

Emission caps and investment in green technologies

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Outline

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Emission caps and investments in green technologies

To mitigate global warming firms must reduce CO2 emissions

→ investment in green technologies: abatement, R&D

CO2 emissions = externalities

→ need government intervention: emission caps, carbon tax

Will firms invest in green technologies? Will government cap emissions?

Expectations about government policy drive firms' actions

“prior to the Paris announcement... firms... downgraded their expectations over the impact of future regulation and... increased their actual carbon footprint...”

These patterns change dramatically in 2016, the year after the Paris announcement. In that year, all firms report upwardly revised beliefs over the impact of climate regulation, and sharply increase carbon abatement”

Ramadorai and Zeni, 2020

Governments' promises are not very credible

“The latest IPCC (Intergovernmental Panel on Climate Change) report is a litany of broken climate promises. Some government and business leaders are saying one thing but doing another... It is time to stop burning our planet.”

Antonio Guterrez (Secretary-general of the United Nations), April 2022

Governments' commitment pb: "Realpolitik"

Press release | 19 August 2022 | Brussels

State aid: Commission approves €27.5 billion German scheme to compensate energy-intensive companies for indirect emission costs

The Commission found that the scheme is necessary and appropriate to support energy-intensive companies to cope with the higher electricity prices and to avoid that companies relocate to countries outside the EU with less ambitious climate policies, resulting in an increase in global greenhouse gas emissions. Moreover, the Commission found that the

Governments' commitment pb: "Realpolitik"

Brussels agrees deal with Germany in spat over combustion engines ban

EU will exempt cars which run on certain types of fuel from new law after lobbying from Berlin

FINANCIAL TIMES

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Europe Express

Climate legislation

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EU lawmakers push to water down methane emissions rules

Governments care about ex-post efficiency

Our goal

Analyze equilibrium interaction between :

1. firm's expectations and actions (*ex ante*),
2. and government actions (*ex post*).

Identify if and how emissions can be curbed, and what could derail the process

Strategic complementarity and equilibrium multiplicity

If firms anticipate future emission caps

- invest in green technologies to comply with caps
- firms' investments reduce own emissions + generate innovations
- spillover: innovations bring down abatement cost for all firms
- government caps emissions (not too costly)

If firms anticipate no emission caps

- don't invest in green technologies
- no innovation: abatement cost remains high
- government reluctant to cap emissions (very costly)

Large fund → can tilt equilibrium towards emission caps

Literature: Aghion et al 2016, Acemoglu et al 2016

Carbon tax, research subsidies → innovation in green technologies

Some firms invest & innovate → spillover effects on other firms

Our model assumes such spillovers

Literature: Fahri Tirole 2012

To bail out distressed banks = low interest rate for all:
non-targeted monetary policy

Macro cost: distorts intertemporal choice (for all)

Don't pay this cost if only a few banks distressed

Multiple equilibria:

Expect bailout → take risk → many distressed → bailout

Expect no bailout → reduce risk → few distressed → no bailout

While related, our mechanism is different: does not hinge on whether policy can be targeted

Firms' and government's actions

Mass 1 continuum of competitive owner-managed firms $i \in [0, 1]$

$t = 1$: invest in green techno $l_i^1 = 1$ at cost c_1 , or not $l_i^1 = 0$

$$\gamma_1 = \int_{i=0}^1 l_i^1 di$$

$t = 2$: gvt obs emissions, emissions capped or not

If emissions capped

i s.t. $l_i^1 = 1$ already meet target

i s.t. $l_i^1 = 0$ must abate, at cost c_2

Abatement costs

- *Time to build*: Hurried late investment (at $t = 2$) to curb emissions is particularly costly,
- *Spillovers*: early investment in green technologies cheapens later investments (Aghion et al, 2016, Acemoglu et al, 2016)

Cost of abatement at $t = 2$:

$$c_2 = \kappa - \lambda\gamma_1$$

If no investment in green tech at $t = 1$ ($\gamma_1 = 0$)

→ high cost of abatement at $t = 2$: $\kappa > c_1$

If lots of investment at $t = 1$ ($\gamma_1 \gg 0$)

