Optimal Environmental Taxes and Information Sharing under Private and Public Information Regimes

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Introduction

- Today, environmental protection is a priority and a challenge for public authorities. The improvement of environmental quality is placed high on public representatives' agendas.
- With the onset of Global Warming, policy makers are often confronted with the dual tasks of choosing environmental goals and selecting policy instruments to achieve those goals.
- Environmental policy is a major device in tackling environmental challenges and shaping industries' use of environmental and natural resources.
- The design of environmental taxation aims to accomplish deep and structural changes in the economic and ecological behavior of agents.

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Introduction

- Environmental taxation is often used for:
  - Correcting externalities (cleaning polluted activities),
  - Financing public goods (developing of renewable energies),
  - Providing good incentives to polluters (reducing emissions and adopting green technologies),
  - Raising governmental revenues, etc.
- Therefore, the proper design of environmental taxation depends on different variables and informational distortions.

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Introduction

Since Weitzman's classic analysis "Prices vs. Quantities" (RESTUD, 1974) was developed, there has been a growing interest in the analysis of emissions taxes under strategic behavior and asymmetric information.

- Oligopoly Markets: Bárcena-Ruiz and Garzón (2006), Yin (2003), Carlsson (2000), Katsoulacos and Xepapadeas (1995), Simpson (1995), Kim and Chang (1993), Levin (1985).
- Entry: Espínola-Arredondo and Muõz-García (2012, JEEM)
- Technological change: Antelo and Loureiro (2009)
- Inefficiencies: Shrestha (2001), Xepapadeas (1991), Segerson (1988), Farrel (1987), Roberts and Spence (1976).

If such *ex ante* assumptions turn out to be wrong, the designed emissions tax may turn out to be even worse than the one that completely ignores the presence of costs uncertainties.

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Introduction

In this paper we consider:

1. a Stackelberg-Cournot setting which implies that the regulatory decision, once made, remains in force for an extended period of time while rivals respond in the marketplace,
2. the situation in which the regulator designs environmental taxes based on the presence of public and private information without specifying the nature of the probability distributions of costs uncertainties,
3. the impact of policy commitment on information transmission by allowing firms to share information.

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Road Map

- Introduction
- The model
  - * Firms and the Regulator
  - * The game
- The optimal environmental policy:
  - * No Information Sharing Case
  - * Information Sharing Case
- Conclusion and extensions

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Market

- A single polluting industry
- Two firms are producing in a Cournot duopoly market
- They are facing the following inverse demand function:

$$p = \alpha - \beta Q = \alpha - \beta \left(q_1 + q_2\right), \alpha, \beta \geq 0$$

- On the supply side, the technology used by each firm is stochastic but it exhibits constant returns to scale.

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Emissions and Environmental Damage

- Emissions depend on the technology of production used by each firm:

$$e_i = \phi q_i, \text{ with } 0 < \phi < 1 \text{ for any } i \in I = \{1, 2\}.$$

- Environmental damages, D, generated by the production activity is:

$$D = \frac{1}{2}\,\delta\,\xi^2 > 0$$

where $\xi = \sum_{i=1}^{2} e_i(q_i)$ represents the aggregate level of emissions; δ represents the degree of convexity of damage function.

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Information Structure

- Marginal production and abatement cost is constant and equals to:

$$\widetilde{x}_i = \widetilde{u}_i + \widetilde{c}_i.$$

  * $\widetilde{u}_i$ is the public cost component, observed by all players:

$$\forall i = 1, 2,\ \widetilde{u}_i \sim \text{iid } \left(\mu_{u_i}, \sigma^2_{u_i}\right).$$

  * $\widetilde{c}_i$ is the private cost component, known only to firm i:

$$\widetilde{c}_i = \widetilde{s} + \widetilde{\varepsilon}_i$$

  * $\widetilde{s}$ is a common cost component, observed by firms but not the regulator:

$$\widetilde{s} \sim \left(\mu_c, \sigma^2_c\right).$$

  * $\widetilde{\varepsilon}_i$ is a noise term:

$$\forall i \in I, \mathbb{E}\left(\varepsilon_i\right) = 0, \text{ and } \mathbb{E}\left(\varepsilon_i^2\right) = \sigma^2_\varepsilon.$$

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Information Structure

Assumption: Ericson (1969) $\forall i, j = 1, 2, i \neq j; \mathbb{E}[\tilde{c}_i|\tilde{c}_j]$ is linear in $\tilde{c}_j$

$$\mathbb{E}[\tilde{c}_i|\tilde{c}_j] = \gamma\tilde{c}_j + \lambda, \text{ where } \gamma = \frac{\sigma_c^2}{(\sigma_c^2 + \sigma_\varepsilon^2)} \text{ and } \lambda = (1-\gamma)\,\mu_c$$

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Timing

1. $\{\widetilde{u}_i\}_{i \in I}$ are drawn randomly and observed by all players.
2. The risk neutral regulator sets the environmental taxes $\{\tau_i\}_{i \in I}$ optimally to maximize the expected welfare.
3. $\{\widetilde{s}\}$ is drawn randomly and observed by both firms, but not by the regulator.
4. $\{\widetilde{\varepsilon}_i\}_{i \in I}$ is drawn randomly and observed by each firm, but not by the regulator or the other firm.
5. Each risk neutral firm determines its output and emission abatement levels, given their information set.

