Pigovian Tax

Kolstad - Chapter 7

Introduction

- Production Cost factory $C(X, Y)$, X amount of Pollution and Y goods output

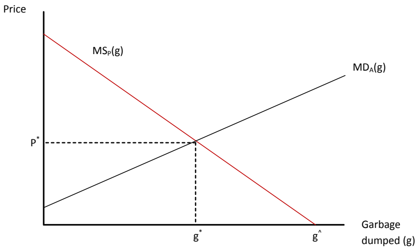
1. Input Price Constant
2. Y will be produced where $C\prime(\cdot) = P_y$

- Simplify (given 1 and 2) the model to $C(X)$
- $MC(X)$ additional cost of producing one more unit of pollution
- $MS(X)$ marginal savings. $MS(X) = -MC(X)$. Assumptions:

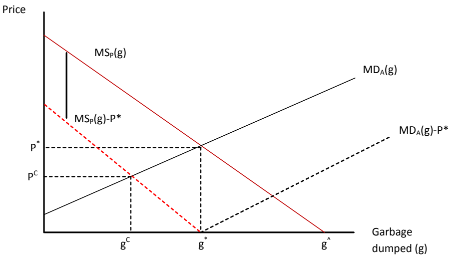
1. N people surrounding the factory
2. Pollution causes damage
3. $D_i(X) = \sum D_i(X)$ damage for person i, $D_i'(X) > 0$
4. $B_i(X)$ benefits from pollution, $B_i(X) < 0$ (or WTP to eliminate pollution)

- $$\min_x \{C(X) + D(X)\}$$
$$MC(X^*) + MD(X^*) = 0 \Leftrightarrow MS(X^*) = \sum D_i(X^*)$$

- **Definition:** *A Pigovian tax is a fee paid by the polluter per unit of pollution exactly equal to the aggregate marginal damage caused by the pollution when evaluated at the efficient level of pollution. The fee is generally paid to the government.*

- Consider the case of Anna and Pedro who are neighbors
- Pedro generates a lot of garbage and Anna does not.
- NO PR, so Pedro gets rid of his excess of garbage by tossing it over the fence into his neighbor's yard.
- 

- Now suppose society institutes a tax of P*
- $MS(g)$ is reduced by $P^*(MS_p - P^*)$
- Without anything happening, Pedro generates g^*
- Now suppose Anna offers to pay P^C for each bag of garbage
- Pedro generates g^C



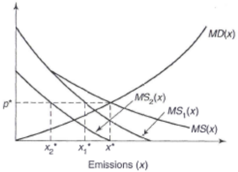
- Assume we have two polluters:
- 

Figure 7.3 The case of two polluters. $MS_1(x)$, Marginal savings from emitting firm 1; $MS_2(x)$, marginal savings from emitting firm 2; $MS(x)$, aggregate marginal savings from emitting; $MD(x)$, marginal damage from emitting; p^*, Pigovian fee; x^*, total amount of emissions with Pigovian fee; x_1^*, emissions from firm 1 with Pigovian fee; x_2^*, emissions from firm 2 with Pigovian fee.

- **Definition:** In controlling emissions from several polluters whose emissions all contribute to damage in the same way, *the equimarginal principle* requires that marginal cost of control be equated across polluters to achieve an emission reduction at the lowest possible cost.

- Is it possible to obtain the same output by subsidizing firms to reduce pollution?
- In the "real world" is there any danger in providing tax breaks and other subsidies for pollution control, rather than making polluters pay for the pollution they generate?
- Is it possible to obtain efficiency using subsidies instead of a fee?

- The tax is efficient, whereas the subsidy can result in too many firms in the industry and thus an inefficient amount of both pollution and the good associated with the pollution.

