Are additional PES efficient?

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JRSS, December 15-16, 2022

Motivation of the paper

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

Literature review

- Additionality and PES (Wunder, 2005; Sills et al. 2008)
- Empirical studies (Mezzatesta et al. 2013; Chabe-Ferret & Subervie 2013)
- Carbon sequestration (Mason &Plantinga, 2013; Chiroleu-Assouline et al. 2018)
- Collective PES (Kaczan et al. 2017)

- The objective of an additionality-based PES is to lower the expenditure level by paying only for additional ES provision
- We want to investigate an additionality-based PES to see how this influences agents' behavior and policy levels
- Are additionality-based PES efficient at achieving the optimal level of ES provision, taking into account policy interactions, externalities, and market power?

  $\Rightarrow$ The aim of this paper

The structure of this paper is the following:

1. The baseline model
2. The second-best policy with market power in the organic sector
3. Concluding remarks

Assumptions (1/2)

- We construct a model with two periods, $t = 0, 1$, with β representing the discount factor
- We consider a representative farmer who has three choices for how to manage his land
- T is his total area of land with $T = x_1^t + x_2^t + y^t$ where:
  - x_1^t : quantity of conventional agriculture production in time t
    - Causes environmental damages, $D(x_1^t)$, with $D'(x_1^t) > 0$, $D''(x_1^t) > 0$
  - x_2^t : quantity of organic agriculture production
    - Neutral impact on environment
  - y^t : grass strip
    - Produces environmental benefits, represented by $BF^1(y^0, y^1) = \psi(y^0)B(y^1)$, with $B'(y^t) > 0$ and $B''(y^t) < 0$, and $\psi'(y^0) > 0$.
    - This function means that the environmental benefit in the final period depends on the benefit level obtained in initial period.
    - We normalize $BF^0(y^0) = B(y^0)$

Assumptions (2/2)

- The area of grass strip is always positive $y^t > 0, \forall t$
- Demand is linear in both markets
  - Conventional demand is represented by the function $p_1^t(x_1^t)$, and p_1^t is the price
  - Organic demand is represented by $p_2^t(x_2^t)$, and p_2^t is the price
- Production costs are increasing, convex, and quadratic in form with $c_1(x_1^t) < c_2(x_2^t)$, $\forall t = 0, 1$

The laissez-faire

The representative farmer maximizes his intertemporal profit by choosing x_1^t and x_2^t:

$$\pi(x_1^0, x_2^0, x_1^1, x_2^1) = p_1^0 x_1^0 + p_2^0 x_2^0 - c_1(x_1^0) - c_2(x_2^0) \\ + \beta\{p_1^1 x_1^1 + p_2^1 x_2^1 - c_1(x_1^1) - c_2(x_2^1)\}$$

Maximizing this function yields typical first order conditions that price should equal private marginal cost for $x_i^t, \forall i, \forall t$:

$$p_i^t - c_i'(\bar{x}_i^t) = 0 \ \forall i, \forall t$$

$\Rightarrow$ This farmer does not consider the environmental damages and environmental benefits
$\Rightarrow$ There is a need for regulation to obtain socially optimal quantities

The first-best regulation 1/3

A social planner maximizes social welfare:

$$W(x_1^0, x_2^0, x_1^1, x_2^1) = \int_0^{x_1^0} p_1^0(u)du + \int_0^{x_2^0} p_2^0(v)dv - c_1(x_1^0) - c_2(x_2^0)$$

$$+ B(T - x_1^0 - x_2^0) - D(x_1^0) + \beta\left\{ \int_0^{x_1^1} p_1^1(w)dw + \int_0^{x_2^1} p_2^1(z)dz - c_1(x_1^1) \right.$$

$$\left. - c_2(x_2^1) + \psi(y^0)B(T - x_1^1 - x_2^1) - D(x_1^1) \right\}$$

The first-best regulation 2/3

Taking the first order conditions we obtain:

$$
\begin{aligned}
p_1^0(x_1^{0*}) - c_1'(x_1^{0*}) - B_{y^{0*}} - \beta\psi'(y^{0*})B(y^{1*}) - D'(x_1^{0*}) &= 0 \\
p_2^0(x_2^{0*}) - c_2'(x_2^{0*}) - B_{y^{0*}} - \beta\psi'(y^{0*})B(y^{1*}) &= 0 \\
\beta\left[p_1^1(x_1^{1*}) - c_1'(x_1^{1*}) - \psi(y^{0*})B_{y^{1*}} - D'(x_1^{1*})\right] &= 0 \\
\beta\left[p_2^1(x_2^{1*}) - c_2'(x_2^{1*}) - \psi(y^{0*})B_{y^{1*}}\right] &= 0
\end{aligned}
$$

The first-best regulation 3/3

Comparing the first-best equations and the benchmark, we easily identify first-best environmental policy in each period:

$$\begin{aligned} t^0 &= D'(x_1^{0*}) \\ t^1 &= D'(x_1^{1*}) \\ s^0 &= B_{y^o} + \beta\psi'(y^{0*})B(y^{1*}) \\ s^1 &= \psi(y^{0*})B_{y^{1*}} \end{aligned}$$

Each environmental tax should correspond to the environmental damage and each PES to the full marginal benefit.

Method

We now incorporate market power on the organic sector as an additional distortion and follow the same method as before:

1. Analyze the farmer's behavior in response to the policies
2. Define the policy levels
3. Calculate the quantities produced and compare to the first-best

To examine the farmer's behavior in response to the policies we use backward induction

1. Maximize the farmer's profit in the final period
2. Maximize the intertemporal profit using the final period quantities found in the previous step

The farmer's behavior under market power: final period

The profit function when the farmer has a monopoly on the organic market becomes:

$$\pi^1(x_1^1, x_2^1) = p_1^1 x_1^1 + p_2^1(x_2^1)x_2^1 - c_1(x_1^1) - c_2(x_2^1) - t^1 x_1^1 + s(y^1 - y^0)$$

The FOCs:

$$\begin{aligned} p_1^1 - c_1'(x_1^{1m}) - t^1 - s &= 0 \\ p_2^{1'}(x_2^{1m})x_2^{1m} + p_2^1(x_2^{1m}) - c_2'(x_2^{1m}) - s &= 0 \end{aligned}$$

Production level responses to policies

Applying the implicit function theorem on the FOCs we obtain:

$$\begin{aligned} \frac{\partial x_1^{1m}}{\partial s} &= -\frac{1}{c_1''(x_1^1)} < 0 \\ \frac{\partial x_1^{1m}}{\partial t^1} &= -\frac{1}{c_1''(x_1^1)} < 0 \\ \frac{dx_2^{1m}}{ds} &= \frac{1}{2p_2'(x_2^1) - c_2''(x_2^1)} < 0 \end{aligned}$$

$\Rightarrow$ Results conform with intuition
$\Rightarrow$ The market power leads to a lower reduction in organic production in the final period

The farmer's behavior with market power: the initial period

The farmer's intertemporal profit function:

$$\pi(x_1^0, x_2^0) = p_1^0 x_1^0 + p_2^0(x_2^0)x_2^0 - c_1(x_1^0) - c_2(x_2^0) - t^0 x_1^0$$
$$+ \beta\{p_1^1 x_1^{1m} + p_2^1(x_2^{1m})x_2^{1m} - c_1(x_1^{1m}) - c_2(x_2^{1m}) - t^1 x_1^{1m} + s(y^{1m} - y^0)\}$$

FOCs:

$$p_1^0 - c_1'(x_1^{0m}) - t^0 + \beta s = 0$$
$$p_2^0(x_2^{0m})x_2^{0m} + p_2^0(x_2^{0m}) - c_2'(x_2^{0m}) + \beta s = 0$$

