Payment for environmental services and pollution tax under imperfect competition

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Motivation of the paper

- Environmental services $\Rightarrow$ Positive externalities
- Payment for Environmental Services (PES) can increase these positive externalities
    - Voluntary transaction
    - Conditionality
- Different forms of PES
    - Without public intervention (Coasean) PES (the Vittel PES)
    - With public intervention: a subsidy. Ex: Paris and farmers
- Different domains: carbon sequestration, biodiversity protection, watershed protection, and landscape beauty.

- In the agricultural sector, we can observe two problems:
  - negative externality (pollution)
  - positive externality (grass strip)
- Negative externalities: literature is well established (Barnett, 1980; Ebert 1991; David and Sinclair Desgagné, 2004)

We know the level of the Pigouvian tax under imperfect competition in several situations

- But what about PES?

⇒ It is the aim of this paper

- Lankoski & Ollikainen (2003) define the optimal level of a PES and a tax with different land qualities but perfect competition
- We want to investigate the optimal PES design under imperfect competition

The structure of this paper is the following:

1. The model
2. The second-best policy without marginal social cost of public funds
3. The second-best policy with marginal social cost of public funds
4. Concluding remarks

Assumptions (1/2)

- We consider $n \geqslant 2$ identical farmers i
- T_i is his total area of land with $T_i = x_{1i} + x_{2i} + y_i$ where:
  - x_{1i} : quantity of conventional agriculture production
    - Competitive market
    - Causes increasing environmental damages, $D(X_1)$, with $D'(X_1) > 0$, $D''(X_1) > 0$
  - x_{2i} : quantity of organic agriculture production
    - Oligopoly
    - Neutral impact on environment
  - y_i : grass strip
    - Produces environmental benefits, $B(y)$, with $B'(y) > 0$, $B''(y) < 0$

Assumptions (2/2)

- Demand is linear in both markets
  - Conventional agriculture demand is represented by the function $p_1(X_1)$, and p_1 is the competitive price
  - Organic agriculture demand is represented by $p_2(X_2)$, and p_2 is the oligopolistic price
- Production costs are increasing and convex with $c_1(x_{1i}) < c_2(x_{2i})$, $c_1'''(x_{1i}) = 0$ and $c_2'''(x_{2i}) = 0, \forall i = 1, ..., n$
- Distortionary taxation: ϵ is the marginal social cost of public funds.

The laissez-faire

Farmer i maximizes his profit by choosing x_{1i} and x_{2i}:

$$\Pi_i(x_{1i}, x_{2i}) = p_1 x_{1i} + p_2(X_2)x_{2i} - c_1(x_{1i}) - c_2(x_{2i}) + \lambda(T_i - x_{1i} - x_{2i})$$

The FOCs are:

$$p_1 - c_1'(x_{1i}) - \lambda = 0$$

$$p_2'(X_2)x_{2i} + p_2 - c_2'(x_{2i}) - \lambda = 0$$

$$\lambda(T_i - x_{1i} - x_{2i}) = 0$$

- Two cases depending on the market structure and production costs: $\lambda > 0$ and $Y = 0$ or $\lambda = 0$ and $Y > 0$.
- In both cases, market power reduces the production of organic agriculture

$\Rightarrow$ This farmer does not consider the environmental damages and environmental benefit

The farmer's behavior with Pigouvian tax and PES

With a tax and a subsidy, the profit for farmer i becomes:

$$\begin{aligned}\Pi_i(x_{1i}, x_{2i}) &= p_1 x_{1i} + p_2(X_2)x_{2i} - c_1(x_{1i}) - c_2(x_{2i}) + \lambda(T_i - x_{1i} - x_{2i}) \\ &\quad - t x_{1i} + s(T_i - x_{1i} - x_{2i})\end{aligned}$$

The FOCs are:

$$p_1 - c_1'(x_{1i}) - t - s - \lambda = 0 \ \forall t, s \tag{1}$$

$$p_2' x_{2i} + p_2 - c_2'(x_{2i}) - s - \lambda = 0 \ \forall t, s \tag{2}$$

$$\lambda(T_i - x_{1i} - x_{2i}) = 0 \tag{3}$$

We have two cases, $\lambda = 0$ with $Y > 0$ and $\lambda > 0$ with $Y = 0$.
Calculations showing how X_1 and X_2 change with t and s can be found in the Appendix

The second-best design of PES and Pigouvian tax

The unbounded case:
Taking into account $X_1(t,s)$ and $X_2(s)$, the social welfare function is:

$$W(s,t) = \int_0^{X_1(s,t)} p_1(u)du + \int_0^{X_2(s)} p_2(v)dv - nc_1(\frac{X_1(s,t)}{n}) - nc_2(\frac{X_2(s)}{n}) + B(T - X_1(s,t) - X_2(s)) - D(X_1(s,t))$$

The FOCs are:

$$\frac{\partial X_1}{\partial s}[p_1(X_1(s)) - c_1'(\frac{X_1(s,t)}{n}) - B_y - D'(X_1(s,t))] + \frac{\partial X_2}{\partial s}[p_2(X_2(s)) - c_2'(\frac{X_2(s)}{n}) - B_y] = 0$$

$$\frac{\partial X_1}{\partial s}[p_1(X_1(s)) - c_1'(\frac{X_1(s,t)}{n}) - B_y - D'(X_1(s,t))] = 0$$