Regulating Pollution

Kolstad - Chapter 8

Introduction

- Two basic theories of regulation:

1. Public Interest Theory
2. Interest Group Theory

- Traditional normative Justification for government regulation

1. Imperfect Competition
2. Imperfect Information
3. Provision of -+

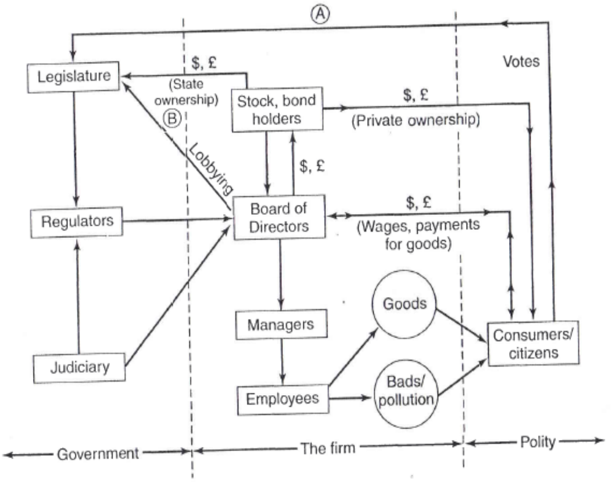
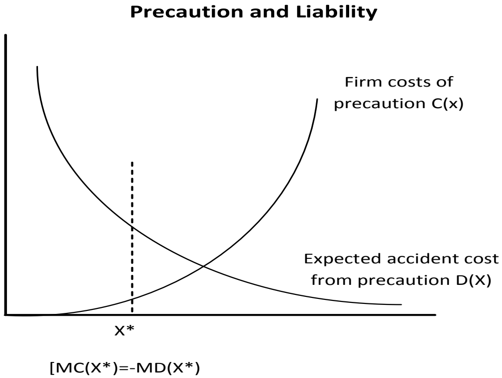
- 

Figure 8.1 Schematic of interactions among government, polluting firms, and consumer citizens.

- The key features:
  - Restricted choice for the polluters as to what means will be used to achieve an appropriate environment target
  - A lack of mechanisms for equalizing marginal control cost among several different polluters
- Advantages:
  - More flexibility in regulating complex environmental process
  - Certainty in how much pollution will result from regulation
  - Simplifying monitoring of compliance with a regulation
- Disadvantages:
  - Informational costs are high
  - Polluter has incentives to distort information provided to the regulator
  - Is difficult to satisfy the equimarginal principle

- **Pollution Fees:** the payment of a charge per unit of pollution emitted
- **Marketable permit:** allows polluters to buy and sell the right to pollute
- **Liability:** If you harm someone, you must compensate that person for damage



- Advantage: Equimarginal Principle
- Disadvantage:
  - Developing Economic Incentives that take into account the complexities is difficult
  - There is a great deal of uncertainty associated with the environmental problem being controlled.

- **How best can regulations be structured for the case in which we cannot observe emissions?**
- **How best can regulations be structured to give polluters incentives to act efficiently and truthfully divulge information necessary for regulation?**
- **How can enforcement policies be designed to give polluters incentives to obey regulations?**

Emissions Fees and marketable Permits

Kolstad - Chapter 9

Introduction

- Problems when using incentives to control pollution:

1. Space

- Space analyze two terms:

Introduction

- Problems when using incentives to control pollution:

1. Space
2. Time

- Space analyze two terms:

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Introduction

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- Space analyze two terms:

1. Source
2. Receptor

- Definition: Suppose a change in emissions from source i ($\triangle e_i$) results in a change in pollution at receptor j ($\triangle p_j$). The transfer coefficient between the source i and the receptor j is defined as the ratio of the change in pollution at j to the change in emissions at i:

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- $$a_{ij} = \frac{\triangle p_j}{\triangle e_i}$$

- Efficient Pollution:

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  -
$$
\begin{aligned}
MDE(e_i) &= \{D(p + \triangle p) - D(p)\}/\triangle e_i \\
MD(p)\frac{\triangle p}{\triangle e_i} &= MD(p)a_i \\
-MC &= MD(p)a_i \quad \forall i = 1, ..., I \\
\frac{MC_n(e_n)}{a_n} &= MD(p)
\end{aligned}
$$

