Reducing Carbon using Regulatory and Financial Market Tools

4th Long-Term Investors' Trends Workshop

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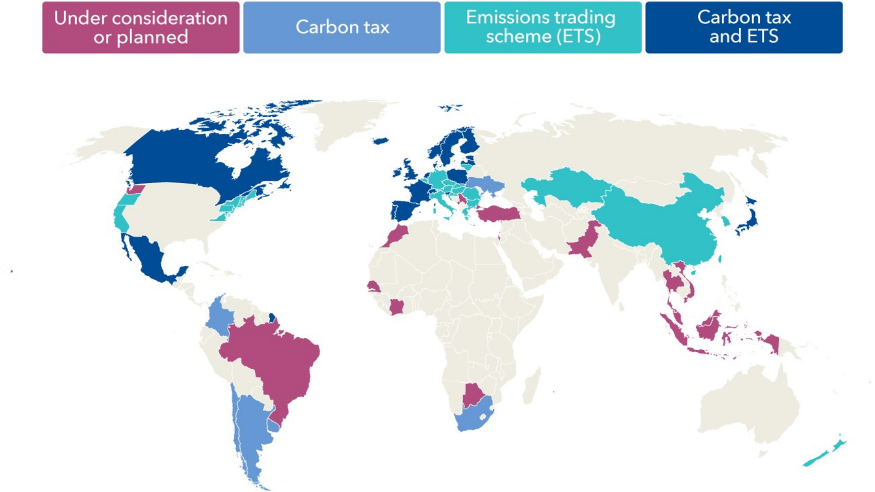
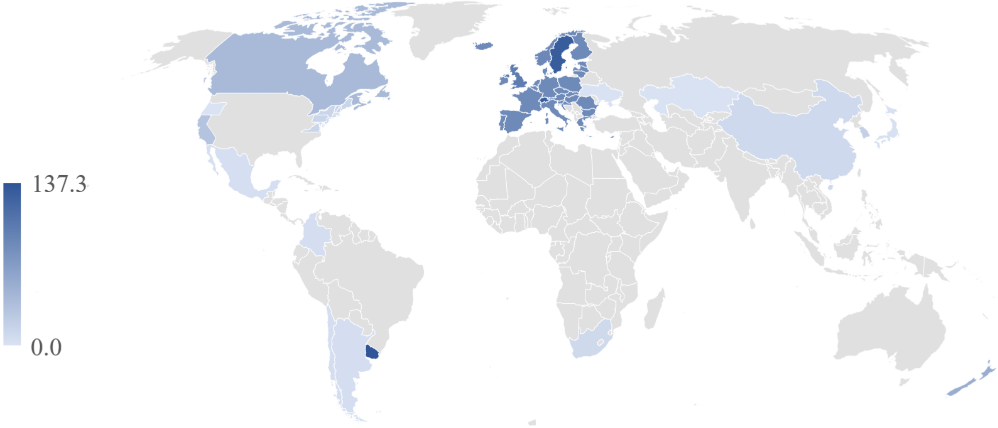
Carbon Pricing Regulation



Paris Climate Agreement goals requires \$5 to \$6.9 trillion per year by 2030

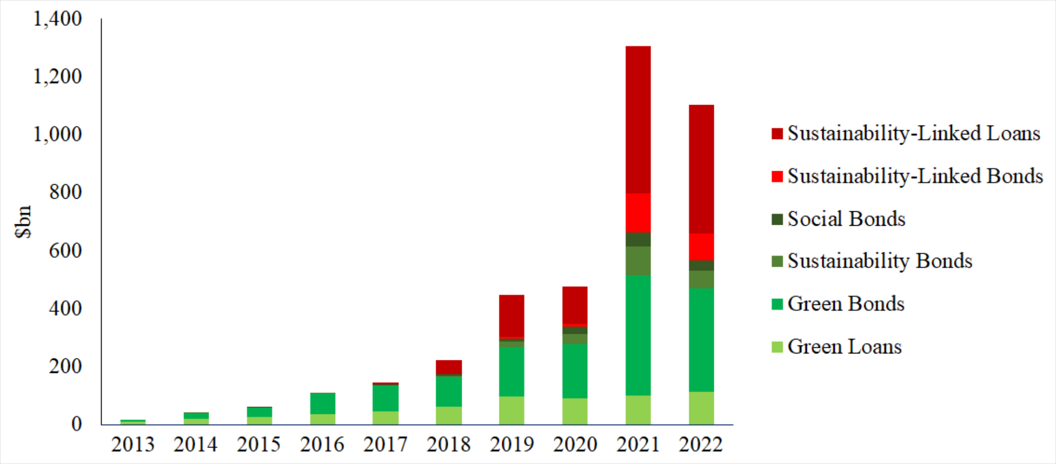
Regulation (Implied) Carbon Price ($/CO2)



