Leave or remain? An evolutionary approach to carbon leakage in Emission Trading Systems

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STOP


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ETS and carbon leakage

- Increasing attention devoted to ETSs both in the EU and outside (California, Quebec, RGGI, New Zealand, China, Switzerland etc..)
- 21 ETSs operating in the world, covering 15 per cent of global emissions
- In the absence of a global carbon market, unilateral carbon policies may have carbon leakage effects.
- To prevent delocalization, most ETSs allow for carbon leakage provisions, e.g. free allocation to sectors "at risk of carbon leakage"
- Heated debate on the criteria (cf. Martin et al, 2014a,b) and growing literature on the possible impact of ETS on carbon leakage and abatement (FSR Climate, 2019)

Literature

- Empirical studies find little/no evidence of carbon leakage effects of the ETS (Verde, 2018; Vivid Economics, 2018; Ellis et al., 2019).
- Dechezlepretre et al. (2015) find no evidence of carbon leakage effect in the EU ETS for multinational companies over the period 2007–2014. Similar conclusions in aus dem Moore et al., (2019); Naegele and Zaklan, (2019)
- Koch and Basse Mama (2016) and Borghesi et al. (2020) find some evidence of carbon leakage for German and Italian firms, respectively;
- However, evidence might emerge as carbon prices increase.
- Aim: contribute with a new theoretical approach
- Grubb et al. (2012): "findings are at odds with classical theory but consistent with theories of behavioral economics"

What's new

- Evolutionary game model (see, e.g., Friedman, 1991; Sethi and Somanathan, 1996; Hofbauer and Sigmund, 2003)
- Bounded rationality and imitative behaviors (see, e.g., Hofbauer and Weibull, 1996; Schlag, 1998)
- Study the functioning of ETS and its impact on the incentive to delocalize in the presence of 2 interacting populations of firms that act strategically
- Build upon and extend Antoci et al. (2019a,b): a) on incentive to eco-innovation in a ETS with floor price and b) on incentive to cheat (i.e. be non-compliant) in an ETS with sanctions, respectively
- Differently from above, we account here for: 1) free permits 2) different costs at home vs abroad

The model

- A population of N firms that produce a unique homogeneous good has to choose between two possible strategies:
  - produce in the home country and be subject to ETS (H) or
  - relocate the production to a foreign non-ETS country (R)
- To avoid buying allowances, ETS-regulated firms can invest in emissions abatement (z)
- To avoid the risk of relocation, the regulator can give an amount of permits (y) for free
- To prevent allowances price from collapsing, ETS regulator can set a floor price
- Denote with $x \in [0, 1]$ and $1 - x$ the share of relocated and home firms, respectively

Payoffs

Profits:

$$\pi_h = p \cdot q_h - \frac{C_h^v}{2} \cdot q_h^2 - C_h^f - \frac{\theta}{2} \cdot z^2 - p_p \cdot (q_h - z - y)$$
$$\pi_r = p \cdot q_r - \frac{C_r^v}{2} \cdot q_r^2 - C_r^f$$

where $p > 0$ is the output price, q_i (with $i = h, r$) represents the quantities produced, $\theta > 0$ is a parameter that captures the (in)efficiency of the abatement technology, $p_p \geqslant 0$ is the permit's price, and $C_i^v, C_i^f > 0$ are the variable and the fixed costs, respectively.

Prices

Both output and allowance markets are perfectly competitive

The allowance price is market clearing, namely, is such that equals demand and supply:

$$(q_h - z - y) \cdot (1 - x) \cdot N = \overline{Q}$$

where $\overline{Q} > 0$ is the supply of emissions allowances.

The output demand is assumed to be linear:

$$p = \overline{p} - \alpha \cdot [q_r \cdot x + q_h \cdot (1 - x)] \cdot N$$

where $\overline{p} > 0$ represents the market reservation price and $\alpha > 0$ is the slope of the output demand.

Replicator dynamics

The time evolution of the share of "relocated" firms is given by the well-know replicator equation (Weibull, 1995):

$$\dot{x} = x \cdot (1 - x) \cdot [\pi_r(x) - \pi_h(x)]$$

If producing abroad is more profitable than producing at home, namely, $\pi_r(x) > \pi_h(x)$, then the share of relocated firms increases; the opposite occurs if $\pi_r(x) < \pi_h(x)$. Finally, if $\pi_h(x) = \pi_r(x)$, then the share of relocated (and home) firms does not change over time.

Output choices

First order conditions:

$$\frac{\partial \pi_h}{\partial q_h} = p - C_h^v \cdot q_h - pp \leqslant 0 \; , \quad \frac{\partial \pi_h}{\partial q_h} \cdot q_h = 0$$

$$\frac{\partial \pi_h}{\partial z} = pp - \theta \cdot z \leqslant 0 \; , \quad \frac{\partial \pi_h}{\partial z} \cdot z = 0$$

$$\frac{\partial \pi_r}{\partial q_r} = p - C_h^v \cdot q_r \leqslant 0 \; , \quad \frac{\partial \pi_r}{\partial q_r} \cdot q_r = 0$$

Equilibrium values

$$p_p^\star = \left\{ \left[\frac{\overline{p}\left(1 - \frac{\alpha R}{C_r^v + \alpha R}\right)}{C_h^v + \alpha H\left(1 - \frac{\alpha R}{C_r^v + \alpha R}\right)} \right] - \frac{\overline{Q}}{(1-x)\,N} \right\} \cdot$$