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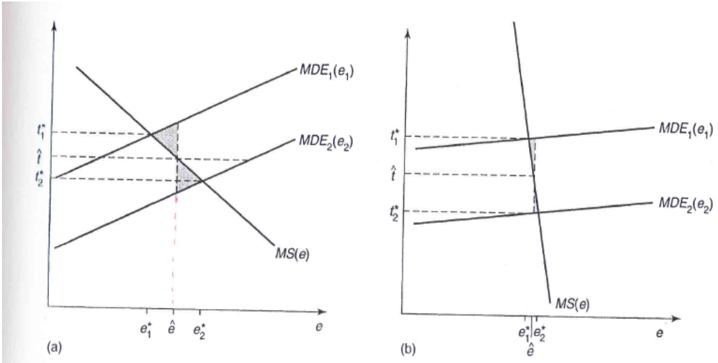
- 

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    - Assume π is the price of the permits (unknown)

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  - Marginal Savings = Permit Price!
  - We can obtain values of e1 and e2 using (A) and $L = a_1 e_1 + a_2 e_2$

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- Assume that pollution damage depends only on $s(t)$. Then if $\delta > 0$ the pollutant is a stock pollutant. If $\delta = 0$, the pollutant is a flow pollutant. $(1-\delta)$ is the fraction of stock that is cleaned out of the env. in one period.

- **The Net Cost of pollution emissions e_t:**

$$
\begin{aligned}
NC &= \sum_{t=1}^{\infty} \beta^{t-1}\{C_t(e_t) + D_t(s_t)) \\
\frac{dNC}{de_1} &= \sum_{t=1}^{\infty} \beta^{t-1}\{C_t'(e_t) + \frac{dD_t(s_t)}{ds_t} \times \frac{ds_t}{de_1}\} = 0
\end{aligned}
$$

- Note that

$$
\begin{aligned}
s_t &= e_t + \delta e_{t-1} + \delta^2 e_{t-2} + \ldots + \delta^i e_{t-i} + \delta^t s_o \backslash \\
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- The discount factor diminishes future marginal damages

Prices vs. Quantities

Martin L. Weitzman

The Review of Economic Studies, Vol. 41, No. 4 (Oct., 1974), pp. 477-49

Introduction

- What is the best way to implement control for the benefit of the organization as a whole?

- Is it better to directly administer the activity under scrutiny or to fix transfer prices and rely on self-interested profit or utility maximization to achieve the same ends in decentralized fashion?
- **Example:control certain forms of pollution by setting emission standards or by charging the appropriate pollution taxes**

- It is neither easier nor harder to name the right prices than the right quantities because in principle exactly the same information is needed to correctly specify either.

- In any particular setting there may be important practical reasons for favouring either prices or quantities as planning instruments
- Even on an abstract level, it would be useful to know how to identify a situation where employing orne mode is relatively advantageous, other things being equal.

- Amount q of a certain commodity can be produced at cost $C(q)$, yielding benefits $B(q)$.
- It is assumed that $B''(q) < 0$, $C''(q) > 0$, $B'(O) > C'(O)$, and $B'(q) < C'(q)$ for q sufficiently large.
- The planning problem is:

$$\max_q B(q) - C(q).$$

$$\begin{aligned} B'(q^*) &= C'(q^*) \\ p^* &\equiv B'(q^*) = C'(q^*) \end{aligned}$$

- Incomplete Information: $C(q, \theta)$, where θ is a disturbance term or random variable, unobserved and unknown at the present time.
- $B(q, \eta)$ η is a RV.
- θ and η are independently distributed.

- Now an ideal instrument of central control would be a contingency message whose instructions depend on which state of the world is revealed by θ and η.

$$B_1(q^*(\theta, \eta), \eta) = C_1(q^*(\theta, \eta), \theta) = p^*(\theta, \eta).$$

- Moral Hazard Problem

- The issue of prices vs. quantities has to be a "second best " problem by its very nature.

$$E[B(\hat{q}, \eta) - C(\hat{q}, \theta)] = \max_q E[B(q, \eta) - C(q, \theta)],$$

$$E[B_1(\hat{q}, \eta)] = E[C_1(\hat{q}, \theta)].$$

- When a price instrument p is announced, production will eventually be adjusted to the output level
- $$q = h(p, \theta)$$
- which maximizes profits given p and θ. Such a condition is expressed as

  $$ph(p, \theta) - C(h(p, \theta), \theta) = \max_q pq - C(q, \theta),$$

  implying

  $$C_1(h(p, \theta), \theta) = p.$$

- If the planners are rational, they will choose that price instrument $\tilde{p}$ which maximizes the expected difference between benefits and costs given the reaction function $h(p, \theta)$:

$$E[B(h(\tilde{p}, \theta), \eta) - C(h(\tilde{p}, \theta), \theta)] = \max_p E[B(h(p, \theta), \eta) - C(h(p, \theta), \theta)].$$