→ spillover: λ

→ low cost of abatement at $t = 2$

CO2 emissions

- Firms which don't invest at $t = 1$, nor abate at $t = 2$, emit θ
- Fraction of firms that invest at $t = 1$ in developing green techno:

$$\gamma_1 = \int_{i=0}^1 l_i^1 di \rightarrow \text{emit } \theta - 1$$

- Fraction of firms that abate emissions at $t = 2$:

$$\gamma_2 = \int_{i=0}^1 l_i^2 di \rightarrow \text{emit } \theta - 1$$

Aggregate CO2 emissions at $t = 2$:

$$\theta - (\gamma_1 + \gamma_2)$$

Disutility from aggregate emissions at $t = 2$:

$$d(\theta - (\gamma_1 + \gamma_2))$$

Utilitarian welfare over the two periods

$$W = \int_{i=0}^1 U_i di$$

$$U_i = [Y - I_i^2 c_2 - d(\theta - (\gamma_1 + \gamma_2))] - I_i^1 c_1$$

1st term: $t = 2$: output – abatement cost – cost of emissions

2nd term: $t = 1$: cost of investment in green technologies

$$W = Y - \gamma_2 c_2 - \gamma_1 c_1 - d(\theta - (\gamma_1 + \gamma_2))$$

First best

1. **Low cost of early investment** : $c_1 \leq \kappa - \lambda$

→ everyone should invest at $t = 1$: $\gamma_1 = 1$

2. **Intermediate case**: $\kappa - \lambda < c_1 \leq d$

→ some invest at $t = 1$, others at $t = 2$ to exploit spillovers

$$\gamma_1 = \frac{\kappa + \lambda - c_1}{2\lambda}, \gamma_2 = 1 - \gamma_1$$

3. **Large cost of early investment**: $c_1 > d$

→ no investment: $\gamma_1 = 0, \gamma_2 = 0$

Government failures

Government lacks commitment power

- $t = 2$: government chooses policy which maximizes utilitarian welfare at that time
- $t = 1$: government cannot credibly commit to $t = 2$ policies that are suboptimal at $t = 2$ (perfect equ. Selten 1965)

Government cannot observe time-1 investment

- cannot directly control time-1 investment
- firms decisions at $t = 1$ reflect beliefs on time-2 policy

Optimal government policy at time 2

Optimal to cap emissions ex-post *on given firm* if:

$$c_2 \leq d$$

abatement cost \leq unabated emissions cost

If $\kappa - \lambda > d$, never optimal to cap. Otherwise, cap if:

$$\gamma_1 \geq \frac{\kappa - d}{\lambda} > 0$$

- Large $\gamma_1 \rightarrow$ large spillovers \rightarrow cap not too costly,
- Spillovers necessary for caps: Requires $\lambda > 0$ when $\kappa > d$

Privately optimal firms' actions

Firms don't internalize cost of emissions, just maximize own profit

If anticipate cap with proba μ , invest in green at $t = 1$ iff:

$$Y - c_1 \geq Y - \mu c_2$$

- RHS: Profit if delay action to $t = 2$,
- LHS: Profit if invest at $t = 1$.

→ Invest at $t = 1$ if proba μ of a $t = 2$ cap is large enough:

$$\mu \geq \frac{c_1}{\kappa - \lambda \gamma_1}$$

Strategic complementarity between firms and gvt

Firms invest in green (γ_1 large) \rightarrow government caps

- because spillover from early investors makes abatement cost reasonable

Government likely to cap (μ large) \rightarrow firms invest in green innovation

- because abating later in a rush would be costly

Brown equilibrium

Firms anticipate no emission cap, i.e., $\mu = 0$

→ no investment in green technologies at $t = 1$: $\gamma_1 = 0$

→ no spillovers

→ large time-2 abatement cost $c_2 = \kappa$

→ government does not cap emissions at $t = 2$

→ rational to anticipate $\mu = 0$

Green equilibrium

Firms anticipate emission cap, i.e., $\mu = 1$

- if $\kappa - \lambda \geq c_1$ all invest at $t = 1$: $\gamma_1 = 1$
- If $c_1 > \kappa - \lambda$ fraction $\gamma_1 = \frac{\kappa - c_1}{\lambda}$ invest at $t = 1$, $1 - \gamma_1$ at $t = 2$

→ large spillovers → low time-2 abatement cost

→ government caps emissions at $t = 2$

→ rational to anticipate $\mu = 1$

Large fund

Owns fraction α of firms

- controls management
- can ensure that firms invest at $t = 1$ in green technologies

Kantian Responsible fund

Forces investment at $t = 1$ in green technologies

- irrespective of beliefs about government's policy
- “Kantian”: does not weigh costs/benefits, just “doing what's right”.

