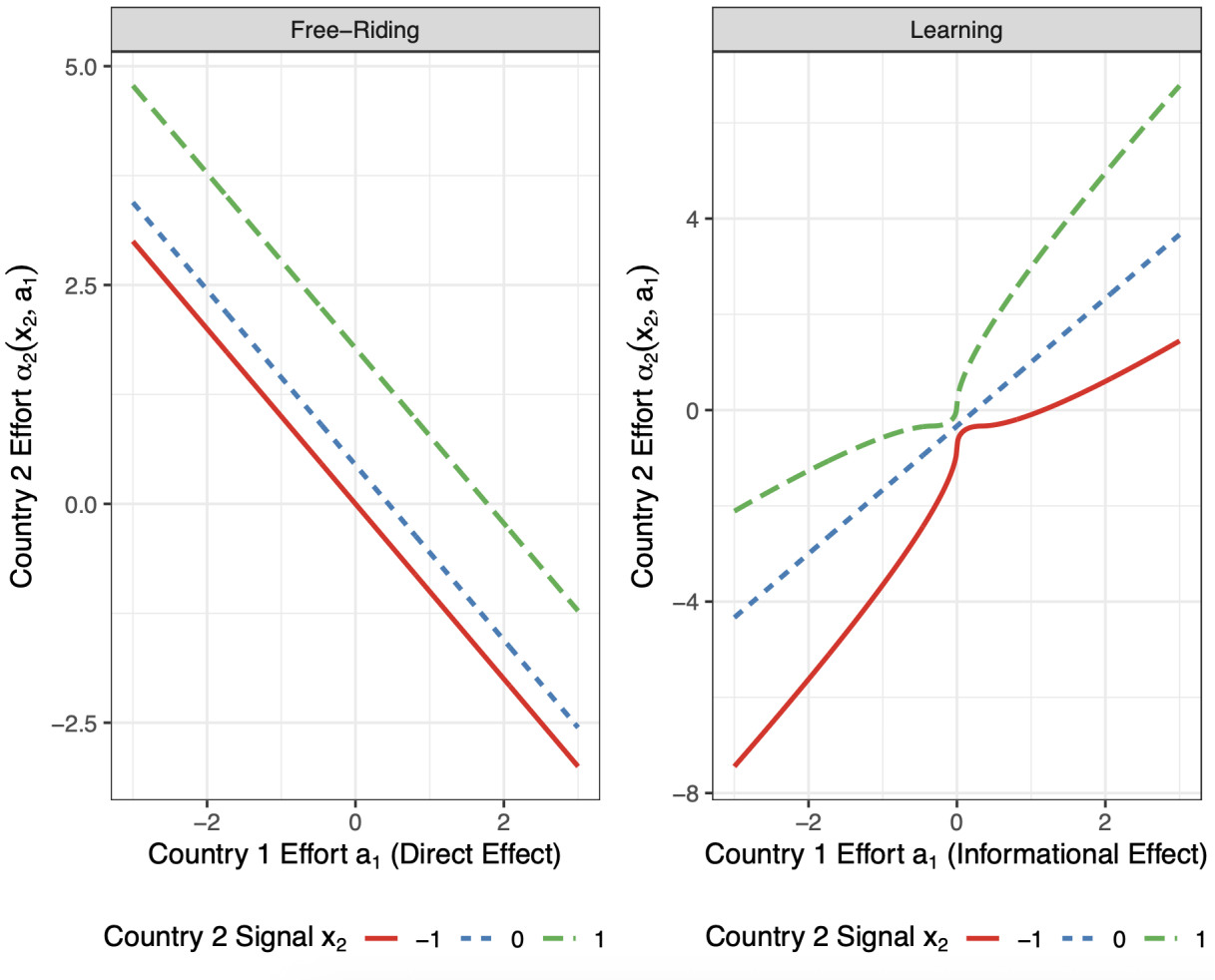

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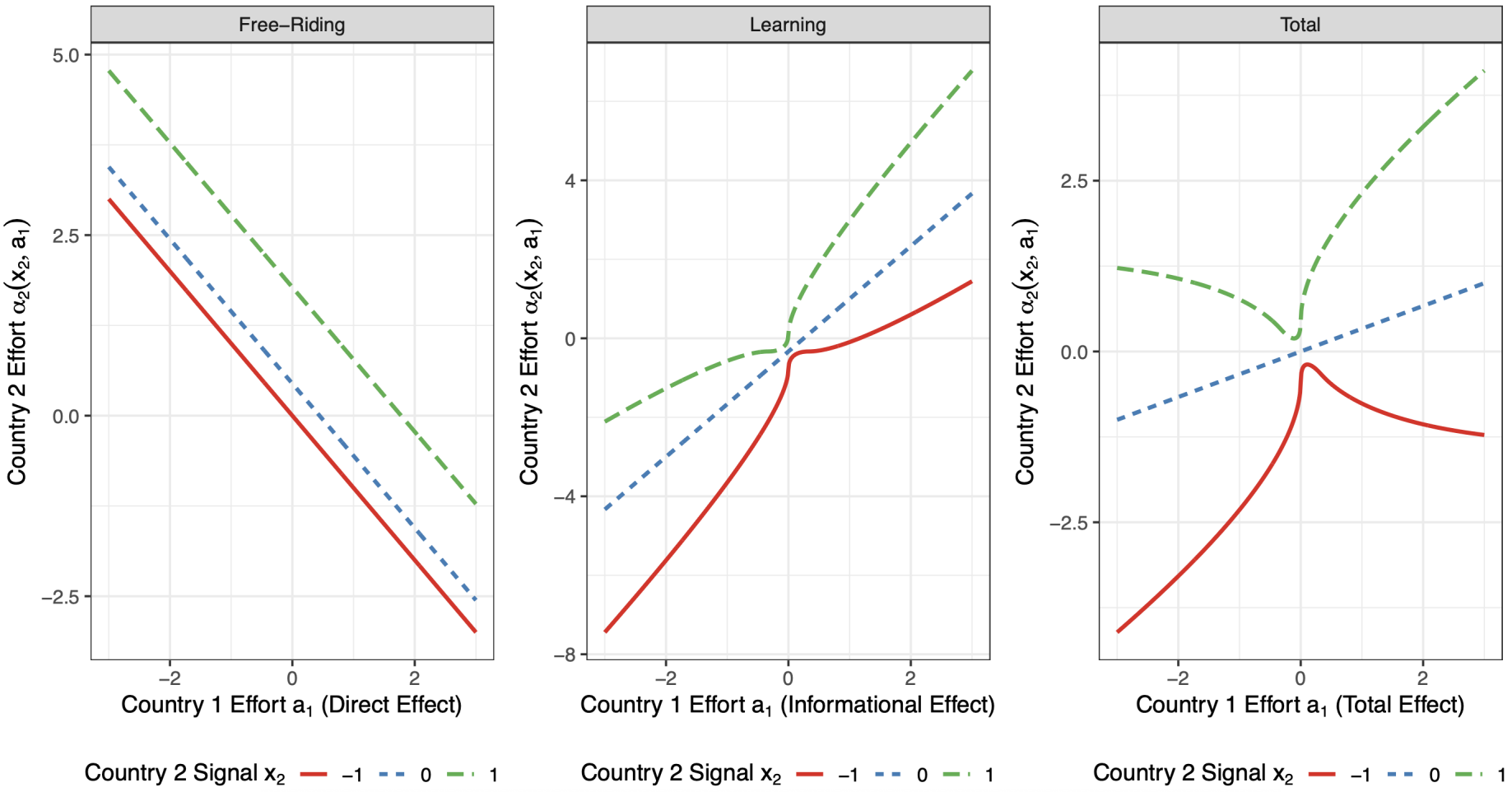

Which Mechanism Dominates?

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Learning effect dominates free-riding effect when:

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

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- Learning helps overcome risks of uncertain investments
  - collective action implications are conditional
  - coordinating expectations $\Longrightarrow$ coordinated efforts

Conclusion

Implications for Institutions

- Institutions built to punish free-riders
  - Kyoto Protocol: fines (Barrett 2003; Victor 2011; Hovi, Ward and Grundig 2015)
  - CBAM/climate clubs: trade policy (Nordhaus 2015)
  - Paris Agreement: naming and shaming (Falkner 2016; Melnick and Smith 2025)

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- Institutions should exploit learning effects!
  - prior expectations (μ and γ)
  - risk attitudes (shape of $g(\cdot)$ and $c(\cdot)$)

Takeaways

- Positive returns to green policy through diffused learning
  - international climate cooperation more than a free-rider problem
  - novel model of climate cooperation where dual effects of learning and free-riding can be disentangled
  - nations respond to optimism within and across borders with ambitious policies
- Evolution of nations' incentives to cooperate on climate policy

Thank you!

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Appendix

- Stylized facts

  laws/stringency table | no year FE | no country FE | time trends | controls | weights | medians | nc | rd table | no country FE | country-month trends | month FE | placebo | sorting | bandwidths | map | obama

- Formal model

  functions | updating | efforts | ineq | cascades

- Implications of learning

  mass tables | dynamics | elite tables | survey coverage

- Conclusions

  qualitative learning examples | institution examples

facts | model | learning | conclusion

Stylized Facts

Climate Law Adoption and Policy Stringency

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$$\text{Laws}_{i,t} = \beta \ \log(\text{Other Laws}_{-i,t-1}) + \alpha_i + \lambda_{i,t} + \varepsilon_{i,t}$$
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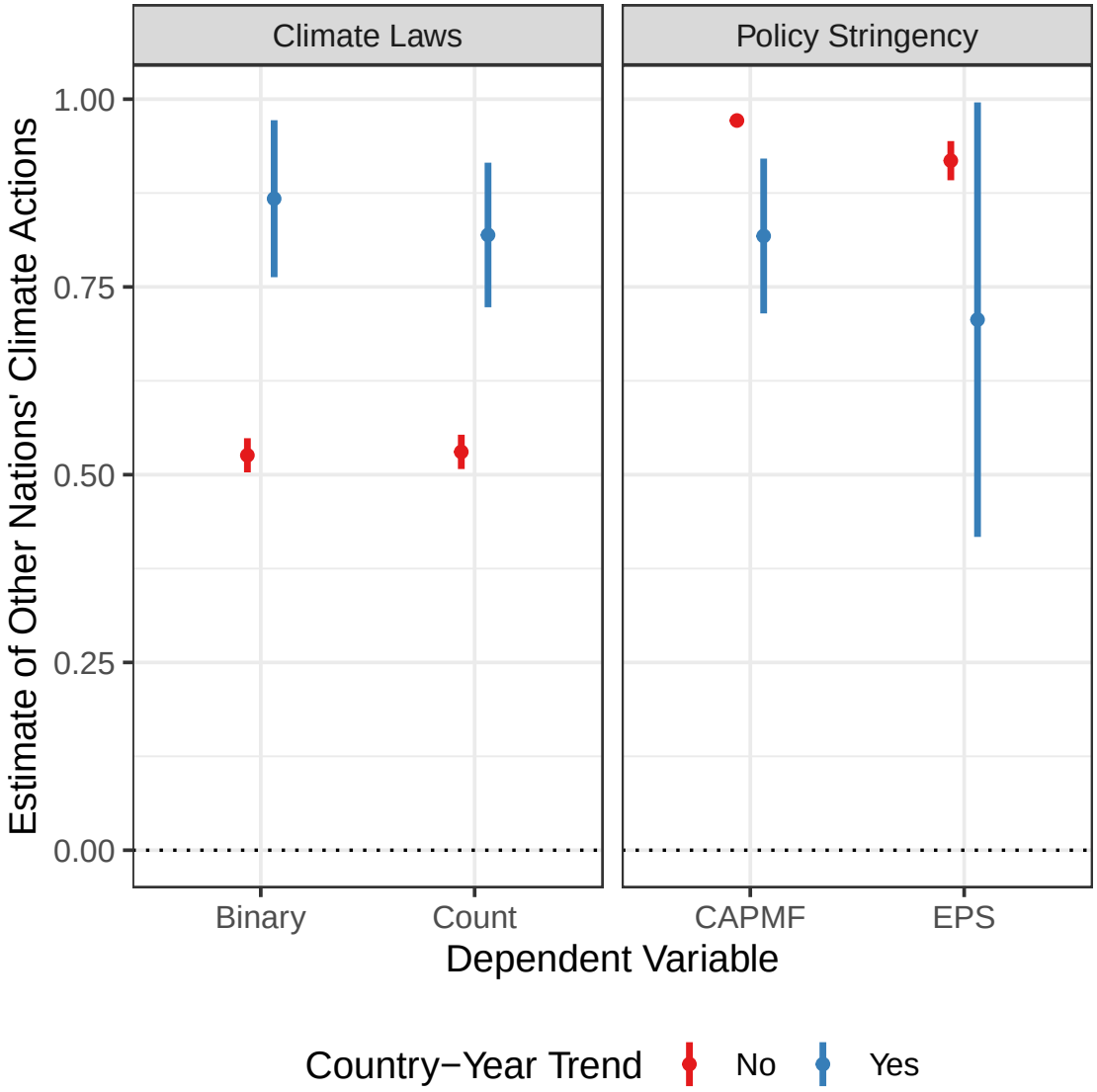
- outcome: adoption/stringency of climate actions by i in year t
- independent variable: climate actions by all but i in year $t-1$
- α_i: country fixed effects (time-invariant factors)
- $\lambda_{i,t}$: country-year time trends (secular adoption, gen eqm effects)
- country-clustered standard errors