The solution $\tilde{p}$ must obey the first order equation

$$E[B_1(h(\tilde{p}, \theta), \eta) \,.\, h_1(\tilde{p}, \theta)] = E[C_1(h(\tilde{p}, \theta), \theta) \,.\, h_1(\tilde{p}, \theta)],$$

which can be rewritten as

$$\tilde{p} = \frac{E[B_1(h(\tilde{p}, \theta), \eta) \,.\, h_1(\tilde{p}, \theta)]}{E[h_1(\tilde{p}, \theta)]}. \qquad \ldots(3)$$

Corresponding to the optimal *ex ante* price $\tilde{p}$ is the *ex post* profit maximizing output $\tilde{q}$ expressed as a function of θ,

$$\tilde{q}(\theta) \equiv h(\tilde{p}, \theta). \qquad \ldots(4)$$

- After the quantity $\widehat{q}$ is prescribed, producers will continue to generate that assigned level of output for some time even though in all likelihood

$$B_1(\hat{q}, \eta) \neq C_1(\hat{q}, \theta).$$

In the price mode on the other hand, $\tilde{q}(\theta)$ will be produced where except with negligible probability

$$B_1(\tilde{q}(\theta), \eta) \neq C_1(\tilde{q}(\theta), \theta).$$

- Neither instrument yields an optimum ex post. The *relevant question* is which one comes closer under what circumstances

- It is natural to define the comparative advantage of prices over quantities as

$$\Delta \equiv E[(B(\tilde{q}(\theta), \eta) - C(\tilde{q}(\theta), \theta)) - (B(\hat{q}, \eta) - C(\hat{q}, \theta))].$$

- The coefficient $\triangle$ is intended to be a measure of comparative or relative advantage only.
- Let the symbol "$\stackrel{\circ}{=}$ " denote an *accurate local approximation*:

$$C(q, \theta) \stackrel{\circ}{=} a(\theta) + (C' + \alpha(\theta))(q - \hat{q}) + \frac{C''}{2}(q - \hat{q})^2 \qquad ...(6)$$

$$B(q, \eta) \stackrel{\circ}{=} b(\eta) + (B' + \beta(\eta))(q - \hat{q}) + \frac{B''}{2}(q - \hat{q})^2. \qquad ...(7)$$

- WLG $\alpha(\theta)$ and $\beta(\eta)$ are standarized,θ

$$E[\alpha(\theta)] = E[\beta(\eta)] = 0 \text{ and } E[\alpha(\theta).E[\beta(\eta)] = 0$$

- **Result of the paper** "COEFFICIENT OF COMPARATIVE ADVANTAGE"

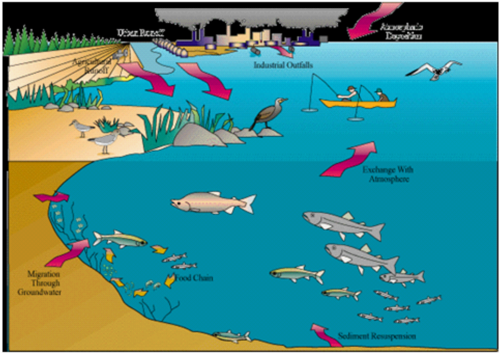
$$\Delta \cong \frac{\sigma^2 B''}{2C''^2} + \frac{\sigma^2}{2C''}.$$

- as σ^2 shrinks to zero we move closer to the perfect certainty case where in theory the two control modes perform equally satisfactorily.
- Clearly $\triangle$ depends critically on the curvature of cost and benefit functions around the optimal output level.
- the sign of $\triangle$ simply equals the sign of $C'' + B''$
- The coefficient $\triangle$ is negative and large as either the benefit function is more sharply curved or the cost function is closer to being linear
  - Using a price control mode in such situations could have detrimental consequences
- When marginal costs are nearly flat, the smallest miscalculation or change results in either much more or much less than the desired quantity.
- The price mode looks relatively more attractive when the benefit function is closer to being linear.