Environmental Protection Agency:

Approx. $190/CO2 to be consistent with Paris Agreement goals.

Global Sustainable Debt Issuance Per Year



Global market: approx $6tn, out of which $1.6tn sustainability-linked

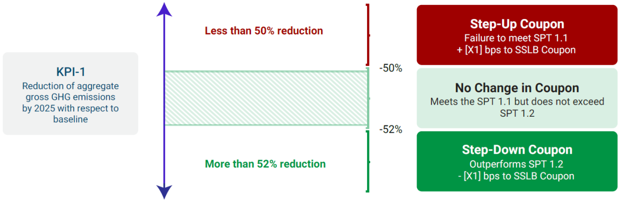
Sustainability-Linked Debt Example

Uruguay's \$1.5bn **SLB** issued in 2022, maturing 2034

KPI: % decrease in aggregate gross GHG emissions per real GDP from 1990 to 2025

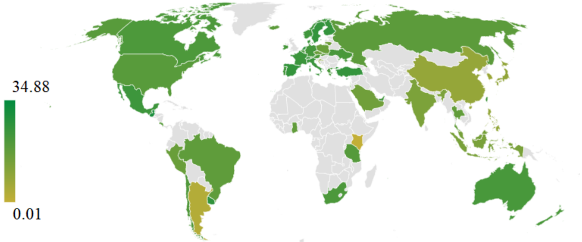
Initial coupon: % 5.75

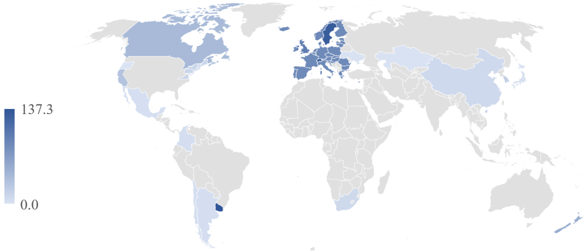
$$\Delta \text{ Coupon} = \begin{cases} +15\text{bps if KPI} < 50\% \\ 0 \quad \text{otherwise} \\ -15\text{bps if KPI} > 52\% \end{cases}$$



Oversubscribed: \$3.96bn

Percentage of Sustainabily-Linked Debt Issuance vs Carbon Price





Research Questions

Premise

- Heterogeneity in political support for regulation, concern for environmental issues and availability of resources to tackle climate change
- Global financial markets deploy significant amounts of capital towards financing sustainability-oriented projects

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- Global financial markets deploy significant amounts of capital towards financing sustainability-oriented projects

Understand interaction between regulatory and financial tools for reducing carbon

- Conditions under which regulation may emerge given political constraints
- Conditions under which carbon-contingent financing may emerge
- Regulation in presence of political constraints and carbon-contingent financing
- When can financial markets alone fully substitute regulation?

Model Setup

Model of investment in polluting or non-polluting technologies

- Standard and environmental risk-neutral agents that behave atomistically
- Regulator chooses a carbon tax subject to median voter constraint

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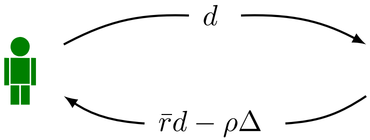
Model of investment in polluting or non-polluting technologies

- Standard and environmental risk-neutral agents that behave atomistically
- Regulator chooses a carbon tax subject to median voter constraint
- Agents can lend and borrow using **carbon-contingent securities** with principal d and payoff

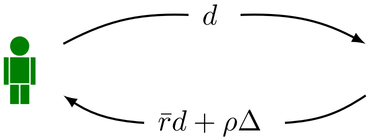
$$\bar{r}d - \rho(\bar{e} - e)$$

with $\bar{r}$ fixed rate of return, ρ market-implied price of carbon, $\bar{e}$ target emissions and e realized emissions.