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Firms Problem

- Firm i knows the public and common cost components as well as its own private cost.
- Given the tax rates, firms maximize their own profits:

$$\max_{\widetilde{q}_i} \ \mathbb{E}_{\widetilde{c}_j} \ \left[(\widetilde{p} - \widetilde{u}_i - \widetilde{c}_i - \phi \ \tau_i) \ \ \widetilde{q}_i \mid \widetilde{c}_i, \widetilde{u}_i, \widetilde{u}_j \right]; \ \forall i, j = 1, 2, i \neq j$$

- **Assumption:** The quantities produced by each firm are linear:

$$\begin{aligned} \widetilde{q}_i =& \theta_{i1} + \theta_{i2} \ \widetilde{c}_i + \theta_{i3} \ \widetilde{u}_i + \theta_{i4} \ \widetilde{u}_j; \ \forall i, j \in I, \ i \neq j \\ \theta_{i1} =& \rho_{i0} + \rho_{i1} \ \tau_i + \rho_{i2} \ \tau_j . \end{aligned}$$

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Regulator's Problem

- The regulator only observes the public component, and has prior beliefs on the other cost components.
- The regulator sets an environmental tax in order to maximize the expected social welfare function given by

$$\mathbb{E}W = \mathbb{E}\left(CS - D\right) + \sum_{i=1}^{2} \mathbb{E}\pi_i + \ell \; \mathbb{E}R$$

  * CS: consumer surplus,
  * D: environmental damage,
  * R: revenue.

- **Assumption:** We assume that the parameter $\ell' = (\ell - 1)$ is strictly positive. It represents the indirect social benefit of environmental taxation.

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Equilibrium under Full Information

- Suppose there is no uncertainty: all agents can observe all marginal production and abatement costs.
- **Proposition:** Optimal taxes are:

$$\tau_i^F = \frac{\alpha\,(2\omega + \ell' - 1)}{2\phi\,(\ell' + \omega)} - \frac{\omega\ (\ell' + 1)\ (x_1 + x_2)}{4\phi\ \ell'\,(\ell' + \omega)} + \frac{x_i(1 - \ell')}{2\phi\ell'};\ \forall i = 1, 2,$$

where $\omega = \left(\frac{1}{3} + \frac{\delta\phi^2}{3\beta}\right)$.

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Equilibrium under Asymmetric Information

- **Assumption:** The quantities produced by each firm are linear:

$$\begin{aligned}\widetilde{q}_i =& \theta_{i1} + \theta_{i2}\ \widetilde{c}_i + \theta_{i3}\ \widetilde{u}_i + \theta_{i4}\ \widetilde{u}_j;\ \forall i, j \in I,\ i \neq j \\ \theta_{i1} =& \rho_{i0} + \rho_{i1}\ \tau_i + \rho_{i2}\ \tau_j.\end{aligned}$$

- **Lemma** Under asymmetric information, the parameter vector θ is given by:

$$\begin{aligned}\theta_{i1} &= \frac{\alpha + \phi\left(\tau_j - 2\tau_i\right)}{3\beta} + \frac{\lambda}{3\beta\left(2+\gamma\right)}; \forall i, j = 1, 2, i \neq j \\ \theta_{12} &= \theta_{22} = -\frac{1}{\beta\left(2+\gamma\right)} \\ \theta_{13} &= \theta_{23} = -\frac{2}{3\beta} \\ \theta_{14} &= \theta_{24} = \frac{1}{3\beta}.\end{aligned}$$

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Equilibrium under Asymmetric Information

- Substituting the expressions of θ into the expressions defining the quantities yields for $i, j = 1, 2, i \neq j$:

$$\tilde{q}_i = \frac{\alpha + \phi\left(\tau_j - 2\tau_i\right)}{3\beta} + \frac{\lambda}{3\beta\left(2+\gamma\right)} - \frac{\tilde{c}_i}{\beta\left(2+\gamma\right)} - \frac{2\widetilde{u}_i}{3\beta} + \frac{\widetilde{u}_j}{3\beta}$$

- and the market price:

$$\widetilde{p} = \frac{\alpha + \phi\left(\tau_1 + \tau_2\right)}{3} - \frac{2\lambda}{3\left(2+\gamma\right)} + \frac{\widetilde{u}_1 + \widetilde{u}_2}{3} + \frac{\tilde{c}_1 + \tilde{c}_2}{\left(2+\gamma\right)}$$

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Equilibrium under Asymmetric Information