- Having seen how C'' and B'' play an essential role in determining $\triangle$, it may be useful to check out a few of the principal situations where we might expect to encounter cost and benefit functions of one curvature or another.
- The amount of pollution which makes a river just unfit for swimming could be a point where the marginal benefits of an extra unit of output change very rapidly.
    - is that it doesn't pay to " fool around " with prices in such situations.
- Quantities are better signals for situations demanding a high degree of coordination.

Uncertainty and Incentives for Nonpoint Pollution Control

K. Sergerson (1988)



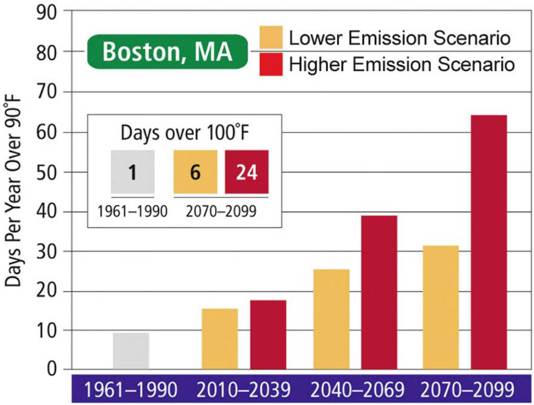
Main Points

Why the standard solutions in controlling point source problems are unworkable for Nonpoint Pollution?

1. *Stochastic Variables*
2. *Combine effects*
3. *Is Xapapadea's model considering NPP?*

Main Points

- Definition of Uncertainty....



Main Points

1. PDF: gives the probability that ambient pollutant levels of a given magnitude will occur at the specified time.
2. PDF depends on..
3. What is the objective of pollution control policies? "FOSD"

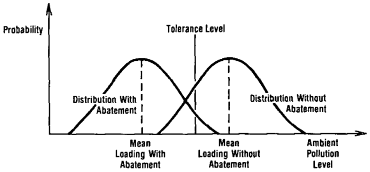


FIGURE 1

4. Stochastic relationship between discharge and ambient pollutant. Solution?

Single Polluter Problem

- x is the ambient level of a given pollutant
- $\bar{x}$ is the cutoff level
- x depends on abatement action and random variables
- $T(x)$ required payments
- $$T(x) = \begin{cases} t(x - \bar{x}) + k & \text{if } x > \bar{x} \\ t(x - \bar{x}) & \text{if } x \leq \bar{x}. \end{cases}$$
- Liabilities of the polluter? Xapapadeas vs Segerson
  - influences outside his control

Single Polluter Problem

- How the polluter chooses his/her level of abatement
  - The polluter gambles on what his tax liability will be and weighs the additional abatement cost against the decrease in expected payments.
- Role of assimilative capacity
- ambient levels vs emissions (abatement)
  - Incentives for additional abatement since...

Single Polluter Problem - SHORT RUN

- a denotes the level of abatement
- $x(a, e)$ is the ambient pollution level, where e is a random variable, $\frac{\partial x}{\partial a} \leq 0$
- y output level, cost of producing y while abating to level a $C(y, a)$
- Social Planner (y^* and a^*):

$$py + E[B(x(0, e) - x(a, e))] - C(y, a),$$

- Firm ($\widehat{y}$ and $\hat{a}$):

$$py - C(y, a) - E(T(x(a, e))).$$

$$E[t(x(a, e))] = t \times E[x(a, e)] - t\overline{x} + k(1 - F(\overline{x}, a))$$

Single Polluter Problem - SHORT RUN

- (a) $k = 0$ and $t = E[B' \cdot x_a]/E[x_a]$,[11]

  (b) $t = 0$ and $k = -E[B' \cdot x_a]/F_a$,

  or

  (c) t is arbitrary and $k = (-E[B' \cdot x_a] + tE[x_a])/F_a$,

Single Polluter Problem - LONG RUN

- N be the number of firms in the industry
- $p(Ny)$ inverse demand curve
- Long run efficiency conditions:

Single Polluter Problem - LONG RUN

- Long run equilibrium conditions of a competitive market:

- The infinite number of combinations of t, k and $\overline{x}$ that yield short run efficiency only one also yields long run efficiency.