Target is met: $\bar{e} - e \equiv \Delta > 0$



Target is not met: $\bar{e} - e \equiv -\Delta < 0$



Model Predictions

Carbon-contingent security design can be equivalent to a carbon tax

- A carbon tax corrects the laissez-faire allocation in which the polluting technology is financed by financially-motivated agents
- Absent political support for tax, carbon-contingent financing provided by environmental agents can substitute regulation and enhances welfare

Model Predictions

Carbon-contingent security design can be equivalent to a carbon tax

- A carbon tax corrects the laissez-faire allocation in which the polluting technology is financed by financially-motivated agents
- Absent political support for tax, carbon-contingent financing provided by environmental agents can substitute regulation and enhances welfare
- Existence of financial markets weakens support for regulation

Why? Environmental agents value emissions associated with their actions
Standard agents internalize possible compensation for reducing emissions

- Welfare losses can occur when markets shift economy from one supporting carbon tax to one that does not, but capital deployed is not large enough

Literature

Financial markets can have an impact

- Heinkel, Kraus, and Zechner (2001), Chowdhry, Davies, and Waters (2019), Broccardo, Hart and Zingales (2020), Pastor, Stambaugh, and Taylor (2020), Oehmke and Opp (2021), Hong, Wang and Yang (2021), Gupta, Kopytov, Starmans (2022)

Regulation, financial markets, and corporate behaviour

- Heider and Inderst (2021), Biais and Landier (2022), Oehmke and Opp (2022), Bustamante and Zucchi (2022), Ramadorai and Zeni (2021), Huang and Kopytov (2022), Dottling and Rola-Janicka (2022), Inderst and Opp (2023)

Broader issues in carbon pricing regulation

- Gollier (2013), Goulder and Schein (2013), Fowlie and Reguant (2016), Stavins (2020), Kortum and Weisbach (2020), Fowlie and Reguant (2020)

Baseline Model

- **Time:** two time periods.
- **Technologies**: two technologies
  (i) A polluting technology, which for input I yields

  $$y_\pi = \pi I \qquad \text{and} \qquad e_\pi = I$$

  where $\pi > 1$ is a production parameter.
  (ii) A non-polluting or green technology, which for input I yields

  $$y_g = gI \qquad \text{and} \qquad e_g = 0$$

  where $1 < g < \pi$ is a green production parameter.

Structure of the Economy (cont.)

- **Agents:** two types of agents indexed by $i = 1, 2$ with endowments h_i

  (i) Standard agents, who form a proportion θ of the population

  $$U_1 = y_1 - \lambda E$$

  (ii) Environmental agents, who form a proportion $1 - \theta$ of the population

  $$U_2 = y_2 - \lambda E - \eta e_2$$

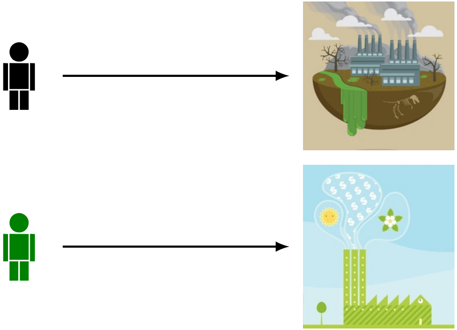
  with $\eta > \pi - g$ green preference parameter, and λ climate exposure parameter with $E = \theta e_1 + (1 - \theta) e_2$ total emissions associated with agents' actions.

