Effluent Charges and Licenses Under Uncertainty

Roberts, M.J. and M. Spence
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Introduction

- The paper is concerned with pollution control when there is uncertainty about firm's cleanup costs

- Once and for all problem
- **Mixed system is preferable to either effluent fees or the licenses used separately.**

- The point of this exercise is not to prove one or another approach better.

- The problem is to minimize the expected total social cost. The authority must quantify its uncertainty about cleanup costs in the form of subjective probabilities.

- Which kind of imperfection is preferable?
    - it depends on the curvature of the damage function
    - EDF is linear, then effluent charge
    - Marginal damage increase sharply, then licenses
- Licenses and effluent charges can be used together further to reduce expected total costs.

- waste dischargers have the same impact.
- x total pollution
- Expected total damages are $D(x)$
- The current level of output of the pollutant by firm i is $\overline{x}_i$
- The cost of cleanup is uncertain (regulators) ϕ, $c^i(x_i, \phi)$ and $c^i(\overline{x}_i, \phi) = 0$
- Total cleanup: $c(x_i, \phi) = \sum_i c^i(x_i, \phi)$
- note that $x = \sum_i x_i$ and for all i and j:$c^i_x(x_i, \phi) = c^j_x(x_j, \phi)$
- $D''(x) > 0$ and $C_x < 0$, $C_{xx} > 0$ (mg cleanup costs increase at an increasing rate)
- $C_\theta < 0$ and $C_{x\theta} > 0$
- $$T = \int [D(x) + c(x, \phi)] f(\phi)\, d\phi = E[D(x) + c(x, \phi)].$$

- The control mechanism has three components:

1. There is a finite set of transferable licenses, l_i and q is the market price
2. s a unit of effluent subsidy, iff $l_i > x_i$.Firm receives $s(l_i - x_i)$
3. Iff $l_i < x_i$ penalty $p(x_i - l_i)$

- This approach has several properties:
    - Allocates cleanup among polluters efficiently
    - It is preferable to either a pure effluent fee or a pure license scheme
    - The system operates as if there were just one polluting firm
- Limit effluents: this is done by issuing marketable licenses, l
- If cleanup costs are overestimated, a residual incentive to cleanup: s
- If cleanup costs turn out to be ver high, an escape valve: penalty, p.

- $$c^i(x_i, \phi) + ql_i - s(l_i - x_i) \quad \text{if} \quad x_i \leqq l_i,$$

  and

  $$c^i(x_i, \phi) + ql_i + p(x_i - l_i) \quad \text{if} \quad x_i \geqq l_i.$$

- The firm minimizes these costs by selectinh x_i and l_i appropriately.

- Suppose $q < s$. (Not a good idea)
- Suppose $q > p$ then $l_i = 0$
- s and p place bounds on the equilibrium value of q: $s \leq q \leq p$
- They show that $c_x^i(x_i, \phi) = -q$. First, suppose $s = q$. then the firm will set $l_i \geq x_i$ and $c_x^i(x_i, \phi) = -s = -q$
- Next suppose: $s < q < p$. Then firm i will set $x_i = l_i$. Cost are: $c^i(x_i, \phi) + qx_i$ and $c_x^i(x_i, \phi) = -q$
- Finally, if $q = p$, then firm will set $l_i \leq x_i$ and minimize wrt x_i : $c_x^i(x_i, \phi) = -q$
- Therefore: $c_x^i(x_i, \phi) = c_x^j(x_j, \phi)$, cleanup is efficiently distributed among polluters.
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The remaining question is what determines the levels of q and x? If $s < q < p$, then $x_i = l_i$ for all i, and hence $x = l$. Condition (3) will be satisfied if

$$s < -c_x(l, \phi) < p. \qquad (4)$$

- Summary:
  - (1) if $c_x(l, \phi) + s > 0$, then $c_x(x_i, \phi) + s = 0$ and $q = s$
  - (2) if $s < -c_x(l, \phi) < p$, then $x = l$ and $q = -c_x(l, \phi)$ and
  - (3) if $c_x(l, \phi) + p < 0$, then $c_x(x_i, \phi) + p = 0$ and $q = p$
- The piecewise linear penalty function is:

$$P(x) = sx + p\,\mathrm{Max}\,(x - l, 0).$$

- If Min $P(x) + c(x, \phi)$:
  - if $s < -c_x(l, \phi) < p$ they would set $x = l$
  - if $-c_x(l, \phi) < s$ they would set $c_x(x_i, \phi) + s = 0$
  - if $-c_x(l, \phi) > p$ they would set $c_x(x_i, \phi) + p = 0$