Advantages and Disadvantages

- Minimum government interference
  - Free to choose the least cost pollution abatement techniques
- Flexibility
- Monitoring ambient pollutant levels
  - Monitoring of firm practices or metering of emissions.
  - Hot spots and crucial time periods
- Environmental quality (stochastic pollution)
  - Rather than emissions or erosion
- Disadvantages??

Ex Post Liability for Harm vs. Ex Ante Safety Regulation: Substitutes or Complements?

Charles D. Kolstad, Thomas S. Ulen, Gary V. Johnson
The American Economic Review, Vol. 80, No. 4 (Sep., 1990), pp. 888-901

Introduction

- Economists have generally viewed ex ante and ex post policies as substitutes for correcting externalities

1. **Ex-Ante:** affect an activity before the externality is generated
2. **Ex-Post:** regulate the externality only after it has been generated and harm has occurred

- Ex ante and ex post policies are very frequently used jointly

- Hospital located next to a noisy, dusty cement-manufacturing plant
    - inefficiencies are minimized by zoning ordinances (Ex-ante)
    - exposing the externality generator to nuisance liability (Ex-post)
- New drugs
    - test before the drugs are licensed by the federal Food and Drug Adm. (Ex-ante)
    - exposing the drug manufacturer to strict product liability (Ex-post)

Ex Post Liability for Harm vs. Ex Ante Safety Regulation: Substitutes or Complements?

- Criticism:

1. In the case of ex ante regulation, the typical criticism is that the central regulator has imperfect information on accident costs and damages.
2. Suit may not always be brought against injurers and that uncertainty regarding the legal standard leads to over or underprotection.

- This paper first identifies a set of inefficiencies associated with ex post liability. These inefficiencies are due to a potential injurer's being uncertain about whether a court will hold him liable in the event of an accident and suit.
- Authors do not assume risk aversion!
- Demonstrate how ex ante regulation, if used jointly with tort liability, can correct some of those inefficiencies.

Ex Post Liability for Harm vs. Ex Ante Safety Regulation: Substitutes or Complements?

- Important Result:
  - When tort liability rules are in place, it is inefficient to set ax ante regulatory standards at the socially optimal level.
  - The only instances when the ex ante regulatory standard should be set at the social optimum are when there is a zero probability of a judgment against a rational injurer under ex post liability

- Risk-neutral firm (Engages in a risky activity)
- The firm can reduce the dangers associated with this activity by taking precaution (Costly)
- x level of precaution
- $C(x)$ cost of taking precaution $C'(x) > 0$ and convex
- $P(x, \varepsilon)$ accidents occurs with prob. $P(\cdot)$
- ε RV, represents the view of the court, $\varepsilon\tilde{}q_\varepsilon$(density function)
- $D(x, \varepsilon)$ size or the damage of accident
- $A(x)$ expectation of $P(x, \varepsilon)D(x, \varepsilon)$ over ε, $A'(x) < 0$
- View of the court is revealed after a court has heard evidence about x and the extent of damage
- $E[\varepsilon] = 0$
- $C(x) + A(x)$ is strictly convex

1. Find socially optimal amount of precaution, x^* [the expected social costs of accidents are minimized]
2. Find $\overline{x}(\varepsilon)$ court's interpretation of social optimum
3. Find $\widetilde{x}$ firm's precaution level (minimize expected private costs to the firm)
4. Comparison between x^* and $\widetilde{x}$

- **First,**

$$\min_x E[C(x) + P(x,\varepsilon)D(x,\varepsilon)] = \min[C(x) + A(x)]$$

- $$C'(x) = -A'(x)$$

- The legal standard is an expost parameter reveal by the court after the accident,

$$\min_x [C(x) + P(x,\varepsilon)D(x,\varepsilon)]$$

- $$C'(x) + \frac{dP(x,\varepsilon)D(x,\varepsilon)}{x} = 0$$

- Under a negligence rule, the injurer is found liable for all damages iff his level of precaution was less than the legal standard of precaution.
- $$TC(x) = E[C(x) + L(x,\varepsilon) \times P(x,\varepsilon) \times D(x,\varepsilon)]$$
- Negligence:

$$\begin{array}{rcll} L(x,\varepsilon) & = & 1 & \textit{if } x < \overline{x}(\varepsilon), \\ & & 0 & \text{otherwise} \end{array}$$