- **Regulator:** maximizes utilitarian social welfare

  $$W = \theta U_1 + (1 - \theta) U_2$$

back

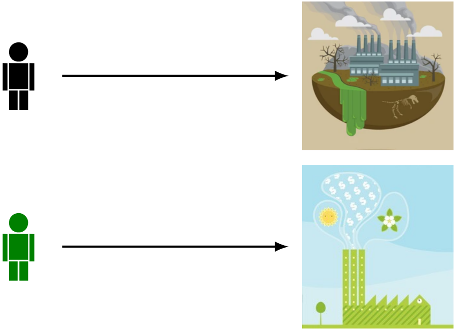
Laissez-Faire



$$E^* = \theta h_1$$

$$W^* = \theta \pi h_1 + (1-\theta) g h_2 - \lambda \theta h_1$$

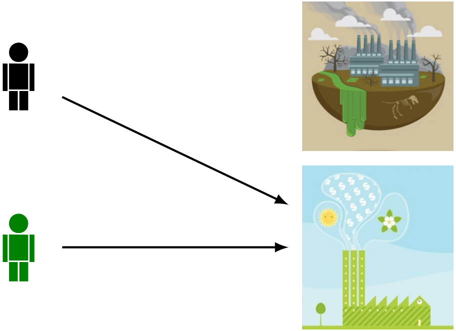
Laissez-Faire



$$E^* = \theta h_1$$

$$W^* = \theta \pi h_1 + (1-\theta) g h_2 - \lambda \theta h_1$$

Carbon Tax $\tau \geq \pi - g$



$$E^\tau = 0$$

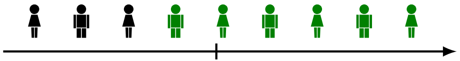
$$W^\tau = \theta g h_1 + (1-\theta) g h_2$$

$$W^\tau > W^* \quad \text{if} \quad \pi - g < \lambda$$

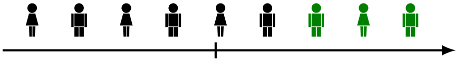
Constrained Carbon Tax

Imposing carbon tax is subject to median voter constraint that at least half the population should be better off

$$\max_{\tau} \; W^{\tau} \quad \text{such that } \tau \leq \tau_{0.5}$$



Median Voter



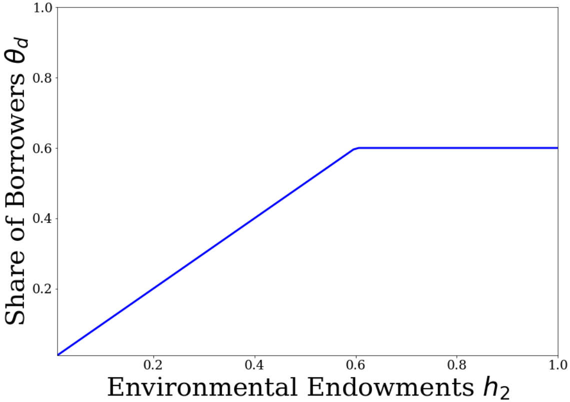
Median Voter

$$\tau^{o} = \pi - g$$

$$\tau^{o} = \begin{cases} \pi - g & \text{if } \; \pi - g < \lambda\theta \\ 0 & \text{otherwise} \end{cases}$$

Carbon-Contingent Financing Equilibrium

If there is no carbon tax $\tau = 0$ a market for carbon-contingent financing arises, in which standard agents act as borrowers and environmental agents act as lenders and the market-implied carbon price is $\rho \in [\pi - g, \eta]$



High lenders' endowments h_2
$\rightarrow$ all standard agents θ can be funded and switch to green technology

Low lenders' endowments h_2
$\rightarrow$ only fraction $\theta_d < \theta$ of standard investors can access funding

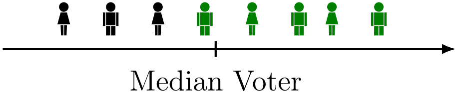
more

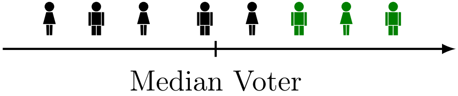
Carbon-Contingent Financing and Political Constraints

How does existence of financial markets for pricing carbon affect support for tax?

If environmental endowments are sufficient high, the constrained optimal carbon tax is $\tau^o = 0$ *and all emissions are priced using carbon-contingent securities.*

Otherwise, if endowments are low





$$\tau^o = \begin{cases} \pi - g & \text{if } \ (\eta - \rho)\frac{\theta_d}{1-\theta} < \lambda(\theta - \theta_d) \\ 0 & \end{cases}$$