Climate Law Adoption and Policy Stringency



U.S. Presidential Elections

How do nations respond to changes in expected international climate governance?

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

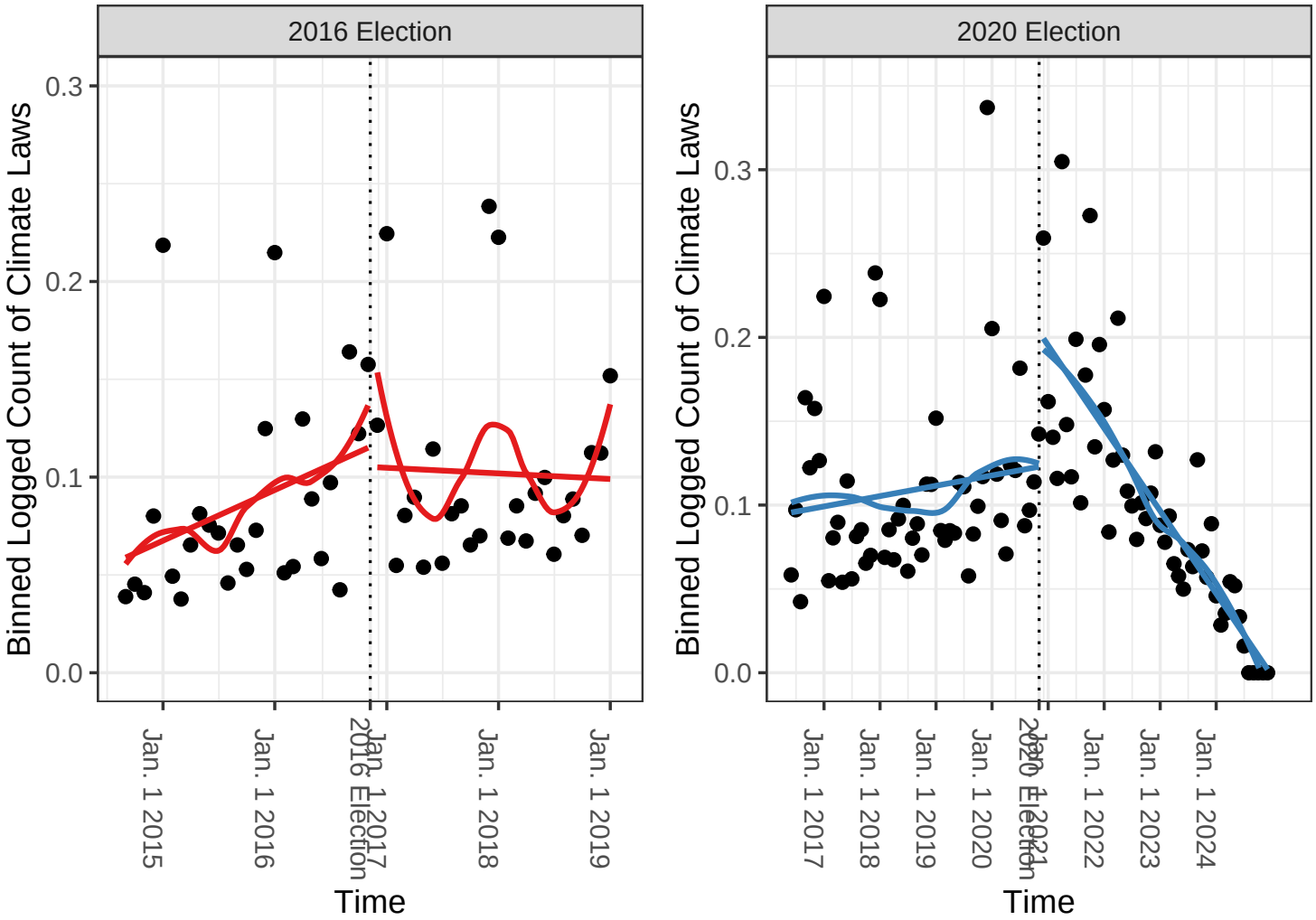
U.S. Presidential Elections

How do nations respond to changes in expected international climate governance?

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

- outcome: adoption of climate laws by i in month m
- independent variable: was m after the election?
- $f(m - t_k)$: polynomial in time around election
- α_i: country fixed effects (time-invariant factors)
- country-clustered standard errors

U.S. Presidential Elections



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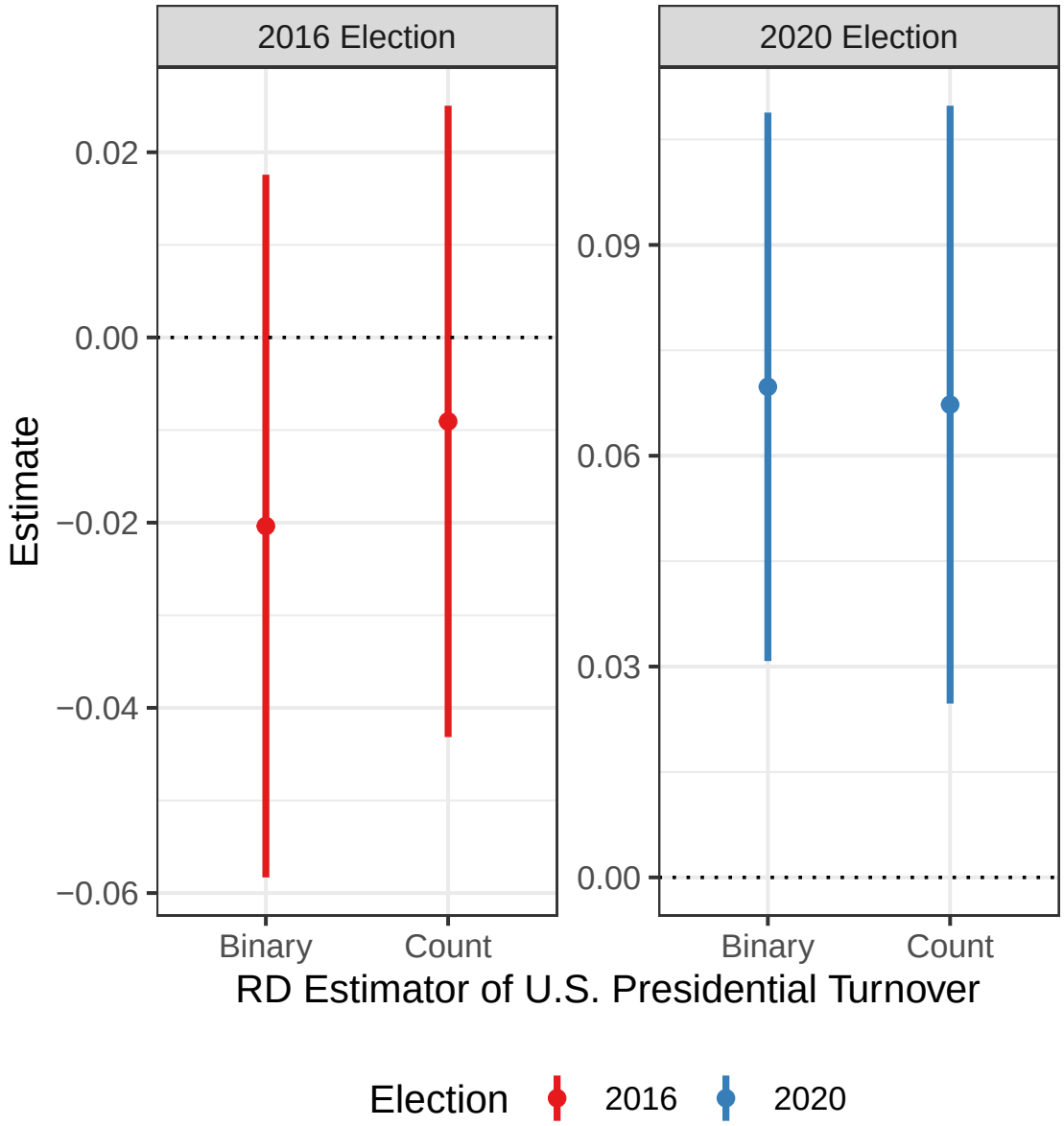

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- Operationalize beliefs in two ways
  1. mass beliefs (respondents from Eurobarometer 2011-2021)
  2. elite beliefs (climate policymakers and scientists in 2020 (Victor, Lumkowsky and Dannenberg 2022; Dannenberg et al. 2023; Lumkowsky et al. 2023))

Mass Beliefs

"How serious a problem do you think climate change is?"

