

# **Optimal environmental policies in a heterogeneous product market under research and development competition and cooperation**

By

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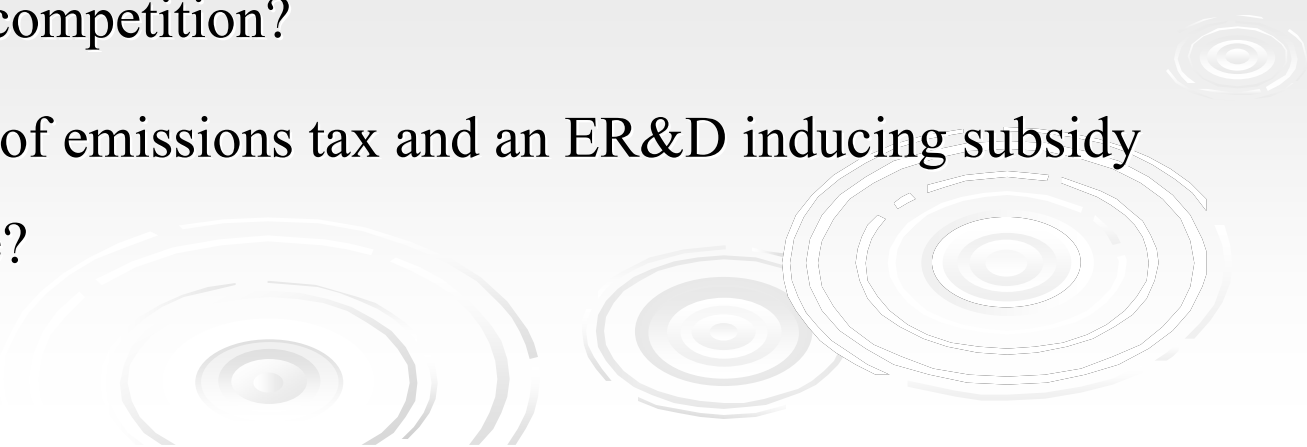
The background features several sets of concentric circles in shades of yellow and green, resembling ripples in water, positioned at the bottom of the slide.

## Introduction

- Pollution externality requires environmental policies
- Firms respond to environmental policies by either:
  - Reducing output or Increasing pollution abatement
- Some policies may not induce Environmental Research and Development (ER&D) => the need for a technology (specific) inducing instrument
- Pigouvian tax => Optimal Tax = Marginal Damage (MD) holds under perfect competition and full information
- Under imperfect competition => Tax < MD
  - output under production due to market power and
  - output over production due to pollution

- Adapt from R&D literature: D'Aspremont and Jacquemin (1988), Kamien, Muller and Zang (1992), Katsoulacos and Xepapadeas (1996a)

This paper attempts to answer the following questions:

- If there is an existing emissions tax in place and there is constant MD from pollution, how should the regulator subsidize ER&D under both ER&D arrangements?
  - Under what circumstances should the regulator encourage ER&D cooperation and competition?
  - Is a combination of emissions tax and an ER&D inducing subsidy socially desirable?
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## Model

- 2 firms producing differentiated products, facing an inverse demand function  $p_i = \alpha - q_i - \gamma q_j$  where  $i \neq j$ ,  $\alpha > 0$  and  $0 \leq \gamma \leq 1$ .
- As  $\gamma \rightarrow 1 \Rightarrow$  goods become very similar (homogeneous at  $\gamma = 1$ ) and as  $\gamma \rightarrow 0 \Rightarrow$  goods are perfectly differentiated (and independent).
- Emissions per unit of output is given by  $e_i = \beta - z_i - \lambda z_j$ , where  $i \neq j$ ,  $z_i \geq 0$  is firm  $i$ 's ER&D level,  $0 \leq \lambda \leq 1$  is the degree of technological knowledge spillover and the baseline emission intensity  $\beta \geq z_i + \lambda z_j$ .