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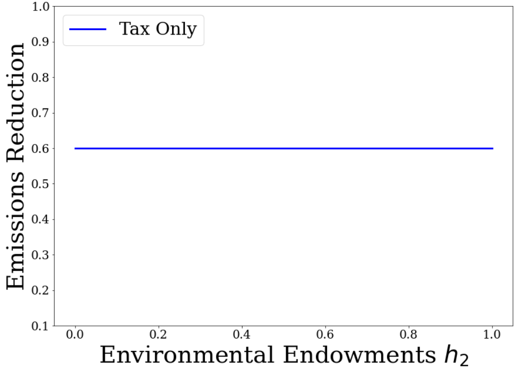
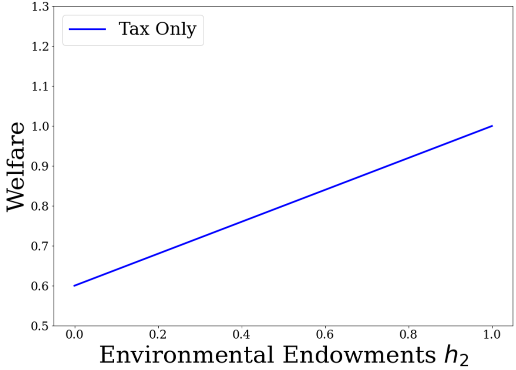
Carbon-Contingent Financing and Political Constraints

Share of standard agents: $\theta = 0.6$





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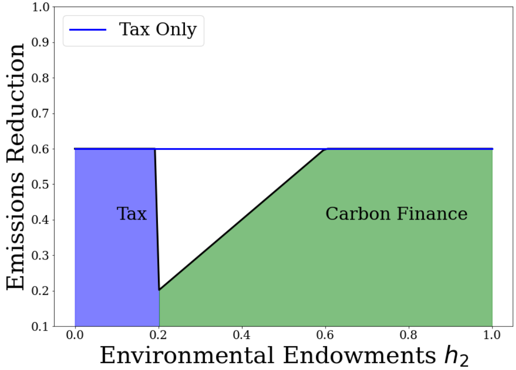
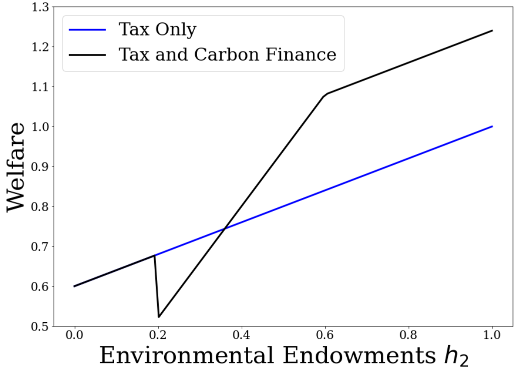




Extended Model

Extended Model Features

- **Heterogeneous preferences**. Mass one of investors $i \in [0,1]$ with green preferences η_i such that $\eta_i^{'} > 0$ and

$$U_i = y_i - \eta_i e_i - \lambda E$$

endowments $h_i = \$1$ for each i, and $E = \int_i e_i di$.

- **Convex abatement cost**. Continuum of technologies $\delta \in [0,1]$ which deliver

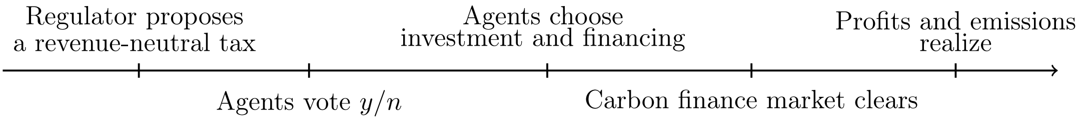
$$e = (1-\delta)I, \quad y = (\pi - \phi(\delta))I$$

for investment I with $\pi > 1$ and $\phi(\delta) = \frac{1}{2}\phi\delta^2$.

- **Regulator** maximizes utilitarian welfare

$$W = \int_0^1 U_i di = \int_0^1 (y_i - \eta_i e_i) di - \lambda E$$

Timeline and Solution



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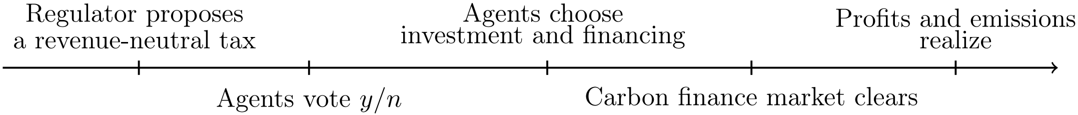
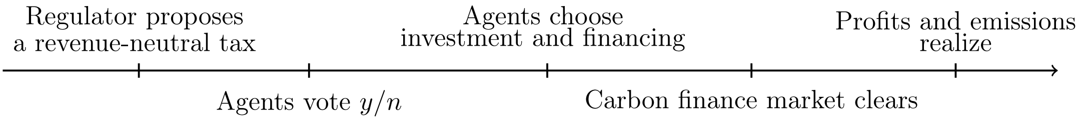