- The mixed system implicitly approximates the expected damage function by a piecewise linear penalty

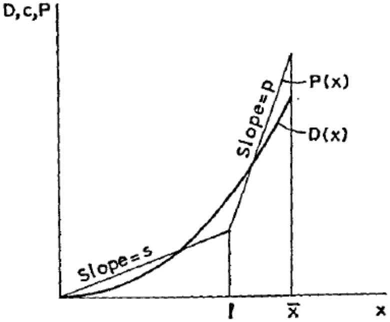

Fig. 1

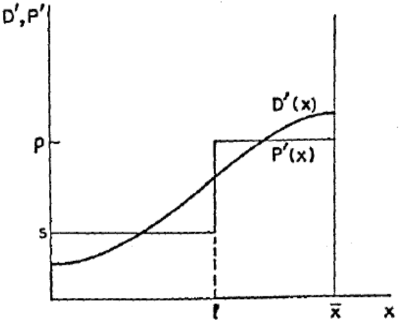

Fig. 2

The regulatory authority's optimizing problem

- The decision variables are s, p and l
- Minimize expected total costs: damages from pollution and cleanup costs.
- Two critical levels of the cost determining ϕ. First, ϕ_1 is the level of cost such that:
  - $c_x(l, \phi_1) = s = 0$
- Second, $\phi_2 > \phi_1$, defined by
  - $c_x(l, \phi_1) + p = 0$
- Let $[0, b]$ be the support distribution $f(\phi)$. Then $x_1(\phi, s)$ and $x_2(\phi, p)$:

$$c_x(x_1(\phi, s), \phi) + s = 0,$$

and

$$c_x(x_2(\phi, p), \phi) + p = 0.$$

- Expected total costs are

$$T(s,p,l) = \int_0^{\phi_1} [D(x_1(\phi,s)) + c(x_1(\phi,s),\phi)]f(\phi)\,\mathrm{d}\phi$$
$$+\int_{\phi_1}^{\phi_2} [D(l) + c(l,\phi)]f(\phi)\,\mathrm{d}\phi$$
$$+\int_{\phi_2}^{b} [D(x_2(\phi,p) + c(x_2(\phi,p),\phi]f(\phi)\,\mathrm{d}\phi.$$

- With perfect information about costs, the authority would set

$$D'(x) + c_x(x, \phi) = 0,$$

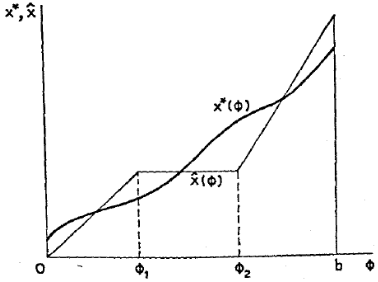

Fig. 4

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Table 1

Control scheme	Expected total costs	Percentage above the optimum
Optimum (also mixed system)	12.416	0
Pure effluent fee	20.6	66
Pure licenses	18.25	46

- With a nonlinear damage function, and uncertain irreversible costs, authors would like to find some way of confronting each firm with incentives to cleanup.
- The mixed system ensures that all firms face the marginal costs, but it depend on what the aggregate cost of cleanup actually turn out to be.
- The subsidy provides a residual incentive for firms to clean up even more when costs are low
- The finite penalty provides an escape valve in case costs are very high
- Once the equilibrium in license prices is established, each firm effectively faces a linear penalty function whose slope is the price of the license.
- As a result marginal cleanup costs are equalized and total cleanup costs are minimized.