The second-best levels of t and s

Using the welfare and profit FOCs we find:

$$s = B_y + p_2'(X_2)\frac{X_2}{n}$$

$$t = D'(X_1) - p_2'(X_2)\frac{X_2}{n}$$

$\Rightarrow$ The second-best PES depends on the marginal benefit, the market power and the number of firms, with:

$$s < B_y$$

$\Rightarrow$ The second-best Pigouvian tax depends on the marginal damage, the market power and the number of firms, with the unusual result:

$$t > D'(X_1)$$

The second-best design of PES and Pigouvian tax

For the bounded case, we substitute in $T - X_2(t) = X_1$ in the welfare function.
Using the same method as before, we find:

$$t = D'(X_1) - p_2'(X_2)\frac{X_2}{n}$$

$\Rightarrow$ The PES is non-incentivizing ($s = 0$)
$\Rightarrow$ The Pigouvian tax is similar to the previous case ($\lambda = 0$)
$\Rightarrow$ The regulator directly regulates environmental damages and indirectly regulates the market power on organic agriculture

Introducing distortionary taxation

- We add the social cost of public funds in our analysis
- When the regulator raises $\$1$, the society pays $\$(1+\epsilon)$,

with ϵ, the marginal social cost of public funds (MCF).

$\Rightarrow$ To what extent are the second-best designs of the Pigouvian tax and the PES impacted?

The unbounded case

The welfare becomes:

$$\begin{aligned} W(s,t) &= \int_0^{X_1(s,t)} p_1(u)du + \int_0^{X_2(s)} p_2(v)dv - nc_1(\frac{X_1(s,t)}{n}) \\ &-nc_2(\frac{X_2(s)}{n}) + B(T - X_1(s,t) - X_2(s)) - D(X_1(s,t)) \\ &+\epsilon t X_1(s,t) - \epsilon s(T - X_1(s,t) - X_2(s)) \end{aligned}$$

After solving, we find:

$$s = \frac{B_y + p_2'(X_2)\frac{X_2}{n}}{1+\epsilon} + \frac{\epsilon}{1+\epsilon}\frac{Y}{\frac{dX_2}{ds}} + \frac{\epsilon}{1+\epsilon}\frac{X_1}{\frac{dX_2}{ds}}$$

$$t = \frac{D'(X_1) - p_2'(X_2)\frac{X_2}{n}}{1+\epsilon} - \frac{\epsilon}{1+\epsilon}\frac{Y}{\frac{dX_2}{ds}} - \frac{\epsilon}{1+\epsilon}\frac{X_1}{(\frac{dX_2}{ds} + \frac{dX_1}{dt})}$$

$$s < B_y \text{ and } t > D'(X_1)$$

$\Rightarrow$ How do s and t change with the marginal social cost of public funds?

$$\begin{aligned}
\frac{\partial t}{\partial \epsilon} &> 0 \text{ if } e_{x_1/t} > -1 \text{ and } \frac{\frac{\partial x_1}{\partial s}}{\frac{\partial x_2}{\partial s}} > \Delta \\
&\Rightarrow \text{contributory component of the incentive tax} \\
\frac{\partial s}{\partial \epsilon} &< 0 \text{ if } e_{x_1/t} > -1
\end{aligned}$$

The bounded case

- Using $X_1 = T - X_2(t)$ in the welfare function, we find:

$$t = \frac{D'(X_1) - p_2'(X_2)\frac{X_2}{n}}{1+\epsilon} - \frac{\epsilon}{1+\epsilon}\frac{X_1}{\frac{dX_2}{dt}}$$

- The introduction of the MCF leads to different values of t for the two cases ($\lambda = 0$, $\lambda > 0$)
- We also find:

$$\frac{\partial t}{\partial \epsilon} > 0 \text{ if } e_{x_1/t} > -1$$

We used a very simple model :
- A farmer can choose to produce two types of crops (organic/conventional crop)
- The farmer is a price maker on the organic crop market and a price taker on the conventional crop market

The aim of this article was to set the optimal level of the PES (and the Pigouvian tax) under
- market failures (positive and negative externalities, market power) and
- marginal social cost of public funds

We obtain several results.

- The PES is not always incentivizing, it is lower than the marginal benefit and decreases with the MCF
- The Pigouvian tax is higher than the marginal damage and increases with the MCF
  - It has a contributory component

Next steps:

- The additionality issue

Thank you for your attention!

Unbounded case

If $\lambda = 0$, we can apply the IFT to the FOCs:

$$p_1 - c_1'(x_{1i}) - t - s = 0$$

$$p_2' x_{2i} + p_2 - c_2'(x_{2i}) - s = 0$$

$\Rightarrow$ A direct effect of the Pigouvian tax on the conventional agriculture:

$$\frac{\partial x_{1i}}{\partial t} = \frac{1}{-c_1''(x_{1i})} < 0$$

$\Rightarrow$ An indirect effect of the PES on the conventional and organic agriculture:

$$\frac{\partial x_{1i}}{\partial s} = \frac{1}{-c_1''(x_{1i})} < 0$$

$\Rightarrow$ The PES diminishes the production level of organic agriculture

$$\frac{dx_{2i}}{ds} = \frac{1}{2p_2'(X_2) + p_2''(X_2)x_{2i} - c_2''(x_{2i})} < 0$$

The bounded case

If $\lambda > 0$, we have: $y = 0$.

We set $x_{2i} = T_i - x_{1i}$ and we solve the system given by (1) and (2).
Using the IFT we find:

$$\frac{\partial x_{1i}}{\partial t} = -\frac{dx_{2i}}{dt} < 0$$

$\Rightarrow$ The Pigouvian tax decreases the production level of the conventional agriculture good
$\Rightarrow$ The Pigouvian tax increases the production level of the organic agriculture good
$\Rightarrow$ No effect of the PES

$\Rightarrow \Longrightarrow \Longrightarrow \Longrightarrow$ Differentiated effects according to the considered case

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