Solve by backward induction:

- Determine supply and demand of carbon contingent financing for given tax τ
  - $\rightarrow$ Solve for equilibrium market price of carbon $\rho(\tau)$ and cutoff type $x(\tau)$

Timeline and Solution

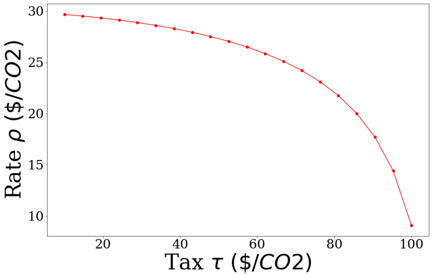


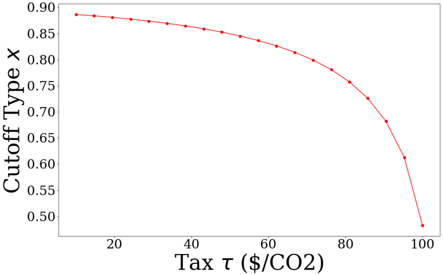
Solve by backward induction:

- Determine supply and demand of carbon contingent financing for given tax τ
  - $\rightarrow$ Solve for equilibrium market price of carbon $\rho(\tau)$ and cutoff type $x(\tau)$
- Determine median-voter threshold $\bar{\tau}_{0.5}$ given financial markets response
  - $\rightarrow$ Solve for the constrained-optimal tax τ^o such that

$$\max_{\tau} W(\tau, \rho(\tau), x(\tau)) \text{ such that } \tau \leq \bar{\tau}_{0.5}$$

Market Price of Carbon given Carbon Tax





Ex: Preferences $\eta_i \leq 40\$/\text{CO2}$

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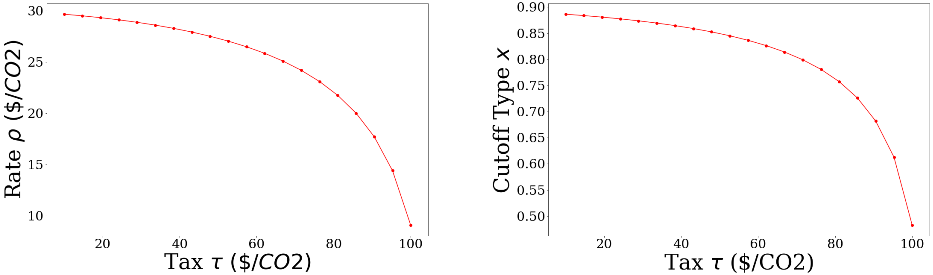

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When tax is very high, no role for financial markets.

High tax reduces abatement potential of issuers as well as lenders' budget.

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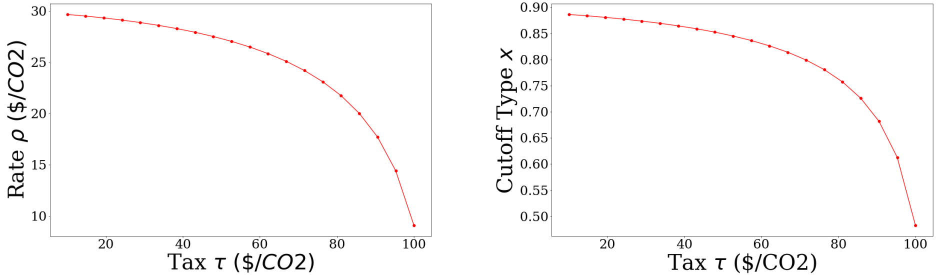

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When tax is very high, no role for financial markets.

High tax reduces abatement potential of issuers as well as lenders' budget.