Mass Beliefs

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Signal correlation

- outcome: (average) belief of seriousness in i in year t
- independent variable: average belief of seriousness of all but i in year $t-1$
- α_i: country fixed effects (country-specific factors to beliefs)
- $\lambda_{i,t}$: country-year time trends (secular trends in beliefs)
- country-clustered standard errors

Mass Beliefs

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Optimistic signal $\implies$ effort

- outcome: policy stringency of country i in year t
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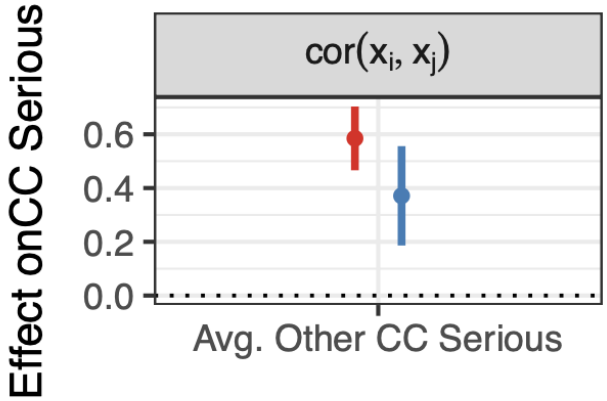
Reduced-form learning

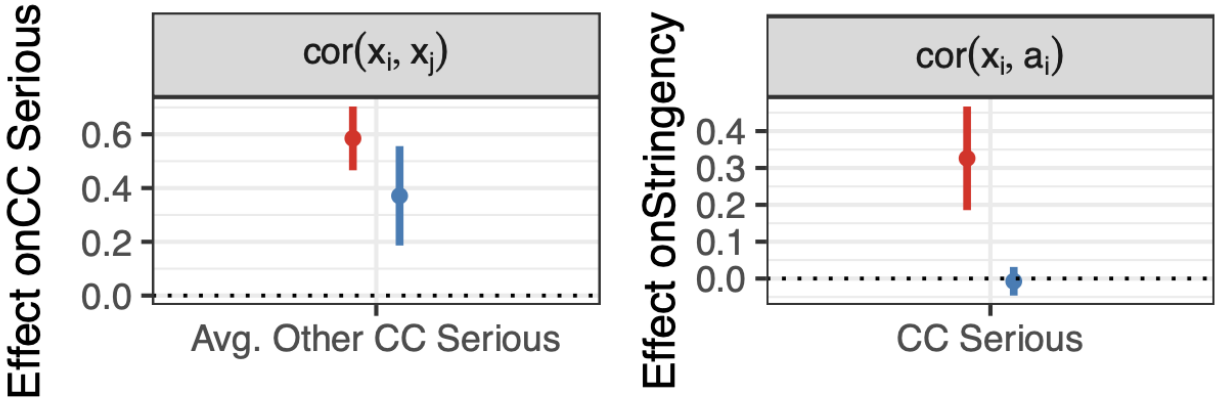
- outcome: policy stringency of country i in year t
- independent variable: average belief of seriousness of all but i in year $t-1$
- α_i: country fixed effects (country-specific factors to stringency)
- $\lambda_{i,t}$: country-year time trends (secular trends in stringency and beliefs)
- country-clustered standard errors

Mass Beliefs

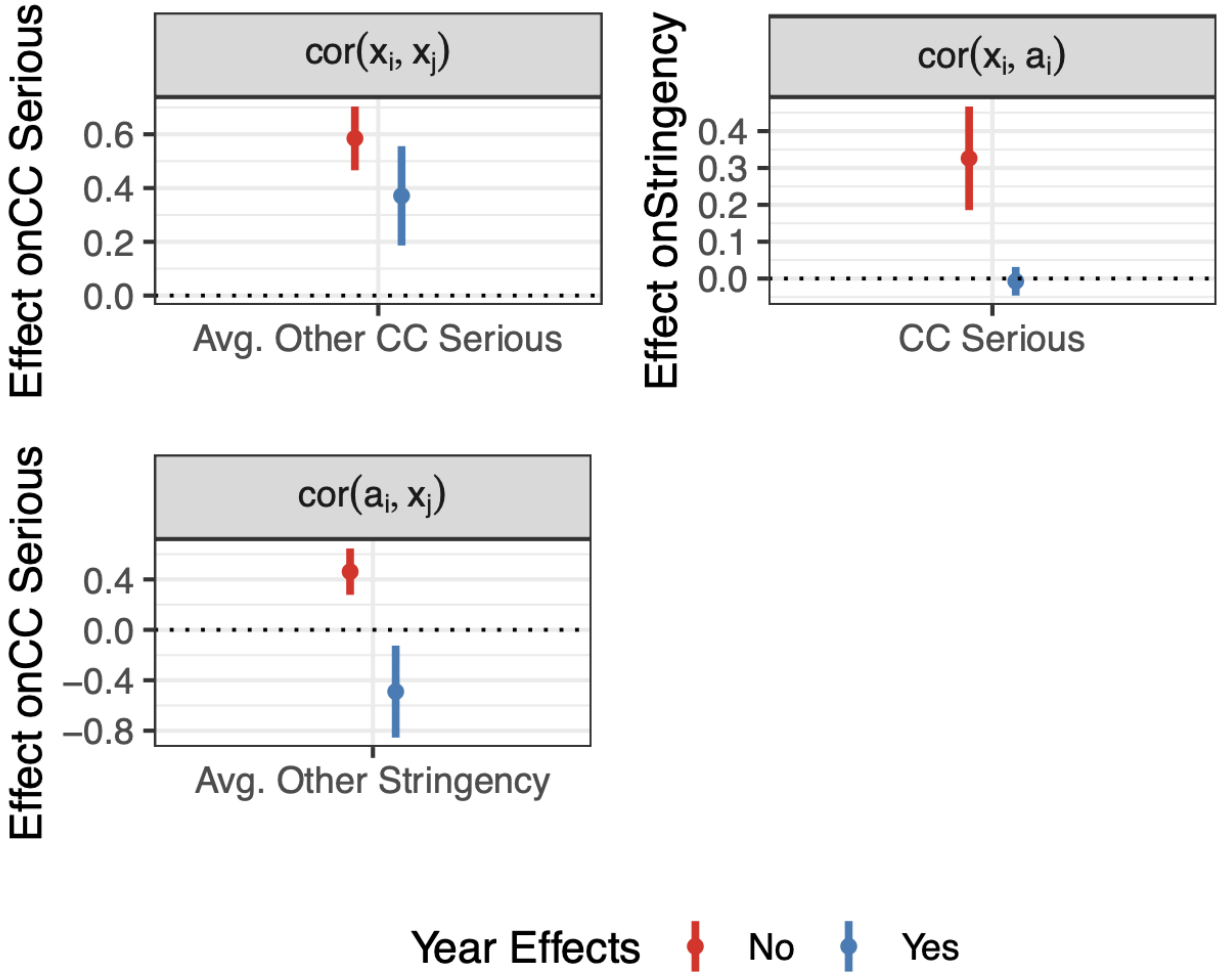


Year Effects No Yes

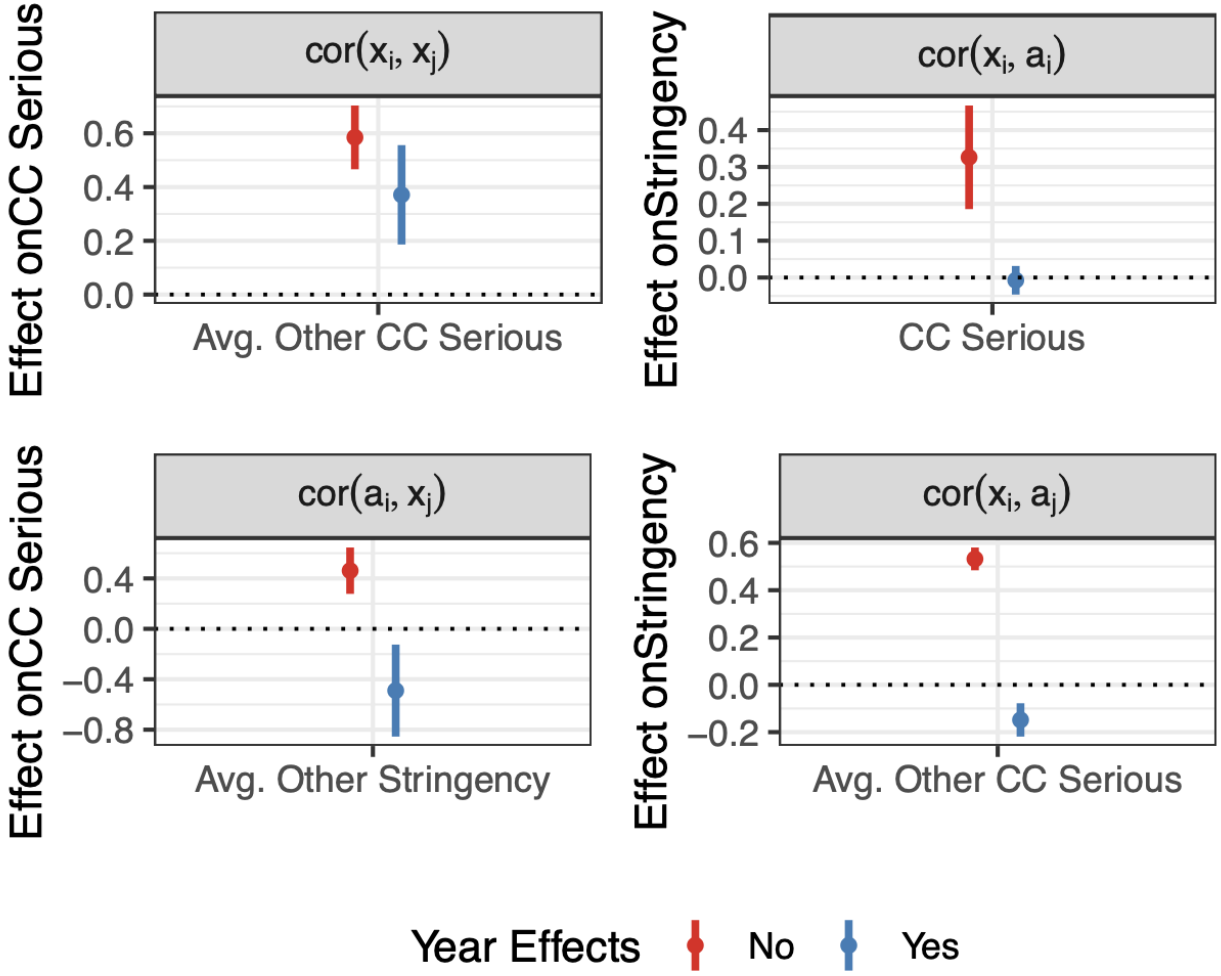
Mass Beliefs



Mass Beliefs



Mass Beliefs



Elite Beliefs

"How confident are you that [country] will fulfill its current NDC submitted under the Paris Agreement? How ambitious is it?"

Elite Beliefs

$$\text{Beliefs}_{r,i} = \beta \text{ Average Other Beliefs}_{-r,i} + \eta_r + \varepsilon_{r,i}$$

Elite Beliefs

$$\text{Beliefs}_{r,i} = \beta \text{ Average Other Beliefs}_{-r,i} + \eta_r + \varepsilon_{r,i}$$

Signal correlation

- outcome: belief of respondent r about country i's NDC
- independent variable: average beliefs of all but r about country i's NDC
- α_i: country fixed effects (country-specific factors to beliefs)
- η_r: expert fixed effects (expert-specific baselines)
- expert-clustered standard errors

Elite Beliefs

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

Elite Beliefs

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

Optimistic signal $\implies$ effort

- outcome: policy stringency of country i in year t (2021, 2022, 2023)
- independent variable: belief of respondent r about country i's NDC
- α_i: country fixed effects (country-specific factors to stringency)
- η_r: expert fixed effects (expert-specific baselines)
- expert-clustered standard errors

Elite Beliefs

$$\text{Beliefs}_{r,i} = \beta\ \text{Stringency}_{i,t-1} + \alpha_i + \eta_r + \varepsilon_{i,r}$$

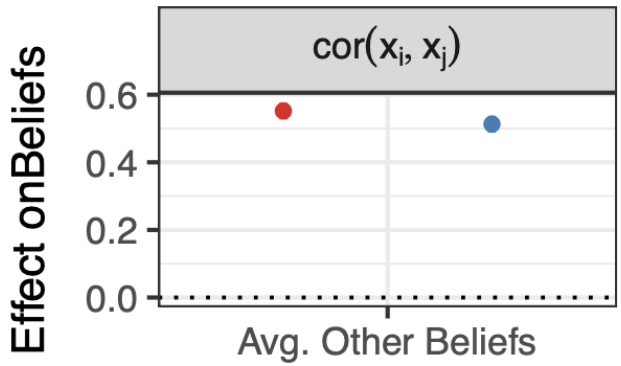
Elite Beliefs

$$\text{Beliefs}_{r,i} = \beta\ \text{Stringency}_{i,t-1} + \alpha_i + \eta_r + \varepsilon_{i,r}$$