- Ideally $x^* = \widetilde{x}$

- **The firm does not know the view of the court, ε, when it chooses $\widetilde{x}$**
- $q(x)$ the injurer's subjective probability distribution around the legal standard
- $q(x)$ is a continuous probability density with support $(-\infty, \infty)$
- $R(x) = \int_{x}^{\infty} q(x)dx$: the probability that the injurer's level of precaution x will end up being below the legal standard
- $E[P(x,\varepsilon)D(x,\varepsilon)] = A(x)$ the injurer will pay damages
- New Assumption: $C(x) + A(x)R(x)$ is strictly convex

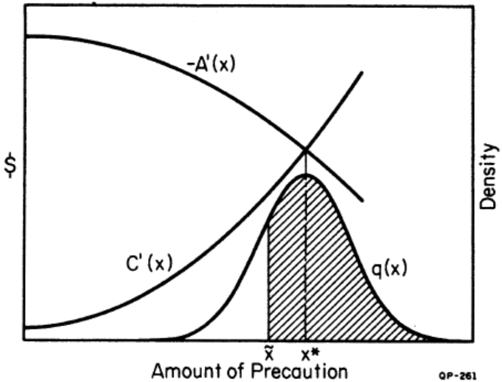
- 

FIGURE 1. THE SOCIAL PROBLEM WITH EVIDENTIARY UNCERTAINTY FOR THE INJURER

- When there is uncertainty, the injurer's objective function

$$\begin{aligned} TC(x) &= E[C(x) + R(x) \times P(x,\varepsilon) \times D(x,\varepsilon)] \\ &= C(x) + A(x)R(x) \end{aligned}$$

- $$\min_x TC(x)$$

- $$TC'(\tilde{x}) = C'(\tilde{x}) + A'(\tilde{x})R(\tilde{x}) - A(\tilde{x})q(\tilde{x})$$

    - $A'(\tilde{x})R(\tilde{x})$: Injury effect (negative) [It represents a saving to the injurer from the application of greater precaution]
    - $A(\tilde{x})q(\tilde{x})$: Liability Effect (negative) [savings from providing slightly higher precaution in that the probability of being held liable is reduced]

- Both terms indicate that the marginal liability cost decline in precaution.

- If $TC'(x^*) < 0$ then $x^* < \widetilde{x}$
- If $TC'(x^*) > 0$ then $x^* > \widetilde{x}$

1. Using
$$C'(x) = -A'(x)$$
2. then,
$$TC'(x^*) = C'(x^*)[1 - R(x^*)] - A(x^*)q(x^*)$$
3. Since $C'(x) \geq 0$ by assumption and $R(x^*) \leq 1$ then $C'(x^*)[1 - R(x^*)] > 0$
4. Since $A(x^*)$ and $q(x^*)$ are greater than zero by definition then $A(x^*)q(x^*) < 0$
5. The sign of equation is indeterminate and the relationship between $\widetilde{x}$ and x^* cannot be discovered without knowing the magnitude of the various terms.

- Two cases:

1. there is a great deal of uncertainty with regard to the legal standard
   1. e.g. Genetic engineering
2. and there is little uncertainty with regard to the standard.
   1. e.g. Automobile accident

-

- Proposition 4. Intuition:
    - The higher the level of the ex ante regulatory standard, the higher the legal standard is likely to be, at least in the eyes of the injurer. Thus, the ex ante regulation can correct cases of underprecaution resulting from exposure to liability alone, but it can also exacerbate overprecaution
- From Proposition 1-3 we know that: Injurers, when faced with only a negligence rule, may choose suboptimal precaution when
    - uncertainty about the legal standard is sufficiently large;
    - the marginal cost of precaution at x^* is large; or
    - the distribution about the legal standard is sufficiently biased to the left of x*
- It follows that when any of these conditions holds, injurers can be induced to increase their level of precaution by establishing a minimum safety regulation, s
- the next question is what level of the ex ante regulation, s^*, will induce firms to choose $\widehat{x}(s) = x^*$?