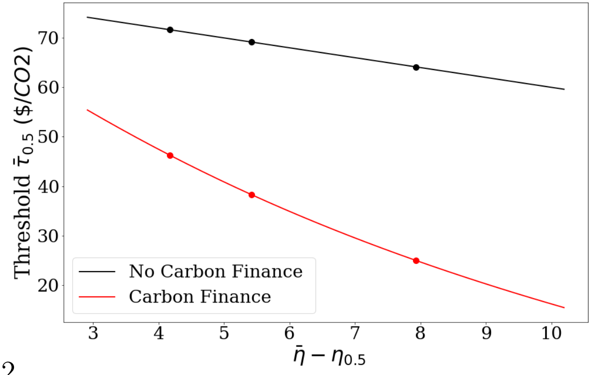
When tax is low, cutoff type is typically above median voter.

Median voter is typically an issuer of carbon-contingent securities.

Median Voter Threshold

Prop: *Median voter's threshold* $\bar{\tau}_{0.5}$ *verifies*

$$\bar{\tau}_{0.5} + f(\rho(\bar{\tau}_{0.5}), x(\bar{\tau}_{0.5})) = \lambda - 2(\bar{\eta} - \eta_{0.5}).$$



Ex: $\lambda = 50\$/\mathrm{CO2}$

Presence of financial markets decreases support for a carbon tax.

Optimal Carbon Tax with Financial Markets

But also, financial markets decrease the optimal carbon tax!

Optimal Carbon Tax with Financial Markets

But also, financial markets decrease the optimal carbon tax! ***Prop:*** *The optimal tax τ^o which maximizes the constrained regulator problem*

$$\max_{\tau} W(\tau, \rho(\tau)) \quad \text{such that} \quad \tau \leq \bar{\tau}_{0.5}$$

satisfies

$$\tau^o = \min\left(\lambda - \rho^o x^o, \bar{\tau}_{0.5}\right)$$

with $\rho^o x^o$ the equilibrium level of abatement financed by the market given $\tau = \tau^o$.

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Absent political constraint, carbon tax optimally below Pigouvian benchmark λ

$\rightarrow$ combined presence of tax and markets enhances welfare

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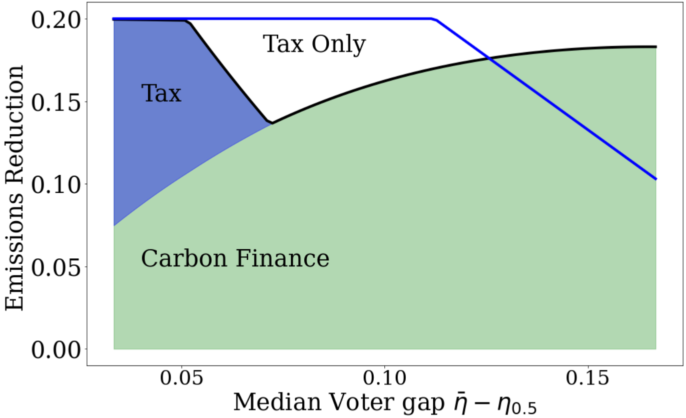
Absent political constraint, carbon tax optimally below Pigouvian benchmark λ
$\rightarrow$ combined presence of tax and markets enhances welfare

However, median voter constraint $\bar{\tau}_{0.5}$ is lower because of anticipated financial markets response $\rightarrow$ possibility of welfare losses.

Carbon-Contingent Financing and Political Constraints



Concluding Remarks

Baseline Model

- Carbon-contingent financing arises when there is no political support for a tax and can fully substitute regulation if the capital deployed is large enough
- When markets shift the economy from one supporting a carbon tax to one that does not, and capital deployed is small welfare losses can occur

Extended Model

- Carbon-contingent financing and tax co-exist (intensive margin substitution)
- Absent support for tax, financial markets offer a welfare-improving alternative
- When support for tax is strong, combined presence of carbon tax and carbon-contingent financing achieves higher welfare than tax alone
- Financial markets weaken support for tax and welfare losses can occur