Belief updating

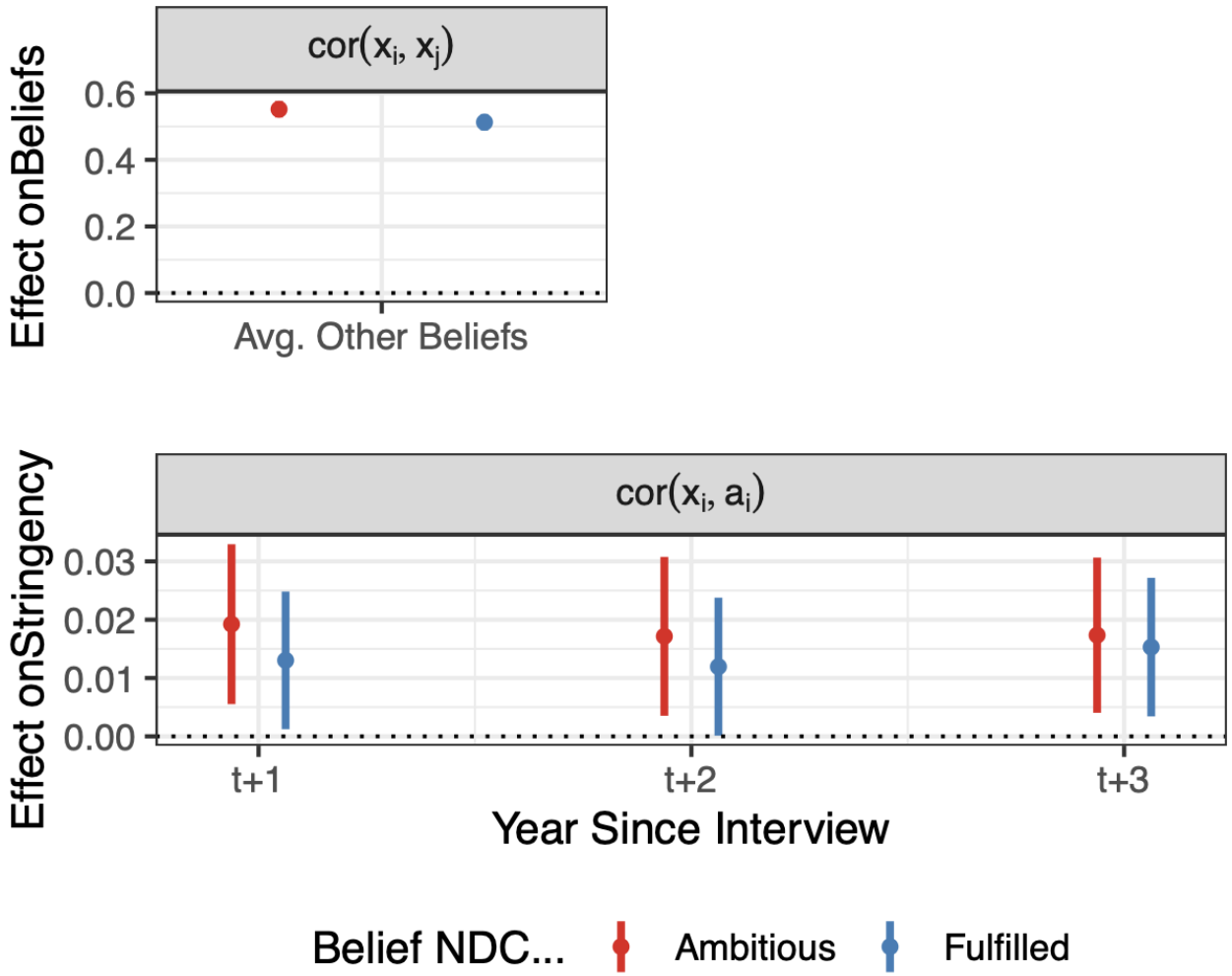
- outcome: belief of respondent r about country i's NDC
- independent variable: policy stringency of country i in year $t-1$ (2019)
- α_i: country fixed effects (country-specific factors to beliefs)
- η_r: expert fixed effects (expert-specific baselines)
- expert-clustered standard errors

Elite Beliefs

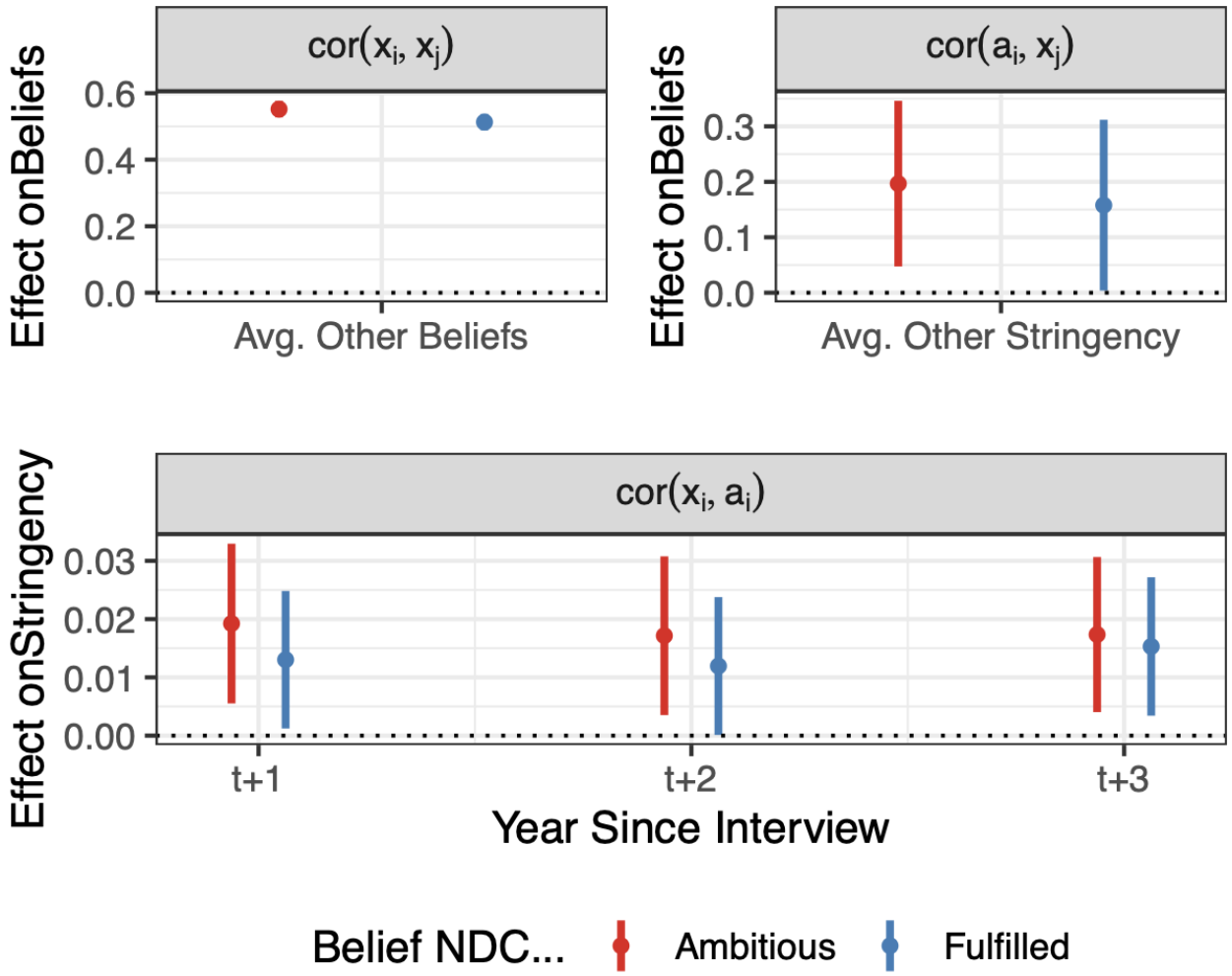


Belief NDC... Ambitious Fulfilled

Elite Beliefs



Elite Beliefs



Climate Law Adoption and Policy Stringency: Full Results

	Laws (Count) (1)	Laws (Binary) (2)	EPS (3)	CAPMF (4)
log(Other Laws)	0.819***	0.867***		
	(0.049)	(0.053)		
Avg. Other Stringency			0.706***	0.818***
			(0.143)	(0.051)
Observations	7,000	7,000	1,200	1,650
R^2	0.331	0.344	0.904	0.962
Within R^2	0.307	0.305	0.852	0.960
DV Mean	0.643	0.713	2.04	1.25
Number of Countries	200	200	40	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

Climate Law Adoption and Policy Stringency: No Year Trends

	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	0.643	0.643	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

Climate Law Adoption and Policy Stringency: No Country FE

	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	0.643	0.643	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

Climate Law Adoption: Alternative Time Trends

	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

Climate Law Adoption: Year Random Effects

	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

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

Climate Policy Stringency: Alternative Time Trends

	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

Climate Policy Stringency: Year Random Effects

	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

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

Climate Law Adoption: Controls

	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

Climate Policy Stringency: Controls

	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

Climate Law Adoption: GDP per capita Weights

	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		✓		✓

p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Robust standard errors clustered at the country level

Climate Law Adoption: GHG per capita Weights

	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		✓		✓

p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Robust standard errors clustered at the country level

Climate Policy Stringency: GDP per capita Weights

	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		✓		✓

p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Robust standard errors clustered at the country level

Climate Policy Stringency: GHG per capita Weights

	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		✓		✓

p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Robust standard errors clustered at the country level

Climate Policy Stringency: Median Stringency

	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

Climate Policy Stringency: No 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