- **Proposition** In a public and private information regimes, under linear conditional expectation properties, a risk neutral regulator sets the following tax rules:

$$\tau_i^* = \frac{(\alpha - \mu_c)\ (2\omega + \ell' - 1)}{2\phi(\ell' + \omega)} - \frac{(\widetilde{u}_1 + \widetilde{u}_2)}{4\phi}\ \frac{(\ell' + 1)\ \omega}{\ell'\ (\ell' + \omega)} + \frac{\widetilde{u}_i}{2\phi}\ \frac{(1 - \ell')}{\ell'};\ \forall i = 1, 2.$$

- The difference $\Delta\tau_i = \tau_i^F - \tau_i^*$ is positive if:

$$c_i > \frac{\omega c_j(\ell' + 1) + 2\ell' \mu_c(2\omega + \ell' - 1)}{\omega(1 - 3\ell') + 2\ell'(1 - \ell')}$$

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The Optimal Tax Rule

- The difference between the tax rates for the two firms:

$$\tau_1^* - \tau_2^* = \frac{\widetilde{u}_1 - \widetilde{u}_2}{2\phi} \frac{(1-\ell')}{\ell'}$$

- **Proposition** Suppose that $\omega < 1$, which implies that the steepness of marginal damages satisfies $\delta \leq \frac{2\beta}{\phi^2}$.
  * For the firm with the lower public cost (i.e. $\widetilde{u}_i \leq \widetilde{u}_j,\ i \neq j$), the tax rate is increasing in ℓ'.
  * Furthermore, for the firm with the higher public cost, the tax rate is decreasing in ℓ' only if:

$$f = \frac{\widetilde{u}_j - \widetilde{u}_i}{\alpha - \mu_c - \widetilde{u}_j} \geq \frac{2\ (1-\omega)\ (\ell')^2}{\omega\ \ (\omega + (\ell')^2 + 2\ell')};\ \text{where } \widetilde{u}_j \geq \widetilde{u}_i,\ j \neq i.$$

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The Information Sharing Case

- Do firms have the incentive to share information about their marginal costs in a strategic environmental policy setting?
- Suppose that some mechanism exists for firms to truthfully share information on their private costs, while the regulator still remains uninformed about the private costs.

The Information Sharing Case

- **Proposition** When the regulator sets up emissions taxes to deal with pollution under asymmetric information about costs, if firms share information about their costs, then the optimal tax rules do not change.

- **Proposition** Under emissions taxes, sharing information may occur and is mutually beneficial to firms when private marginal costs are high and the cost differential between the two firms is small. In equilibrium, sharing information yields higher output level and entails an increase in emissions.

$$\begin{cases} c_j \geq \frac{c_i(1+2\gamma)}{(2+\gamma)} + \frac{\mu_c(1-\gamma)}{(2+\gamma)} \\ c_i \geq \frac{c_j(1+2\gamma)}{(2+\gamma)} + \frac{\mu_c(1-\gamma)}{(2+\gamma)} \end{cases} \Rightarrow \begin{cases} q_j^S \geq q_j^{NS} \\ q_i^S \geq q_i^{NS} \end{cases}$$

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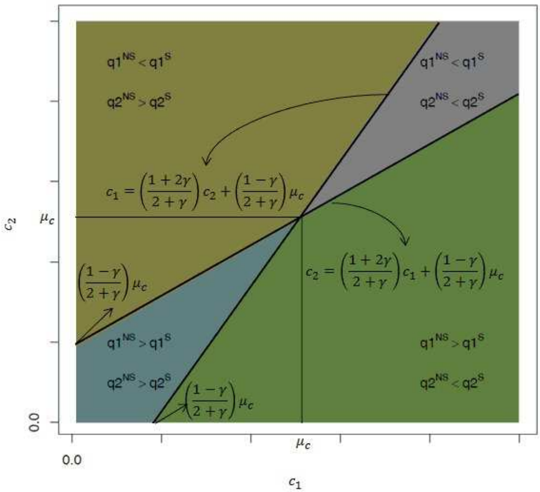
Information Sharing



Conclusion

- We analyzed the impact of public and private information about production and abatement costs on the efficiency of emission taxes design.
- Facing private costs only, the regulator cannot distinguish the players in the marketplace. The regulator sets a common tax rule.
- Facing private and publicly-disclosed information about marginal production and abatement costs, the regulator sets firms specific environmental taxes.
- Sharing information may be mutually beneficial to firms if both firms have high marginal costs and the cost differential between firms is small.

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Conclusion

- Technological Change:
  - * What happens if one of the firms comes clean?!
  - * Already done the preliminary analysis for the case where new tech is completely clean...
- Endogenous Entry: Espínola-Arredondo and Muõz-García (2012, JEEM)
  - * Two firms: an incumbent and a new entrant.
  - * The regulator knows the incumbent very well, but does not know the type of the entrant.
  - * The entrant can be a high-cost or low-cost firm (Binomial distribution).
  - * Propose to extend the information structure: Angeletos and Pavan (2007, ECMA).
  - * Propose to allow multiple firms entering the market.