Time-consistent carbon pricing

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Motivation

- Profitability of low-carbon investments is determined by climate policy
- Climate policy is prone to time inconsistency and credibility problems
  - multiple objectives in the policy agendas and political alternation
    $\rightarrow$ *motivation* for ex-post reneging on ex-ante commitment
  - irreversibility and specificity of low-carbon investments
    $\rightarrow$ *scope* for ex-post reneging on ex-ante commitment
- This paper
  - shows the time-inconsistency problem in a simple model of carbon pricing
  - shows that reputational forces can bring some improvement
  - investigates whether complementing the price with additional policies can futher improve on the problem (short run vs long run) *[very preliminary]*

Literature

- Time-inconsistency and credibility issues
  - monetary policy (Barro 1983, Kydland and Prescott 1977)
  - climate policy
    - time-inconsistent carbon taxes (Marsiliani and Renstrom 2000, Helm et al. 2003, 2004, Abrego and Perroni 2002)
    - time-inconsistent carbon pricing (Laffont and Tirole 1996)
    - Solutions: tax earmarking, delegation to an independent environmental agency, investment subsidies, procurement
- Repeated regulation relationships (Salant and Woroch 1992, Gilbert and Newbery 1994, Martimort 2006)

Model. Setting

- Demand of a polluting good (e.g., steel, energy) $Q(p)$, $Q' < 0$
- p carbon price "set" by the government
- There is a single firm producing the good at no cost and meeting all demand
- Production of the good produces emissions $E = eQ(p)$, $e > 0$
- Emissions can be reduced if the firm invests in a cleaner technology: $e(Q(p) - x)$
- Investing x implies cost $C(x) = c\frac{x^2}{2}$, $c > 0$ and revenues $xpQ(p)$
- Symmetric information and risk-neutrality

Model. Timing

- t=0 Government announces a carbon price
- t=1 Firm makes investment decision
- t=2 Government implements the price and demand realizes
  - Government Nash leader, firm Nash follower

- Government:

$$W = \int_{p}^{\overline{p}} Q(z)dz - e[Q(p) - x(p)] \tag{1}$$

- Firm:

$$\Pi = (1 + x)pQ(p) - c\frac{x^2}{2} \tag{2}$$

Committment benchmark

- Problem of the government:

$$\max_p \int_p^{\overline{p}} Q(z)dz - e[Q(p) - x(p)] \tag{3}$$

where: $x(p) = \frac{pQ(p)}{c}$

- First-best solution is implemented

$$p^{FB}: \quad Q(p) = \frac{e}{c}[Q(p) + pQ'(p)] - eQ'(p) \tag{4}$$

$$x^{FB} = \frac{p^{FB}Q(p^{FB})}{c} \tag{5}$$

No committment

- Problem of the government

$$\max_p \int_p^{\overline{p}} Q(z)dz - e[Q(p) - x] \tag{6}$$

- Solution: $p^* = 0 \rightarrow x^* = x(p^*) = 0$
- Value functions

$$W(p^*, x^*) = \int_0^{\overline{p}} Q(z)dz - eQ(0) \tag{7}$$

$$\Pi(p^*, x^*) = 0 \tag{8}$$

- Static pricing game is repeated for infinite periods
- No dynamics: demand and investment are unchanging over periods
- Government and firm have the same discount factor $\delta \in [0, 1]$
- Can a more cooperative outcome ($p > p^*$, $x > x^*$) can be sustained as a trigger strategies SPE?
- Trigger strategies:
  - If the government deviates from announced p at any date, the firm will not invest anymore at any future date
  - If the firm deviates from investing x at any date, the government will implement a 0 price at any future date