U.S. Presidential Elections: Full Results

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

U.S. Presidential Elections: No Country FE

	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

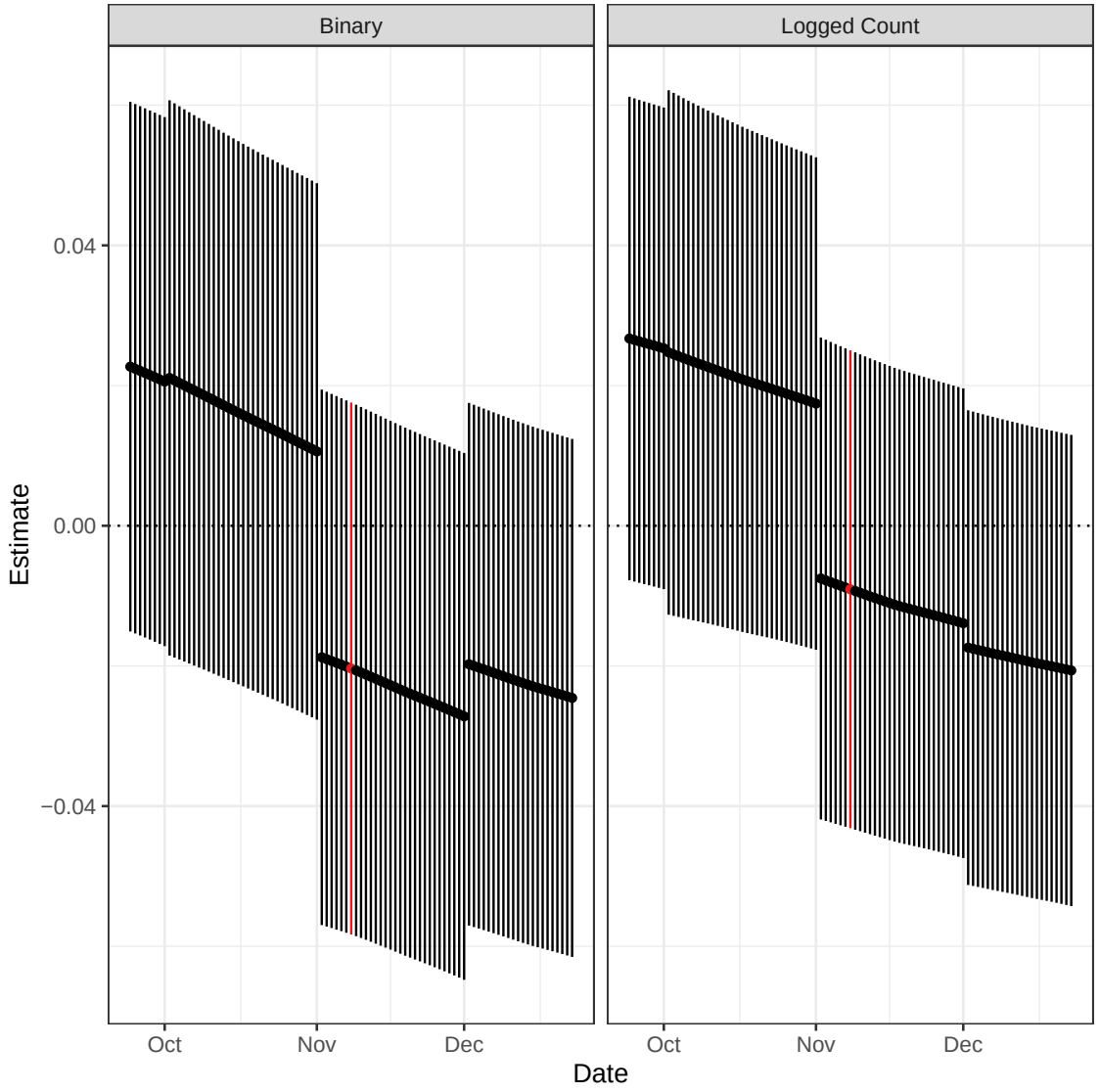
U.S. Presidential Elections: Country-Month Trends

	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	✓	✓	✓	✓
Country × Month time trends	✓	✓	✓	✓
Bandwidth (days)	829.619	824.242	1610.132	1510.144
Effective Observations	10746	10746	20298	19701

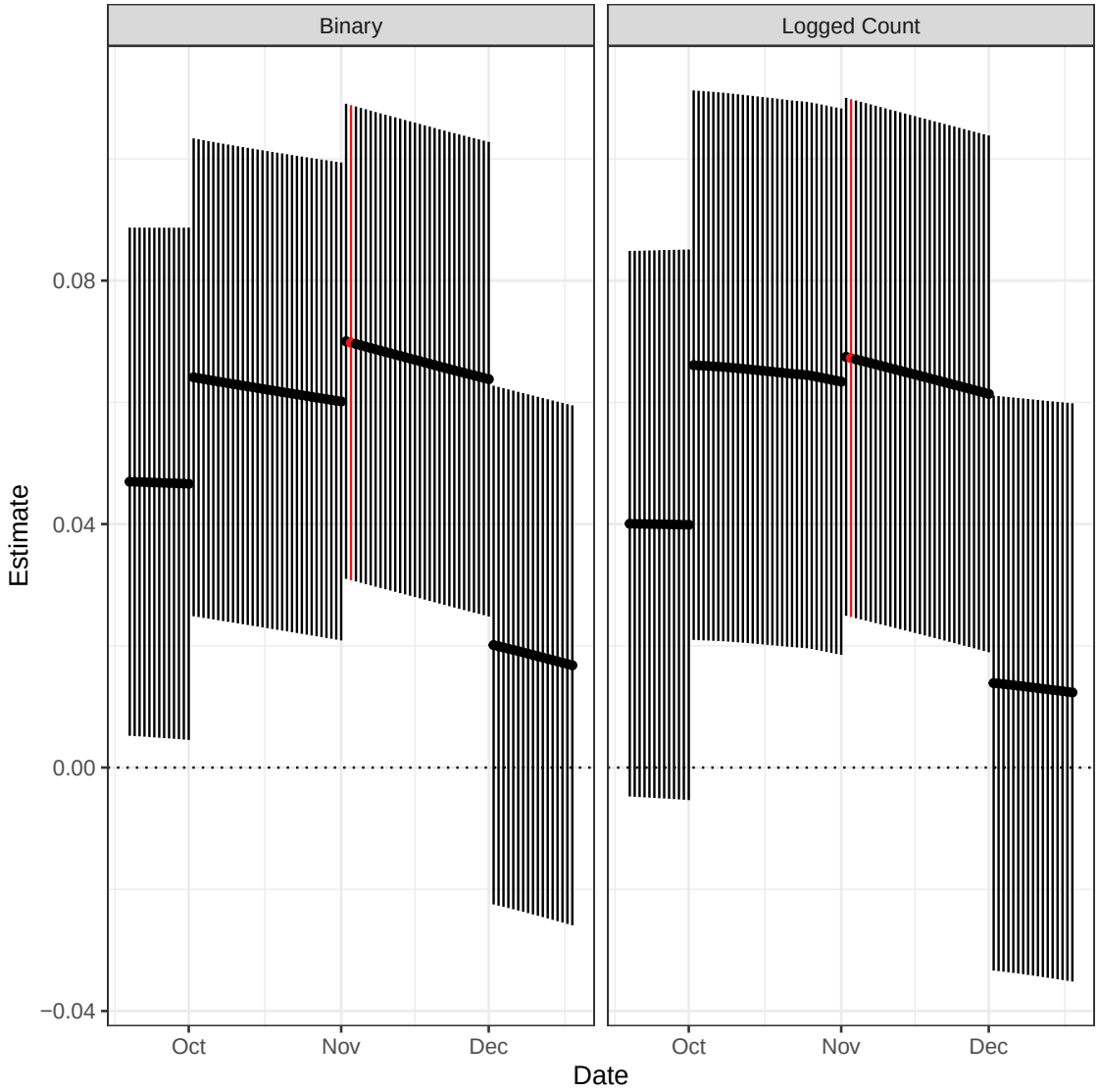
U.S. Presidential Elections: Month FE

	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

U.S. Presidential Elections: RD Placebo Estimates



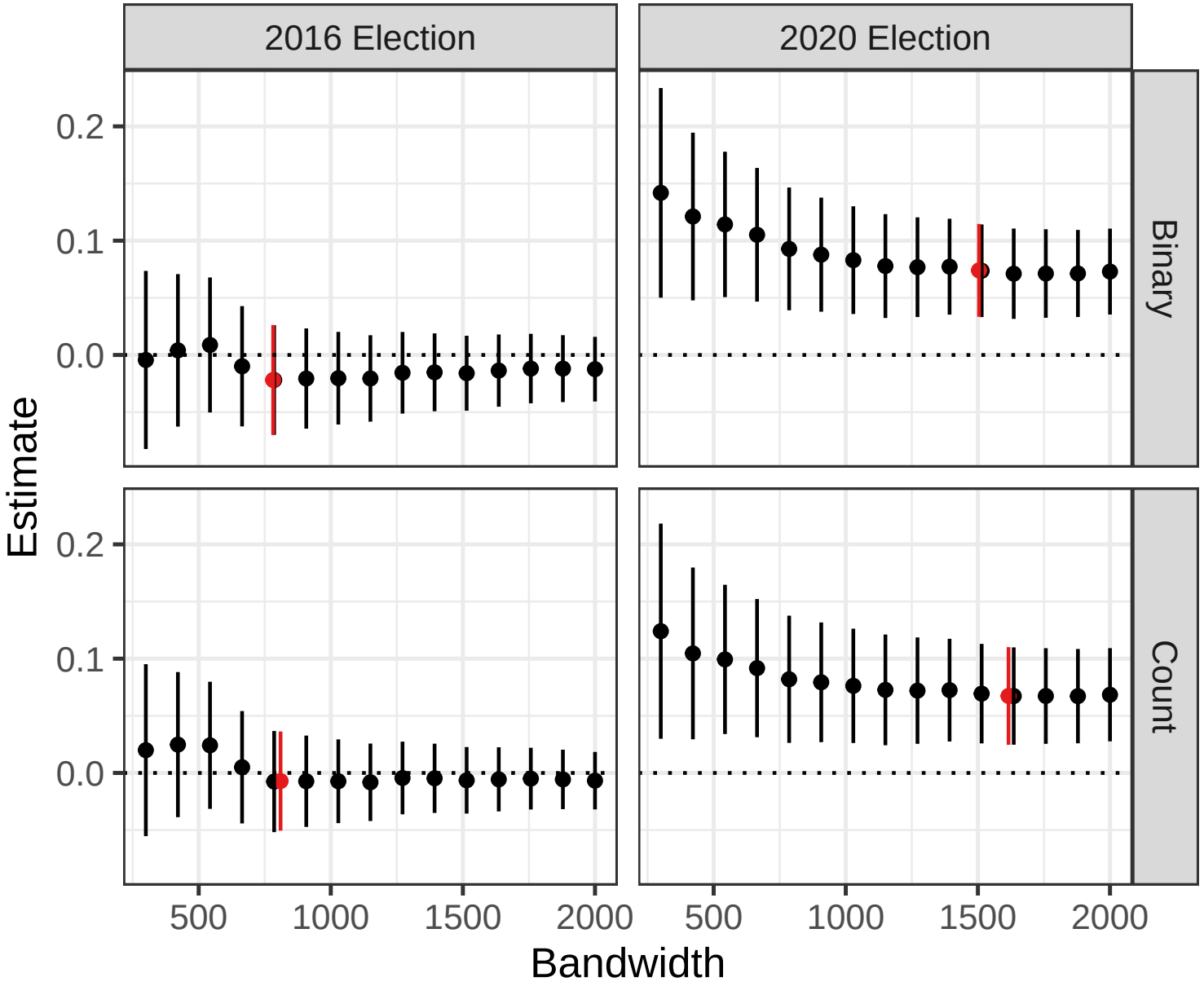
U.S. Presidential Elections: RD Placebo Estimates