- ER&D expenditure  $R_i = \frac{\delta z_i^2}{2}$ , with  $\delta > 0$  and total cost  $C(q_i, z_i) = cq_i + \frac{\delta z_i^2}{2}$ .

- Firm  $i$  in the final stage chooses its quantity to maximize profit

$$\pi_i = (\alpha - q_i - \gamma q_j)q_i - \tau e_i q_i - cq_i - (1-s) \frac{\delta z_i^2}{2}$$

### 3.1. Under competitive ER&D symmetric equilibrium ER&D is:

$$z_e = \frac{2\tau(\alpha - c - \tau\beta)(2 - \gamma\lambda)}{\delta(2 + \gamma)^2(1 - s)(2 - \gamma) - 2\tau^2(1 + \lambda)(2 - \gamma\lambda)}$$

where  $\alpha - c - \tau\beta > 0$  and  $\delta(2 + \gamma)^2(1 - s)(2 - \gamma) - 2\tau^2(1 + \lambda)(2 - \gamma\lambda) > 0$

$$\tau = 0 \Rightarrow z_e = 0. \frac{\delta z_e}{\delta s} > 0 \text{ only if } \tau > 0, \text{ and } \frac{\delta z_e}{\delta \tau} > 0$$

$$q_e = \frac{\alpha - c - \tau\beta + (1 + \lambda)\tau z_e}{(2 + \gamma)}, \quad p_e = \alpha - (1 + \gamma)q_e \quad \text{and} \quad e_e = \beta - (1 + \lambda)z_e$$

$$\frac{dz_e}{ds} > 0 \text{ for } \tau > 0 \Rightarrow \frac{\delta q_e}{\delta s} > 0 \text{ and } \frac{dq_e}{d\tau} < 0. \quad \frac{de_e}{ds} < 0 \text{ and } \frac{de_e}{d\tau} < 0$$

- In the first stage, the regulator chooses the tax and subsidy rates to maximize

$$\text{social welfare } W_e(\tau, s) = 2\alpha q_e - (1 + \gamma)q_e^2 - 2cq_e - \delta z_e^2 - D(2e_e q_e)$$

Using the first order conditions of the welfare maximization combined with the firm's first order conditions and after some manipulations we get:

- Optimal competitive ER&D tax  $\Rightarrow \tau^* = D' - (q_e/e_e)$

- Optimal competitive ER&D subsidy  $\Rightarrow s^* = 1 - \frac{\tau^*}{D'} \frac{2}{(4 - \gamma^2)} \frac{(2 - \lambda\gamma)}{(1 + \lambda)}$

**3.2. Cooperative ER&D** leads to full information sharing  $\Rightarrow e_i = \beta - z_i - z_j$ .

- Firms jointly choose  $z_i$  and  $z_j$  to maximize second stage joint profit

$\Pi = q_i^2 + q_j^2 - (1 - s) \frac{\delta}{2} z_i^2 - (1 - s) \frac{\delta}{2} z_j^2$  which gives symmetric equilibrium cooperative

ER&D as:  $z_c = \frac{2t(\alpha - c - t\beta)}{\delta(1 - \rho)(2 + \gamma)^2 - 4t^2}$ ,  $\alpha - c - t\beta > 0$ , and  $\delta(1 - s)(2 + \gamma)^2 - 4t^2 > 0$

$q_c = \frac{1}{2 + \gamma} [\alpha - c - t\beta + 2tz_c]$ ,  $p_c = \alpha - (1 + \gamma)q_c$  and  $e_c = \beta - 2z_c$

- Optimal cooperative ER&D tax  $\Rightarrow t^* = D' - (q_c/e_c)$

- Optimal cooperative ER&D subsidy  $\Rightarrow \rho^* = 1 - \frac{t^*}{D'} \frac{1}{(2 + \gamma)}$

**Proposition 1:** *If  $\tau = t$ , for any  $\gamma \in (0,1)$ , constant marginal damage  $D' = d$ , and sufficiently low spillover  $\lambda$ ,  $\rho^* > s^*$ . Also, when  $\lambda$  is high enough and  $\gamma$  is sufficiently low,  $\rho^* > s^*$  while for sufficiently high  $\lambda$  and  $\gamma$ ,  $\rho^* < s^*$ .*