No-deviation conditions

- Government

$$\sum_{t=0}^{\infty} \delta^t \left[\int_p^{\overline{p}} Q(z)dz - e[Q(p) - x] \right] \geq$$
$$\int_0^{\overline{p}} Q(z)dz - e[Q(0) - x] + \sum_{t=1}^{\infty} \delta^t \left[\int_0^{\overline{p}} Q(z)dz - eQ(p) \right] \tag{9}$$

$$\delta xe \geq \int_0^{p} Q(z)d(z) - [Q(0) - Q(p)]e \tag{10}$$

- Firm

$$(1+x)pQ(p) - c\frac{x^2}{2} \geq 0 \tag{11}$$

Solutions of the repeated pricing game

- If $\delta \to 1$, the first-best solution can be implemented

$$p^{FB}: \quad \frac{e}{c} = Q(p) + eQ'(p)Q(p) + pQ'(p) \tag{12}$$

- For lower values of δ, government's incentive constraint is binding

$$p^{SB}: \quad \frac{e\delta}{c} = Q(p) + eQ'(p)Q(p) + pQ'(p) \tag{13}$$

- Since RHS of (12) and(13) is increasing in p, $p^{SB} < p^{FB} \to x^{SB} < x^{FB}$
- Intuition: lowering the price spreads the benefit from investment, increasing the opportunity cost from forgoing the relationship

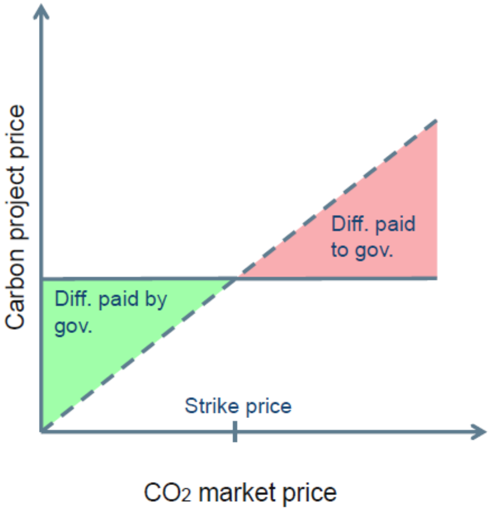
Role of additional policies

- Idea: policies that lower the gain from short term deviation
  - improvement for the short term: $p^*_{AP} > p^* = 0$, $x^*_{AP} > x^* = 0$
  - improvement for the long term: $p^{FB} > p_{AP} > p^{SB}$, $x^{FB} > x_{AP} > x^{SB}$
- Policies under consideration
  - project-based carbon contracts
  - public co-funding of investment

Project-based carbon contracts

- At the design stage in the EU for industry. Some experience in UK for the power sector
- Government and firm sign a contract where the firm is guaranteed a carbon price p_G for a share k of investment
- Implementation option as a contract for differences:
  - if $p < p_G$, government pays $(p_G - p)kx$ to the firm
  - if $p > p_G$, firm pays $(p - p_G)kx$ to the government
- Objective functions:
  - $W_{cc} = \int_p^{\overline{p}} Q(z)dz - e[Q(p) - x] - (p_G - p)kx$
  - $\Pi_{cc} = (1 + x)pQ(p) + (p_G - p)kx - c\frac{x^2}{2}$

Project-based carbon contracts as contract for differences



Project-based carbon contracts (cont'd)

- Timing

  - t=0 Government announces a carbon price and signs a binding carbon contract with the firm (p_G)
  - t=1 Firm makes investment decision
  - t=2 Government implements the carbon price and payments are made

- Firm's reaction function $x(p, p_G) = \frac{pQ(p)+k(p_G-p)}{c}$
- NE of static game: $p^*_{CC} > 0$, $x^*_{CC} > 0$

Conclusion

- Time-inconsistency of carbon pricing deters investments in low-carbon technologies
- Reputation effects can bring some improvement
- Complementing the carbon price with other policies can bring further improvement
- Next steps and possible extensions
  - Public co-funding of investment
  - Dynamics
  - Technology frontier
  - Competition effects
  - Incomplete information
  - Risk-aversion of the firm