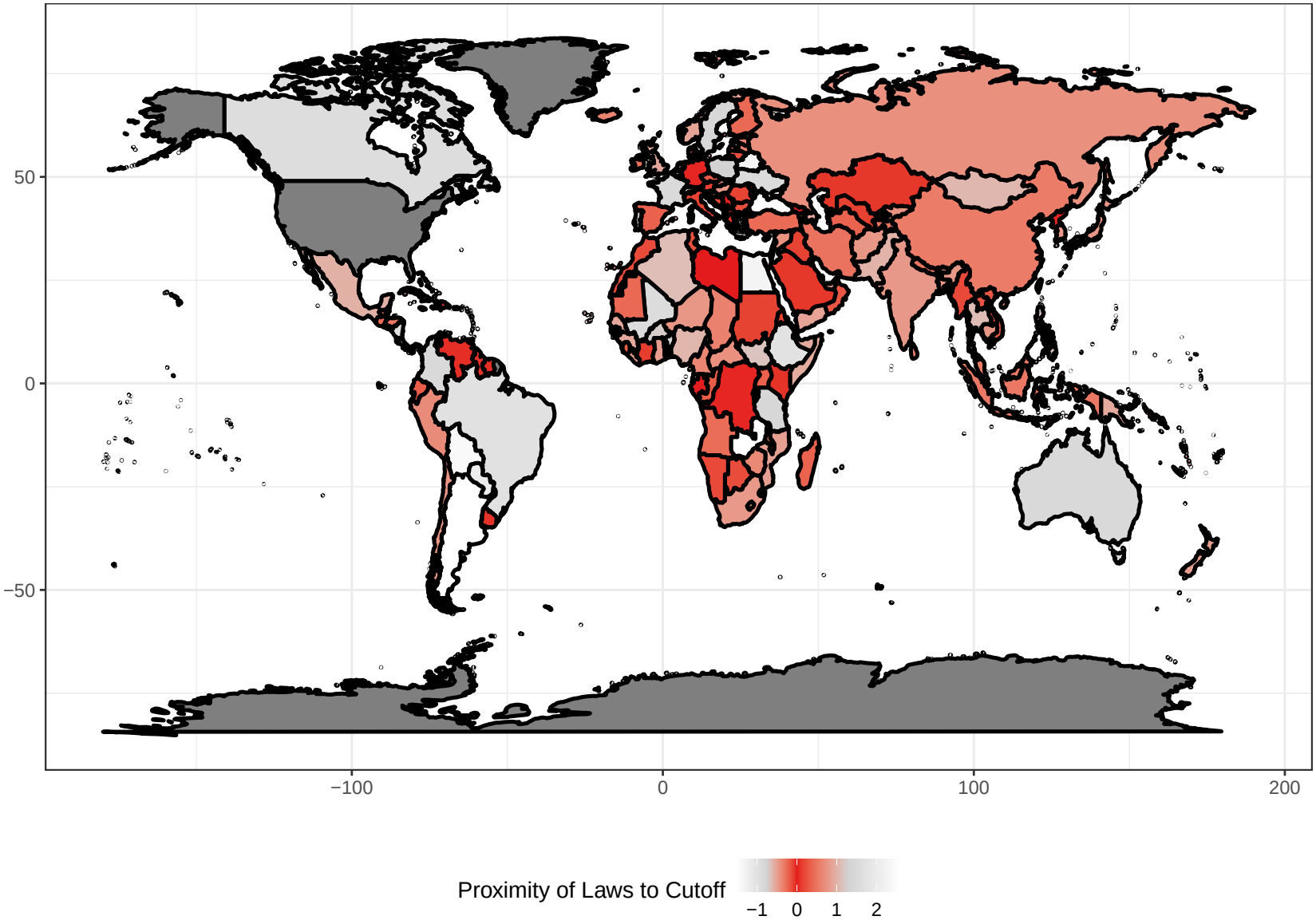
U.S. Presidential Elections: Sorting Tests

Test	Election	p-value
McCrary (2008)	2016	0.091
McCrary (2008)	2020	0.149
Cattaneo et al. (2018)	2016	0.985
Cattaneo et al. (2018)	2020	0.931

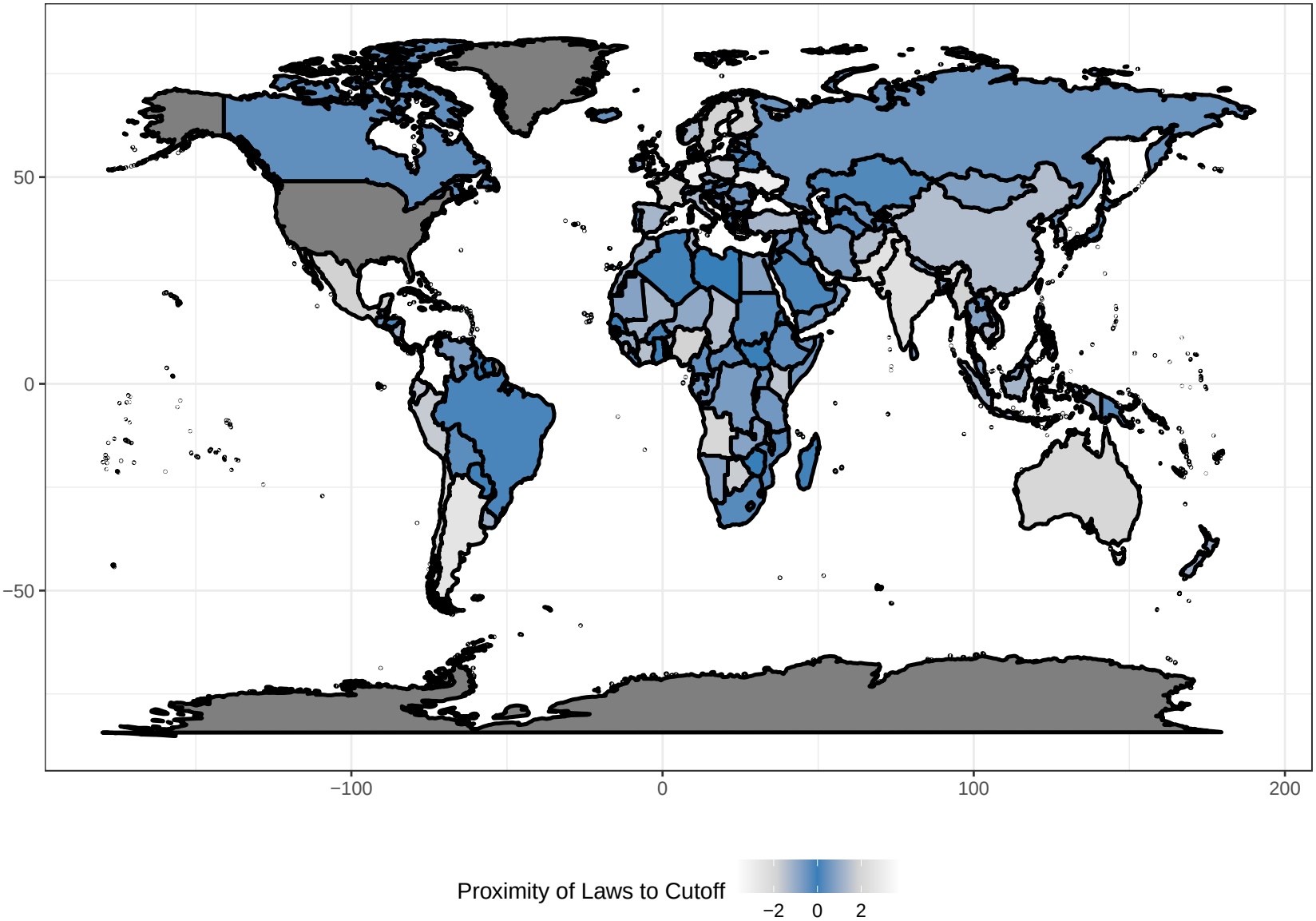
U.S. Presidential Elections: Alternative Bandwidths



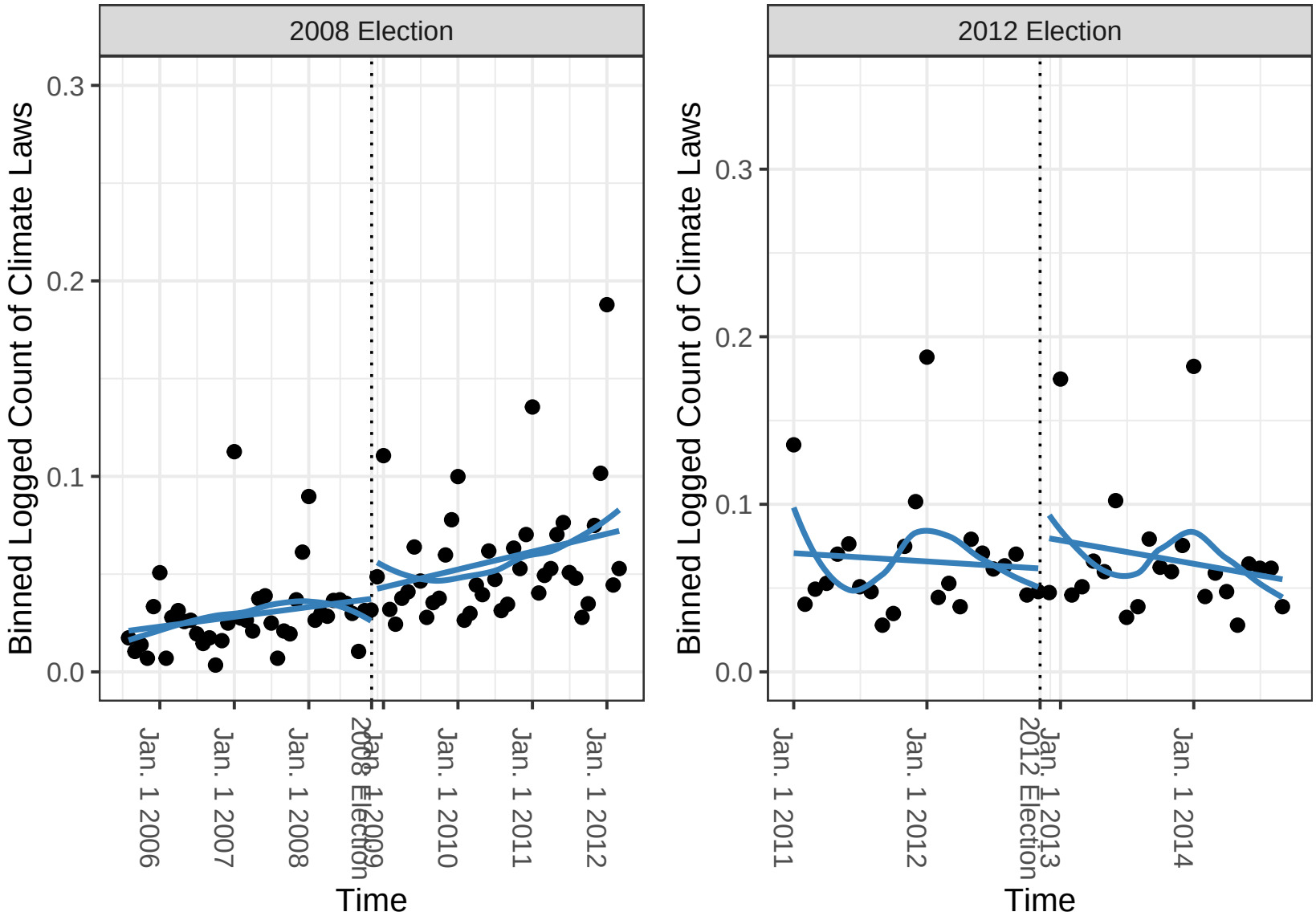
U.S. Presidential Elections: Variation around Cutoff



U.S. Presidential Elections: Variation around Cutoff



U.S. Presidential Elections: Obama



U.S. Presidential Elections: Obama

	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

Model Setup: Parameterizations

- Global effort $A = a_1 + \lambda a_2$, value $g(A)$ with cost $c(a_i)$
  - general assumptions: $g'(A) > 0$, $g''(A) \leq 0$, $c'(a_i) > 0$, $c''(a_i) \geq 0$
  - parameterize $g(A) = \begin{cases} \sqrt{A} & A \geq 0 \\ -\sqrt{|A|} & A < 0 \end{cases}$ and $c(a_i) = c_i|a_i|$
- Tractability and ability to integrate over negative reals
- Preserves one-to-one nature of strategies

Equilibrium Effort: Bayesian Updates

2. To form $E[\theta|x_2, a_1]$ we assume $\alpha_1(x_1)$ is one-to-one so $x_1 = \alpha_1^{-1}(a_1)$
   Then by Bayes's Rule:

$$\theta|x_2, a_1 \sim N\Big(\frac{\gamma\mu + \beta\alpha_1^{-1}(a_1) + \beta x_2}{\gamma + 2\beta}, \frac{1}{\gamma + 2\beta}\Big)$$

1. By Bayes's Rule:

$$\theta|x_1 \sim N\Big(\frac{\gamma\mu + \beta x_1}{\gamma + \beta}, \frac{1}{\gamma + \beta}\Big)$$

   and

$$x_2|x_1 \sim N\Big(\frac{\gamma\mu + \beta x_1}{\gamma + \beta}, \frac{2\beta + \gamma}{\beta(1 + \gamma)}\Big)$$