**Corollary 1:** *If  $\tau = t$ , for  $\gamma = 1$  with constant marginal damage  $D' = d$ , for  $\lambda = 0.6$ ,  $s^* = \rho^*$ , for  $0 < \lambda < 0.6$ ,  $s^* < \rho^*$  and for  $0.6 < \lambda < 1$ ,  $s^* > \rho^*$ .*

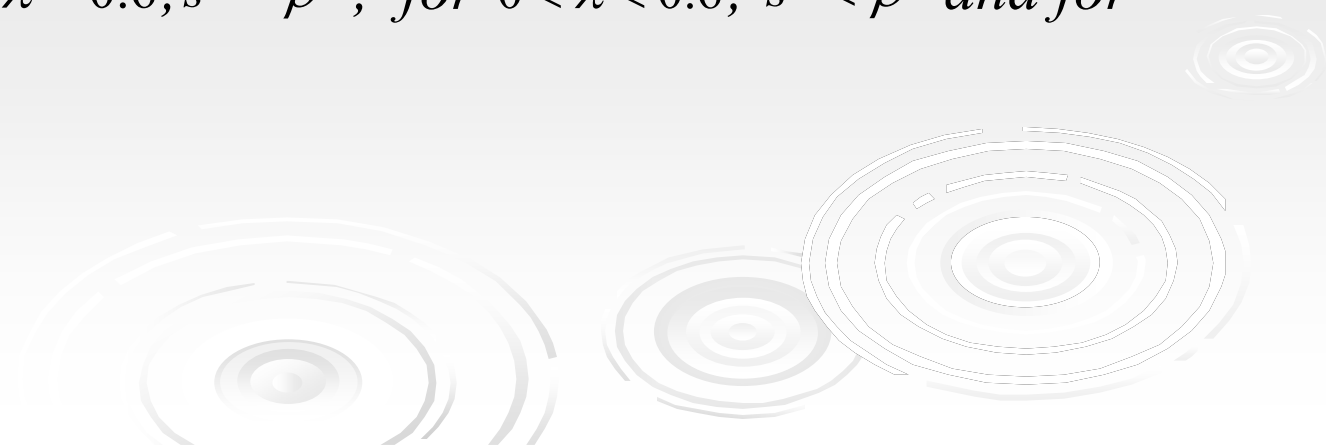


Figure 1: Optimal Tax Plot

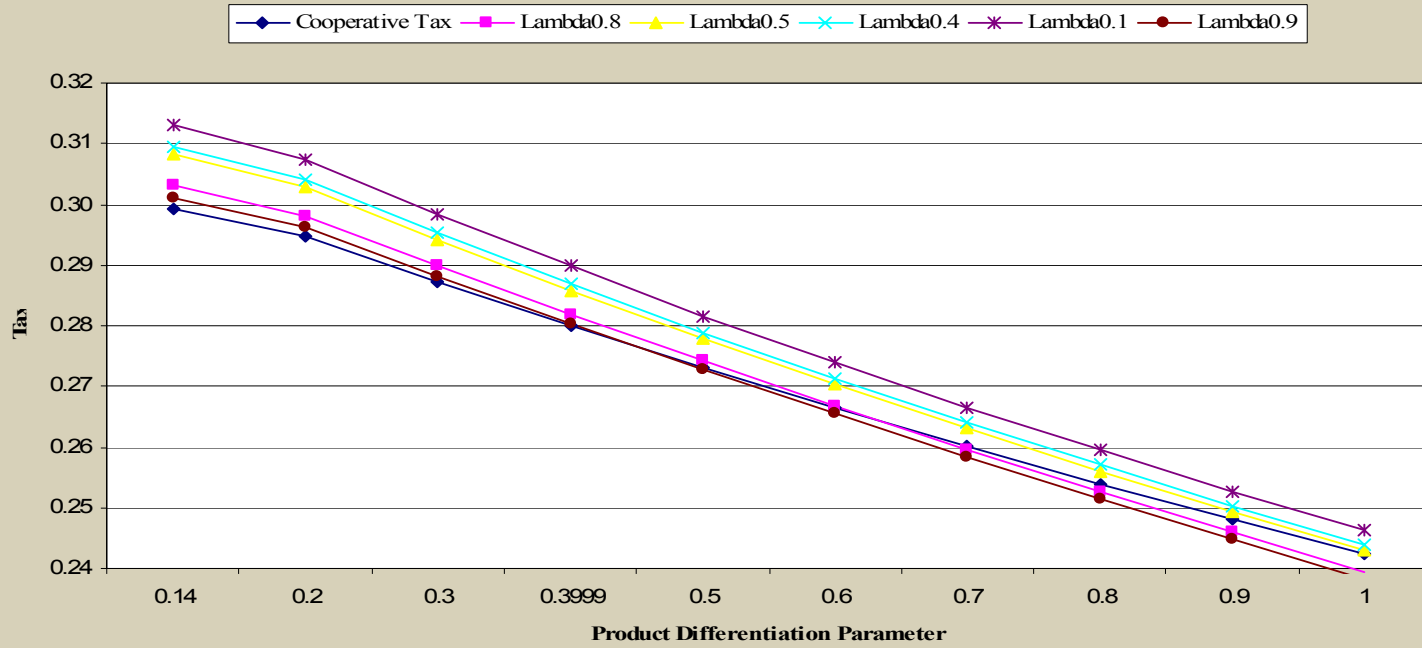
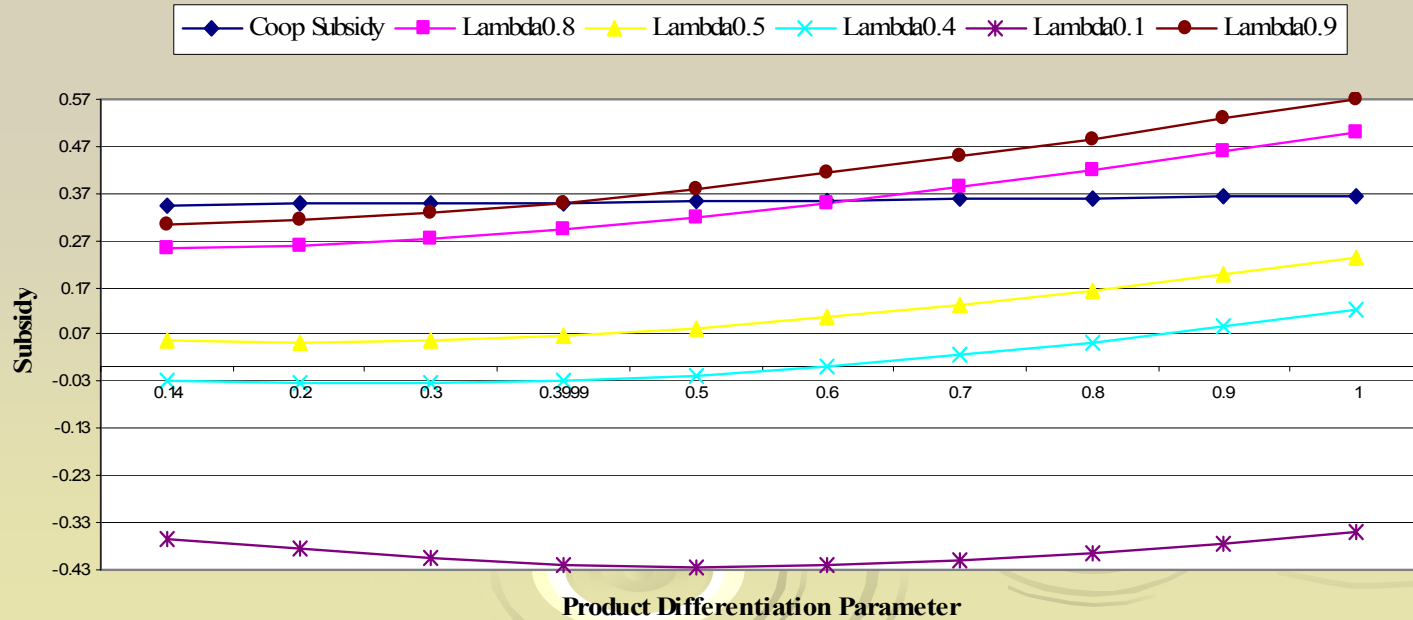