Can responsible fund eliminate Brown equilibrium?

Yes, if

$$\alpha > \frac{\kappa - d}{\lambda}$$

→ when that condition holds, all firms anticipate emission caps at $t = 2$

→ unique equ. (iterated elimination of dominated strategies)

Impact and Performance of responsible fund

How much impact does fund have vis-a-vis counterfactual?

- Question of “additionality” (Brest&Born (2013)):
- Eliminating “bad equilibrium” is a form of impact

Does the responsible fund under-perform?

- NO as soon as large enough to force equilibrium selection.

What if fund not Kantian but profit maximizing?

Disutility d from global warming broken down in two components:

$$d = d^f + d^c$$

- d^f global warming reduces firms' profits
- d^c global warming make citizens' life miserable

Large fund is pivotal

If fund large enough ($\alpha > \frac{\kappa-d}{\lambda}$) and impact of global warming **on profits** is large ($d^f > c_1$)

→ **profit maximizing fund selects the good equilibrium** by investing in green technologies at time 1

“Bright side” of common ownership (internalizing externality).

Robustness

- Taxes and subsidies
- Credit rationing
- Licences
- Equilibrium selection: risk-dominance
- Global games

Taxes and subsidies

Gvt announces transfers at time 2, conditional on observed emissions:

- tax firms which did not invest, while subsidizing others

Commitment pb: political economy friction

- transfers implemented at time 2 only if majority are in favor.

→ Brown equilibrium still exists

- under Brown beliefs, majority against transfer scheme ex-post

Credit rationing can eliminate Green equilibrium

Suppose firms have no cash at $t = 1$

→ must borrow c_1 to fund investment in green technologies

Suppose fraction δ of output can be diverted

→ only $(1 - \delta)Y$ can be pledged

If $c_1 > (1 - \delta)Y$, firms can't invest at $t = 1$ → no cap at $t = 2$

Green subsidies can restore Green equilibrium

If government offers subsidy

$$s = c_1 - (1 - \delta)Y$$

→ if firms anticipate cap: invest at $t = 1$

→ gvt caps emissions

→ subsidy restores existence of Green equilibrium

Which equilibrium ?

If I anticipate Green equilibrium to prevail with probability p , I prefer to invest early if

$$\frac{c_1}{c_2} < p$$

range of beliefs on p for which I invest early: $[\frac{c_1}{c_2}, 1]$
larger than range of beliefs for which I wait: $[0, \frac{c_1}{c_2}]$

When $c_1 \leq \frac{\kappa - \lambda}{2}$, $\frac{c_1}{c_2} \leq \frac{1}{2} \rightarrow$ Green equilibrium risk dominant

When $c_1 > \frac{\kappa - \lambda}{2}$, $\frac{c_1}{c_2} > \frac{1}{2} \rightarrow$ Brown equilibrium risk dominant

“Global game” does not eliminate multiplicity

Extend model // Carlsson Van Damme 1993, Morris Shin 1998

N equiprobable realizations of \tilde{d} : $d_1, \dots, d_n, \dots, d_N$

In state d_n , ε firms obs S_{n+1} , $1 - 2\varepsilon$ obs S_n , ε obs S_{n-1}

If

$$(1 - \varepsilon)(\kappa - \lambda) + \varepsilon\lambda > c_1 > \varepsilon(\kappa - \lambda)$$

then, “invest at $t = 1$ iff $S_n \geq S_{n^*}$ ” is an equilibrium for all n^* s.t

$$\kappa - \lambda < d_{n^*-1} < d_{n^*} < \kappa$$

→ multiplicity of threshold equilibria

Conclusion

- **Strategic complementarity** between govts' and firms' policies in climate mitigation
 - Bad coordination → bad outcome in which govt does not cap emissions, and firms under-invest
- **Large fund** imposing investment in green technologies can tilt towards Pareto dominant equilibrium
 - Suggests **additionality** (aka. impact) definition could include contribution to **equilibrium selection**