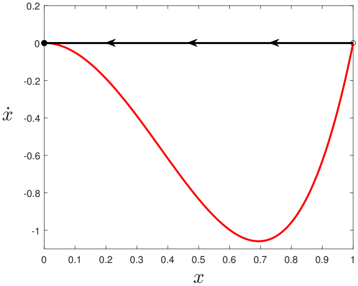
$$\cdot \left\{ \frac{\theta\left[C_h^v + \alpha H\left(1 - \frac{\alpha R}{C_r^v + \alpha R}\right)\right]}{\theta + C_h^v + \alpha H\left(1 - \frac{\alpha R}{C_r^v + \alpha R}\right)} \right\}$$

$$q_h^\star = \frac{\overline{p}\left(1 - \frac{\alpha R}{C_r^v + \alpha R}\right) - p_p^\star}{C_h^v + \alpha H\left(1 - \frac{\alpha R}{C_r^v + \alpha R}\right)}$$

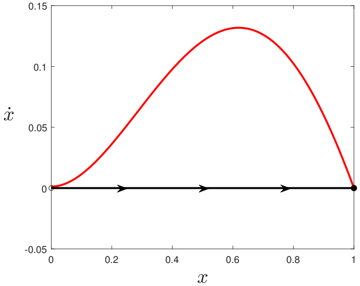
$$q_r^\star = \frac{\overline{p} - \alpha H q_h^\star}{C_r^v + \alpha R}$$

$$z^\star = \frac{p_p^\star}{\theta}$$

Dynamic regimes: extreme equilibria



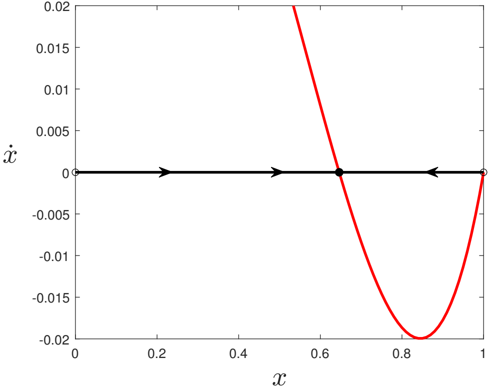
(a) No firm leaves (all remain)



(b) All firms leave (none remains)

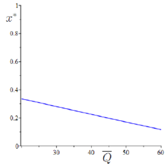
Parameter values: $\overline{p} = 30$, $C_h^v = 0.5$, $C_r^v = 0.8$, $C_h^f = 0.5$, $C_r^f = 1.5$, $\overline{Q} = 0.5$, $N = 50$, $\alpha = 0.5$, $\theta = 0.5$.

Dynamic regimes: inner equilibrium

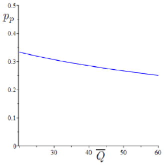


Coexistence between firms

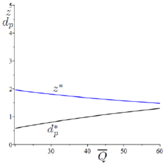
Numerical simulations: changes in emissions cap



(a) Share of firms that relocate abroad.

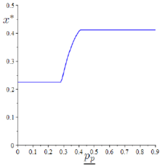


(b) Permits price.



(c) Abatement activities and permits demand

Numerical simulations: changes in floor price



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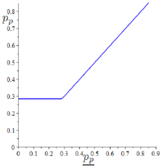
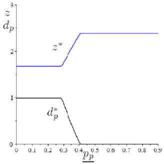
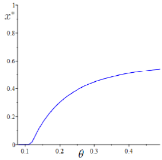


(b) Permits price



(c) Abatement activities and permits demand

Numerical simulations: changes in the marginal abatement



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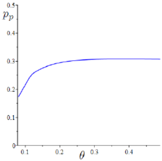
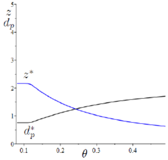
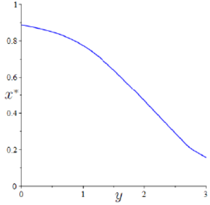


(b) Permits price

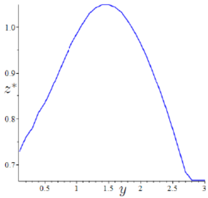


(c) Abatement activities and permits demand

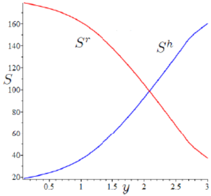
Numerical simulations: changes in free permits



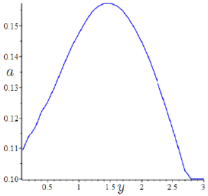
(a) Share of firms that relocate abroad.



(b) Individual firm's abatement.



(c) Total output production (blue= at home, red=abroad).



(d) Permits' price.

Conclusions

- Simple dynamic evolutionary model that can describe the dual choice (leave/remain) in a population of ETS-regulated firms.
- Differently from previous evolutionary models: 1) free permits 2) different costs at home vs abroad 3) firms' abatement decision
- Preliminary results show the existence of: (i) extreme equilibria (everybody leaves/remains) and (ii) a coexistence equilibrium, depending on the number of free permits.
- Imitative behaviors may lead to heterogeneous and non-linear effects of the policy parameters (smooth vs steep changes in the dependent variables)
- Next step: what if the ETS design depends on the pollution dynamics?

THANKS!