Figure 2: Optimal Subsidy Plot

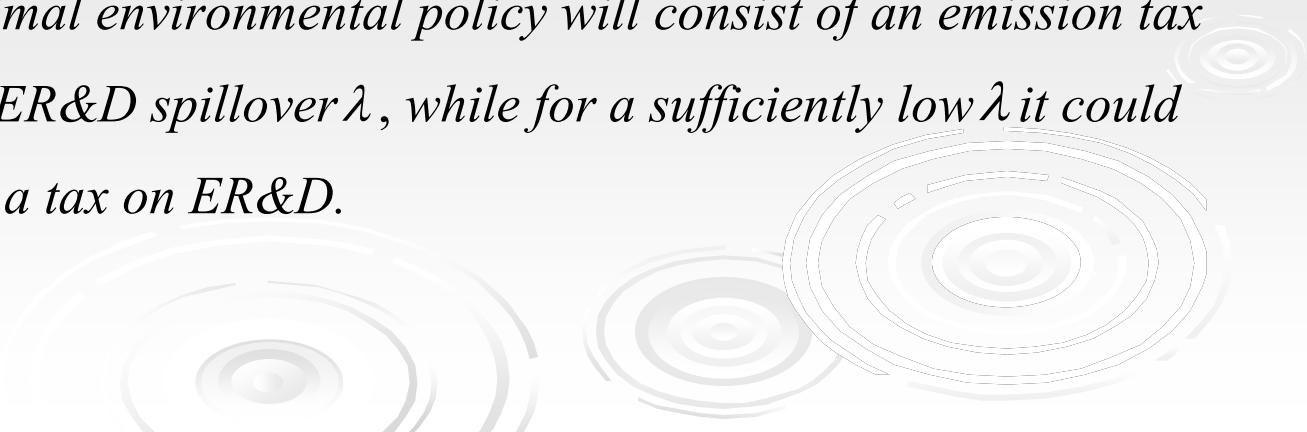


The numerical simulations give the following results:

(i) For  $0 < \gamma < 0.3999$  and  $\lambda \in (0,1)$ ,  $\tau^* > t^*$ , while  $s^* < \rho^*$

(ii) For  $0.3999 \leq \gamma \leq 1$ , and low spillovers  $\lambda$ ,  $\tau^* > t^*$ , while  $s^* < \rho^*$  while for sufficiently high spillovers  $\tau^* < t^*$  and  $s^* > \rho^*$ .

**Proposition 2:** For any  $\gamma \in (0,1)$ , optimal environmental policy under cooperative ER&D is a combination of emission tax and subsidy, while under competitive ER&D optimal environmental policy will consist of an emission tax and subsidy for a high ER&D spillover  $\lambda$ , while for a sufficiently low  $\lambda$  it could be an emission tax and a tax on ER&D.



## Conclusion

- Coordination in ER&D is not always socially desirable.
- ER&D cooperation is socially desirable when
  - (i) Products are highly differentiated and
  - (ii) Products are less differentiated and spillover effects are small
- Competitive ER&D will be socially desirable when products are less differentiated and there is high spillover effect.
- Depending on the perceived level of product differentiation in an industry, regulator monitoring and inspection are necessary to ensure technological spillovers exist. Based on this, a regulator should encourage the appropriate ER&D arrangement by imposing on the industry lower emissions tax coupled with high subsidy.
- A combination of an emissions tax and ER&D subsidy is socially desirable.