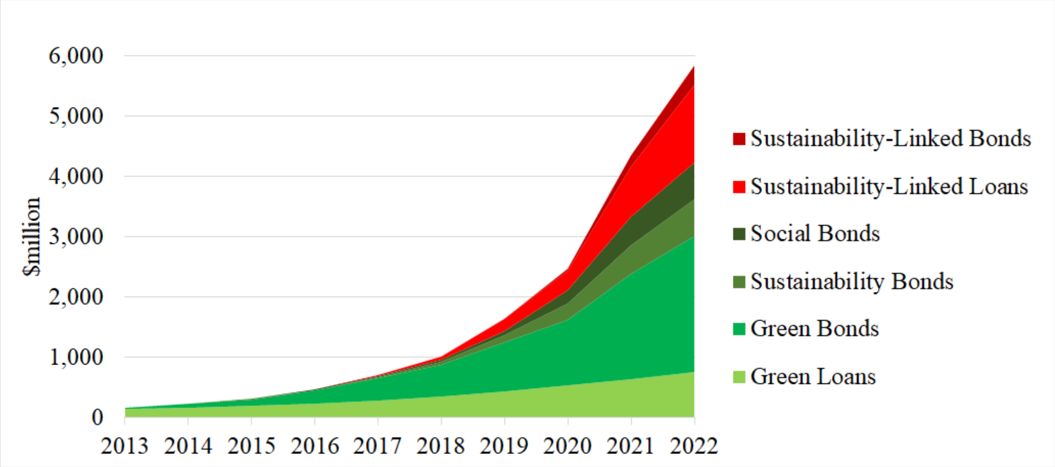
Implications

We study conditions under which carbon-contingent financing can substitute carbon tax within one economy. Important first step in thinking about transition globally

- In 2009 developed countries committed to jointly mobilize \$100bn a year by 2020 to developing countries
- Capital mobilized through sustainability-linked debt is orders of magnitude larger (\$1.6tn total) and has a wider reach, being implemented in countries where support for regulation has been insufficient
- Carbon-contingent securities combine global nature of capital markets with the carbon-price incentives of regulation

Thank You!

Cumulative Sustainable Debt Issuance



back

Borrower's problem: i borrows d_i and invests $h_i + d_i$ in preferred technology

$$U_i = \max_{I_\pi, I_g} \pi I_\pi + g I_g - (\eta_i + \tau) I_\pi - \bar{r} d_i + \rho(\bar{e}_i - e_i) - \lambda E \quad \text{s.t.} \quad I_\pi + I_g \leq h_1 + d_1$$

with $\eta_1 = 0$ and $\eta_2 = \eta$, and $\theta(\bar{e}_1 - e_1) = (1-\theta)(\bar{e}_2 - e_2) \geq 0$.

- Environmental agent: $\bar{e}_2 = 0 \rightarrow$ never borrows
- Standard agent: $\bar{e}_1 = h_1$ if not tax $\tau = 0$ and $e_1 = I_\pi$. Borrows if $\rho \geq \pi - g$ and switches to green technology

Lender's Problem: agent i lends d_i and invests $h_i - d_i$ in preferred technology

- Standard agent

$$U_1 = \max_{d_1 \leq h_1} (\pi - \tau)(h_1 - d_1) + \bar{r} d_1 - \rho(\bar{e}_1 - e_1),$$

yields $\rho = 0$ and $\bar{r} = g$ if $\tau = \pi - g$, or $\rho = 0$ and $\bar{r} = \pi$ if $\tau = 0$ never lends

Carbon-Contingent Financing

Lender's Problem: agent i lends d_i and invests $h_i - d_i$ in preferred technology

- Environmental agent lends at $\rho \in [\pi - g, \eta]$.

$$U_2 = \max_{d_2 \leq h_2} g(h_2 - d_2) + \bar{r} d_2 - \rho(\bar{e}_2 - e_2) + \eta(\bar{e}_2 - e_2),$$

with $\theta(\bar{e}_1 - e_1) = (1-\theta)(\bar{e}_2 - e_2) \geq 0$ and subject to financing constraint

$$g(h_2 - d_2) + \bar{r} d_2 - \rho(\bar{e}_2 - e_2) \geq 0,$$

agents lends at $\bar{r} = g$ and $\rho = \eta > \pi - g$. Standard agents borrows and switches at $\rho \in [\pi - g, \eta]$. If endowments satisfy

$$h_2 \geq \frac{\pi - g}{g} \frac{\theta}{1-\theta} h_1$$

all standard agents access carbon-contingent financing and switch to green technology. Otherwise, only fraction $\theta_d < \theta$ obtaining financing and switches

back