Equilibrium Effort: Effort Functions

2

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

1

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

Which Mechanism Dominates? Equilibrium Effort

In equilibrium, learning dominates free-riding iff

$$|\gamma\mu + \beta x_1 + \beta x_2| > \frac{2c_2^2(\gamma + 2\beta)^3}{\beta\lambda^2}$$

Cascades: Model Setup

- Countries $i = 1, \ldots, n$ sequentially take climate action $a_i \in \{0, 1\}$
- Common/global state variable $\theta \in \{0, 1\}$ is "success of green transition"
- Countries have private beliefs about θ $p_i \sim F(\cdot|\theta)$ and domestic implementation costs $c_i \sim U[0, 1]$
  - standard FOSD $F(p|1) < F(p|0)$
- Denote history $h_i = (a_1, \ldots, a_{i-1})$, public likelihood ratio $\ell_i = \frac{1-P(\theta=1|h_i)}{P(\theta=1|h_i)}$
- "Collective action penalties" $z_i : h_i \to [0, 1]$ increasing in $\sum h_i$
  - think $z_i = \frac{\sum h_i}{i-1}$ for $i \geq 2$, $z_1 = 0$
  - capture strategic substitutability in reduced form
  - weight $k > 0$, "free-riding incentives"
- Payoff for country i:

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

- Weak PBE: strategy for i is $a_i \in \{0, 1\}$ given h_i, p_i, and c_i

Cascades: Contrast with Main Model

1. $n > 2$ countries, can analyze long-run dynamics
2. No strategic interdependence, only informational
3. Free-riding incentives based only on previous actions
4. Binary state, binary action, random costs c_i rather than known parameter

Cascades: Equilibrium

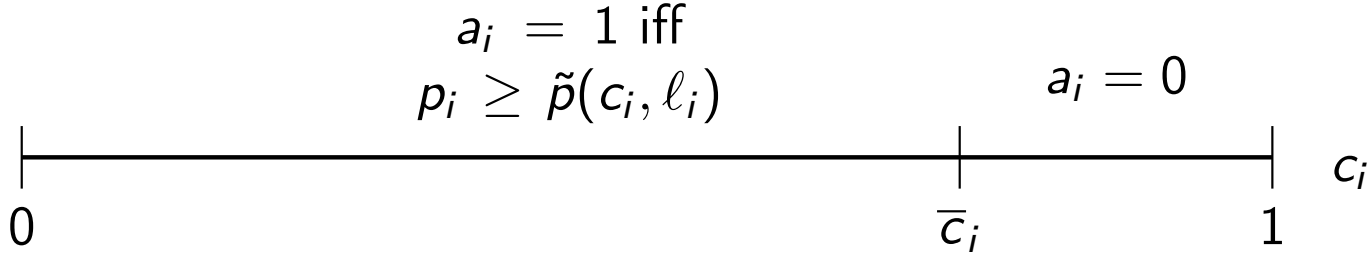
- By Bayes's Rule

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

- Country i takes climate action iff

$$\mu_i - c_i - kz_i \geq 0 \;\Leftrightarrow\; p_i \geq \tilde{p}(c_i, \ell_i)$$

- Country i's equilibrium strategy



- Probability of climate action (conditional on θ)

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

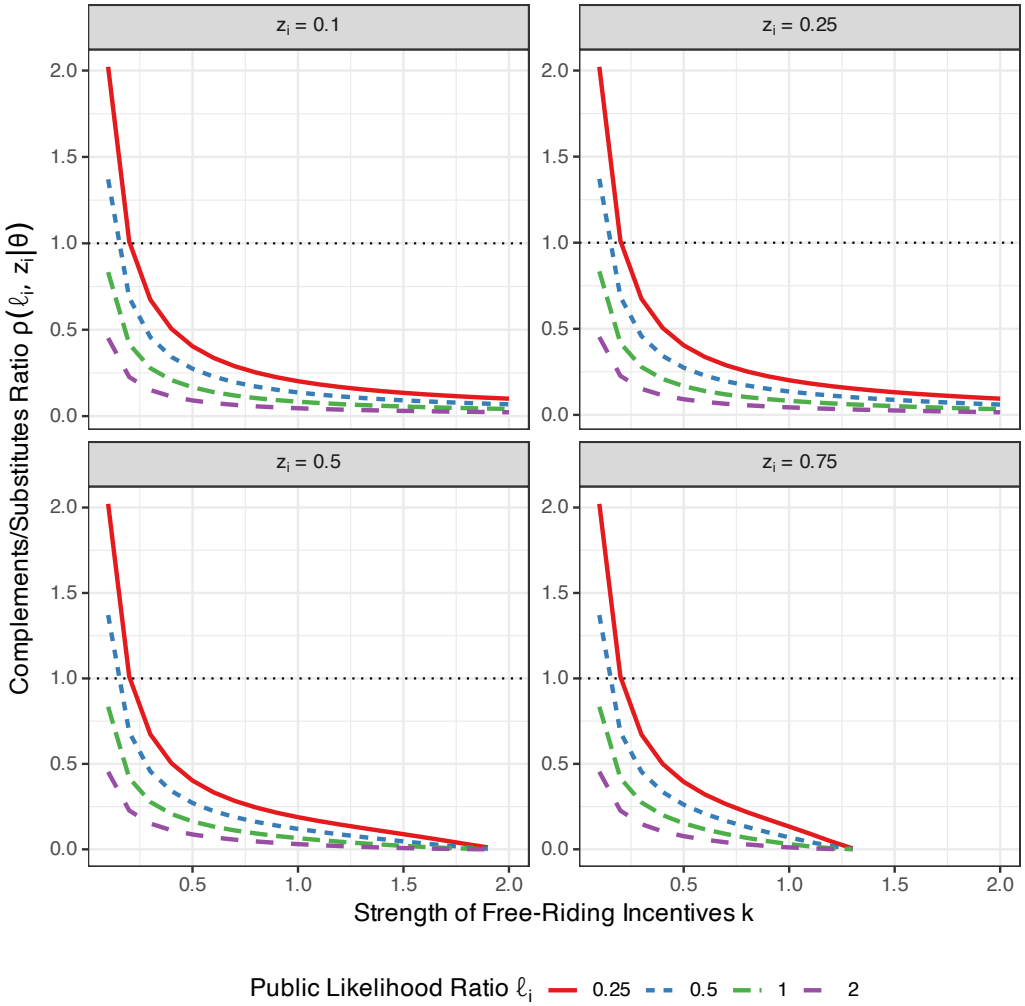
Cascades: Which Effect Dominates?

- Quantify the tradeoff/strength of these two competing effects

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

- Complementarity effects dominate if free-riding incentives k small ($\rho(\ell_i, z_i|\theta) > 1$)

Cascades: Which Effect Dominates?



Cascades: Dynamics and Convergence

- Conditional on $\theta = 1$, $< \ell_i >$ is a martingale
  - Martingale Convergence Theorem ensures belief convergence to the truth

- Simple updating with conditionally independent signals

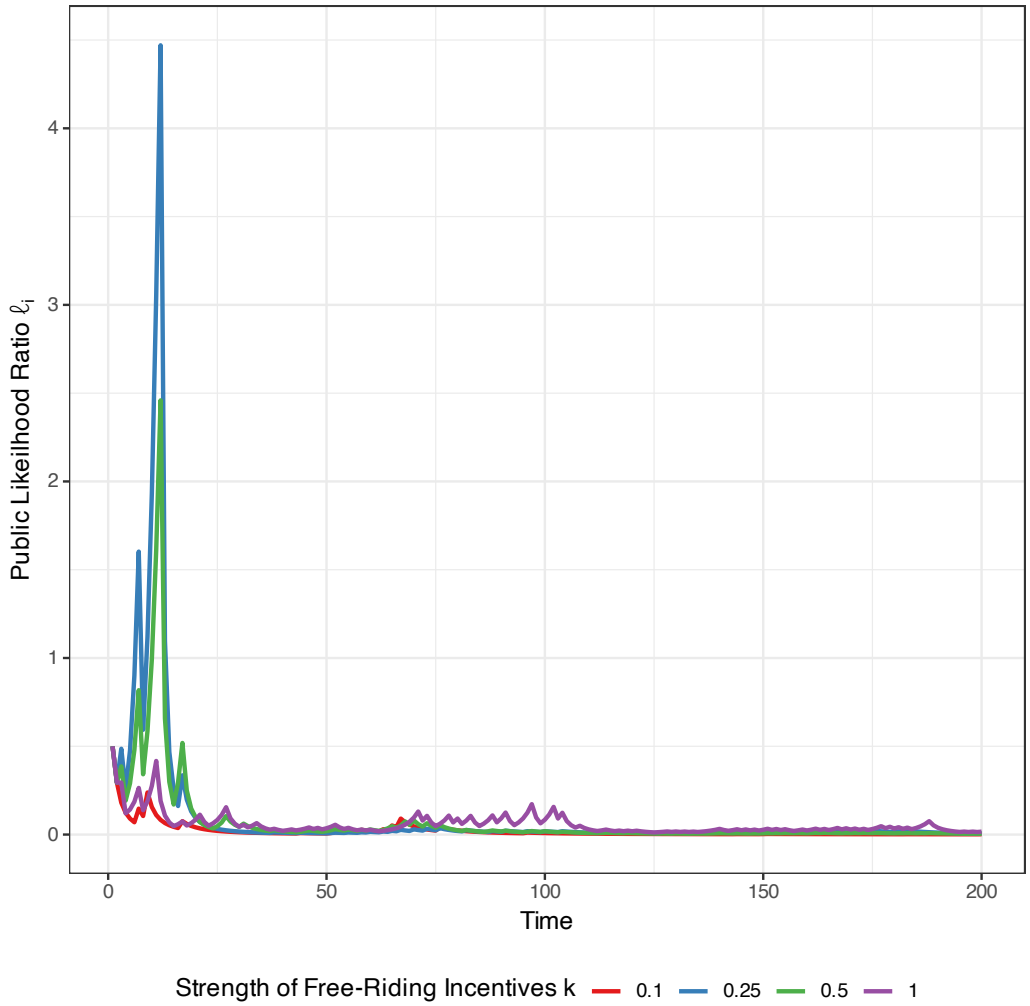
$$\ell_{i+1} = \varphi(a_i, \ell_i) = \ell_i \frac{\alpha^*(a_i|\ell_i, 0)}{\alpha^*(a_i|\ell_i, 1)}$$