Production level responses to policies

Applying the implicit function theorem on the FOCs we obtain:

$$\frac{\partial x_1^{0m}}{\partial s} = -\frac{\frac{\partial J}{\partial s}}{\frac{\partial J}{\partial x_1^0}} = \frac{\beta}{c_1''(x_1^0)} > 0$$

$$\frac{\partial x_1^{0m}}{\partial t^0} = -\frac{\frac{\partial J}{\partial t^0}}{\frac{\partial J}{\partial x_1^0}} = -\frac{1}{c_1''(x_1^0)} < 0$$

$$\frac{dx_2^{0m}}{ds} = -\frac{\frac{\partial K}{\partial s}}{\frac{\partial K}{\partial x_2^0}} = -\frac{\beta}{2p_2'(x_2^0) - c_2''(x_2^0)} > 0$$

Proposition

Market power in the organic market reduces the strategic behavior introduced by the additional PES.

Second-best policy designs

Our objective is to determine the PES and tax levels in the context of:

- policy interaction
- environmental externalities
- distortions from the additionality-based PES
- market power in the organic market

Method:

- We construct the welfare as before, using $x_i^t, \forall i, t$ from the profit maximization
- We use the first order conditions from the welfare maximization to solve for s, t^0, and t^1

The second-best additional PES under market power

$$s^m = \frac{\psi(y^{0m})B_{y^{1m}} - [B_{y^{0m}} + \beta\psi'(y^{0m})B(y^{1m})]}{1+\beta} + \frac{p_2'(x_2^{1m})x_2^{1m} - p_2'(x_2^{0m})x_2^{0m}}{1+\beta}$$

Can also write the PES as:

$$\begin{aligned} s^m &= s^c + \frac{p_2'(x_2^{1m})x_2^{1m} - p_2'(x_2^{0m})x_2^{0m}}{1+\beta} \\ s^m &> s^c \text{ if } \frac{p_2'(x_2^{1m})x_2^{1m} - p_2'(x_2^{0m})x_2^{0m}}{1+\beta} > 0 \end{aligned}$$

The second-best taxes

$$t^{0m} = D'(x_1^{0m}) + \frac{B_{y^{0m}} + \beta[\psi(y^{0m})B_{y^{1m}} + \psi'(y^{0m})B(y^{1m})]}{1+\beta} + \frac{\beta[p_2'(x_2^{1m})x_2^{1m} - p_2'(x_2^{0m})x_2^{0m}]}{1+\beta}$$

$$t^{1m} = D'(x_1^{1m}) + \frac{B_{y^{0m}} + \beta[\psi'(y^{0m})B(y^{1m}) + \psi(y^{0m})B_{y^{1m}}]}{1+\beta} + \frac{-p_2'(x_2^{1m})x_2^{1m} + p_2'(x_2^{0m})x_2^{0m}}{1+\beta}$$

The taxes are adjusted to take into account the indirect effects of market power on the conventional agriculture market.

Calculated quantities

We plug in the values of s, t^0, and t^1 to the profit FOCs to find the production quantities that result from the environmental policies.
$\Rightarrow$The quantities chosen are not equal to the first-best quantities.

Conclusion

The aim of this article was to investigate the efficiency of an additionality-based PES to reach the optimal level of environmental benefits.

We used a model with two time periods and considered a representative farmer's behavior in a perfect information scenario.

The regulator sets a PES to only remunerate additional benefits

We obtain several results.

- The second-best additionality-based PES is equal to the discounted difference of the marginal environmental benefit in each period
- The second-best additionality-based PES is meant to reduce the budget constraint but also generates a new distortion
- The environmental taxes in each period adjust to correct for the distortions induced by the PES
- When market power is introduced, the additionality-based PES either increases or decreases depending on the relative sizes of the distortions on the organic market in each period

Possible extensions

- Consider infinite time horizon using an optimal control model
- Consider asymmetric information
- Introduce the marginal social cost of public funds

Thank you for your attention!