- Actions are a Markov chain

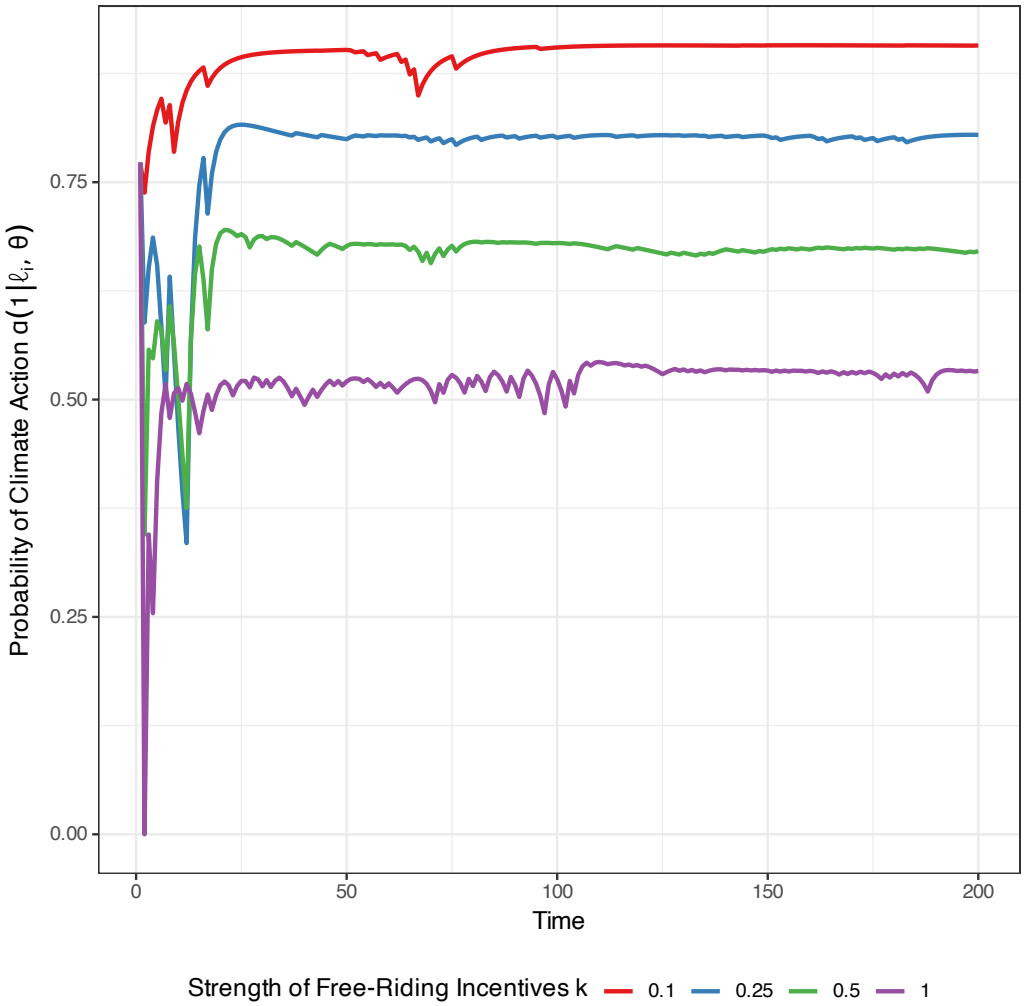
$$(a_i, \ell_i) \mapsto (a_{i+1}, \varphi(a_{i+1}, \ell_i)) \text{ with probability } \alpha^*(a_{i+1}|\ell_i, 1)$$

  - Partial action convergence (conditional on c_i small)

Cascades: Dynamics and Convergence



Cascades: Dynamics and Convergence



Mass Beliefs: Full Results

Panel A: $cor(x_i, x_j)$	CC Serious	
	(1)	(2)
Avg. Other CC Serious	0.585^{***}	0.371^{***}
	(0.058)	(0.090)
Observations	323	323
Within R^2	0.347	0.520
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

Mass Beliefs: Full Results

Panel B: $cor(x_i, a_i)$	Stringency	
	(1)	(2)
CC Serious	0.326^{***}	-0.007
	(0.068)	(0.019)
Observations	322	322
Within R^2	0.182	0.0005
Country fixed effects	✓	✓
Year fixed effects		✓

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

Mass Beliefs: Full Results

Panel C: $cor(a_i, x_j)$	CC Serious	
	(1)	(2)
Avg. Other Stringency	0.461***	-0.490**
	(0.089)	(0.178)
Observations	349	349
Within R^2	0.210	0.481
Country fixed effects	✓	✓
Country × Year trends		✓

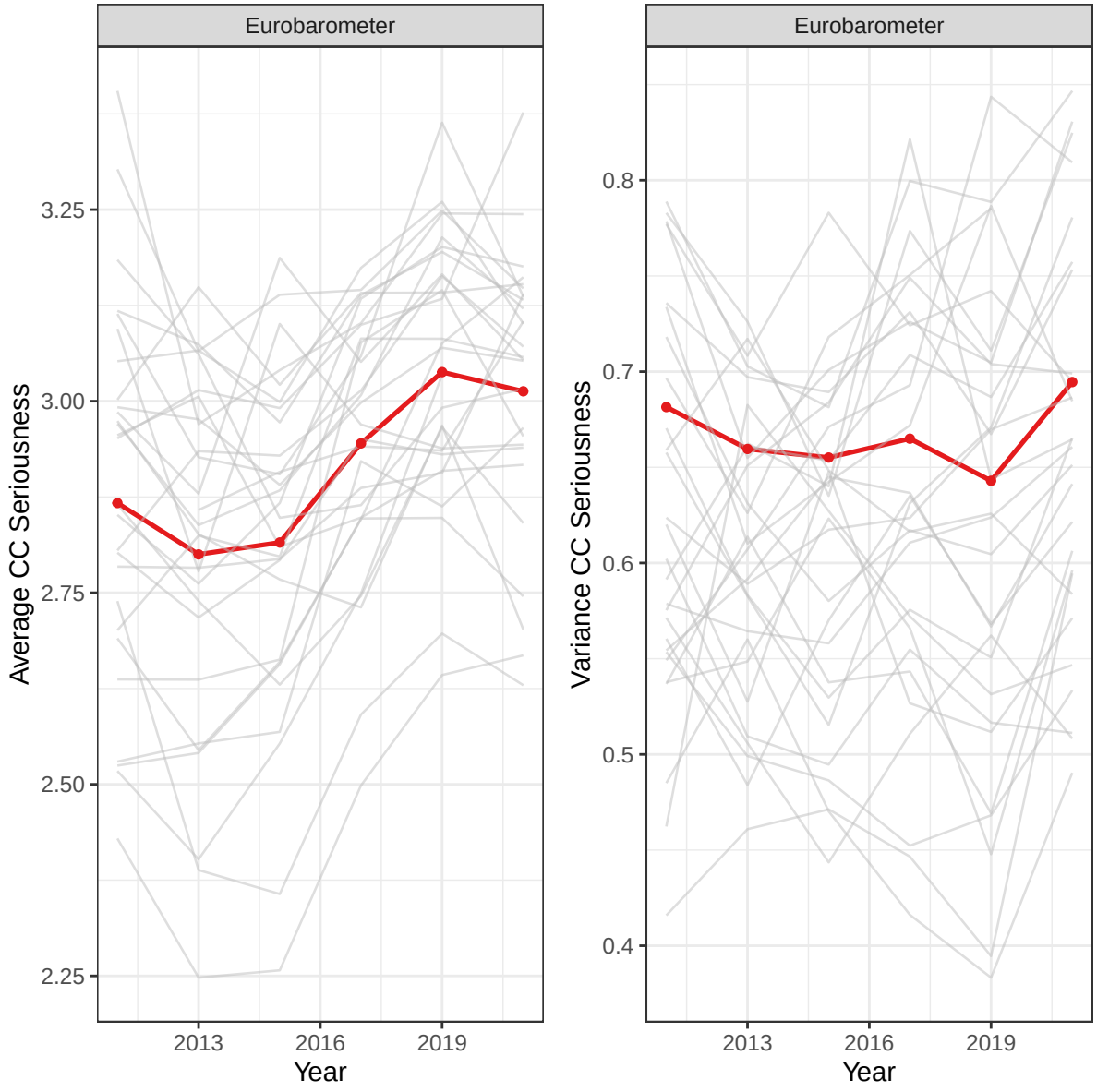
p-values: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Robust standard errors clustered at the country level

Mass Beliefs: Full Results

Panel D: $cor(x_i, a_j)$	Stringency	
	(1)	(2)
Avg. Other CC Serious	0.532***	-0.148***
	(0.023)	(0.034)
Observations	324	324
Within R^2	0.474	0.875
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

Mass Beliefs: Dynamics



Elite Beliefs: Full Results

Panel A: $cor(x_i, x_j)$	Belief Ambitious (1)	Belief Fulfilled (2)
Avg. Other Belief NDC Ambitious	0.552^{***}	
	(0.013)	
Avg. Other Belief NDC Fulfilled		0.513^{***}
		(0.013)
Observations	5,097	5,313
Within R^2	0.316	0.272
Respondent FE	✓	✓

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

Elite Beliefs: Full Results

Panel B: $cor(a_i, x_j)$	Belief Ambitious (1)	Belief Fulfilled (2)
Stringency_{2019}	0.197^{***}	0.158^{**}
	(0.076)	(0.078)
Observations	3,824	3,983
Within R^2	0.003	0.002
Respondent FE	✓	✓
Surveyed Country FE	✓	✓

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

Elite Beliefs: Full Results

Panel C: $cor(x_i, a_i)$

	Stringency_{2021}		Stringency_{2022}		Stringency_{2023}	
	(1)	(2)	(3)	(4)	(5)	(6)
Belief NDC Ambitious	0.019^{***}		0.017^{**}		0.017^{**}	
	(0.007)		(0.007)		(0.007)	
Belief NDC Fulfilled		0.013^{**}		0.012^{**}		0.015^{**}
		(0.006)		(0.006)		(0.006)
Observations	3,824	3,983	3,824	3,983	3,824	3,983
Within R^2	0.004	0.002	0.003	0.002	0.003	0.003
Respondent fixed effects	✓	✓	✓	✓	✓	✓
Surveyed Country fixed effects	✓	✓	✓	✓	✓	✓

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

Elite Beliefs: Surveyed Countries

- "Please evaluate the ambition of the current Nationally Determined Contributions (NDCs) submitted under the Paris Agreement by the following countries or group of countries. Please think of ambition of the NDC relative to a country's economic strength."
- "How confident are you that the following countries or group of countries will fulfill their current NDC submitted under the Paris Agreement?"
  1. Australia
  2. Brazil
  3. China
  4. European Union
  5. India
  6. Russia
  7. Saudi Arabia
  8. South Africa
  9. United States
  10. Your home country

Qualitative Examples: U.S. - Canada

- Biden's BBB spurs meetings with Trudeau in February 2021
- Leaders "expressed their shared commitment to taking real action to fighting climate change while growing the economy and creating good jobs," and announced a formal diplomatic project to "align [their] policies and [their] goals to increase ambition to tackle the climate crisis"
- Two months later, Trudeau initiated programs to incentivize Canadian businesses to achieve net-zero emissions and develop cleaner industry

Qualitative Examples: E.U. - South Korea

- Europe's Green Deal serves as an explicit template for South Korean 2020 Democratic legislative election campaign
- Commits to carbon neutrality by 2050, includes large-scale investments in renewable energy, introduces a carbon tax, phases out coal financing by public institutions, and creates a jobs transition programs
- Compared policy proposals in 2021, highlighting complementarities, "climate, energy and environment policies have to be addressed holistically, in the light of the interdependence of challenges"

Qualitative Examples: South Africa

- Zuma commits to reduce emissions by 34% below current expected levels by 2020 and by about 42% by 2025 at Copenhagen in 2009
- Never had committed to a pledge before, strong status quo bias because of Eskom
- Observers note that, while Zuma never justified his sudden commitment, it may have been due to similarly ambitious pledges from peer countries like China, India, and Brazil (e.g., Hochstetler 2020)

Implications for Institutions: Paris Agreement

- Articles 13, 14, 15 outline information dissemination and review, leading to global stocktake
- Disseminate information about countries' policy successes, bolstering public expectations about the value of green investments

Implications for Institutions: Partnership for Market Readiness

- PMR "supports countries to assess, prepare, and implement carbon pricing instruments, serves as a platform for countries to share knowledge and work together to shape the future of cost-effective climate change mitigation"
- Accredited with transforming global familiarity with, understanding of, and comfort with carbon pricing instruments, increasing uptake
- By dispersing knowledge on carbon pricing and supporting its implementation, PMR makes carbon pricing a more accessible policy tool, thereby facilitating learning among nations about policies that can assist in the green transition