- A comparison of the administrative costs of the tort liability system and of the ex ante system should be made.
- Uncertainty surrounding the legal standard could be further broken down into its different components
- The possibility of bankruptcy could be introduced.
- Uncertainty regarding the ex ante regulation could be introduced into the model.

Correlated Uncertainty and Policy Instrument Choice

Robert N. Stavins (1996), JEEM

Main Points

- Cost uncertainty can have significant effects, depending upon the relative slopes of the marginal benefit damage and marginal cost functions.
- In the real world, we rarely encounter situations in which there is exclusively either benefit uncertainty or cost uncertainty.
- What can be said about optimal policy instruments under these conditions?

- In his very general approach, Weitzman assumed that the random error characterizing uncertainty was sufficiently small to justify quadratic approximations of generalized total cost and total benefit functions

$$\Delta_{\mathrm{pq}} \approx \frac{\sigma_{\mathrm{C}}^{2} B''}{2 C''^{2}} + \frac{\sigma_{\mathrm{C}}^{2}}{2 C''},$$

- Δ_{pq} is the net welfare advantage of the price inst. relative to the quantity
- B'' is the slope of the MB function and C'' the slope of the MC
- σ_c^2 is the variance of costs

- Adar and Griffin simply assumed linearity in the marginal benefit and marginal cost functions

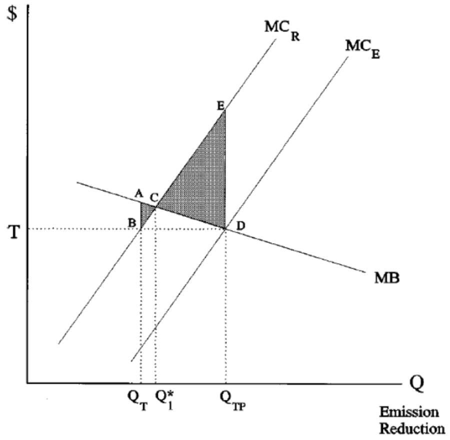


FIG. 1. Cost uncertainty and the choice of policy instrument.

- When the uncertainty is exclusively with marginal benefits, both instruments achieve the same realized level of control and hence exhibit the same social loss

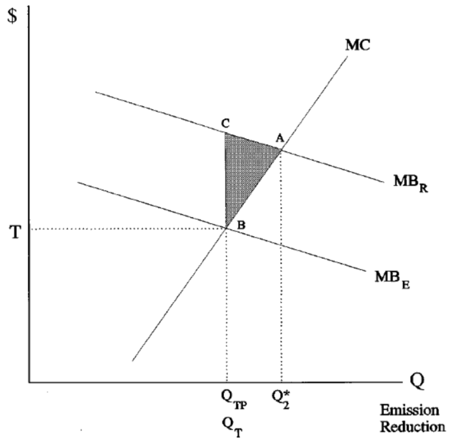
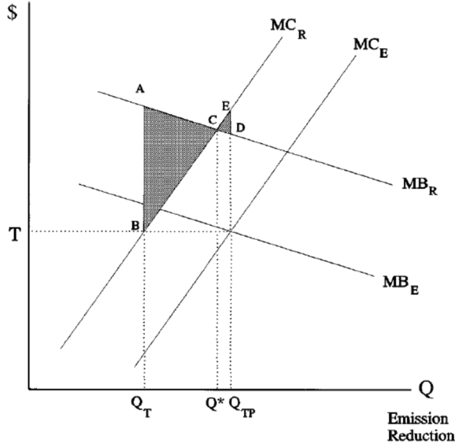


FIG. 2. Benefit uncertainty and the choice of policy instrument.

- Despite the fact that the same expected and realized functions as before are pictured, we now find that the optimal instrument is no longer the Pigouvian tax, but the tradeable permit system instead



- How should we think about these results in more general and more rigorous terms?
- Weitzman noted that if benefit uncertainty and cost uncertainty are simultaneously present and B and C are not independently distributed, the correct form becomes:

$$\Delta_{\mathrm{pq}} \approx \frac{\sigma_{\mathrm{C}}^{2} B''}{2 C''^{2}} + \frac{\sigma_{\mathrm{C}}^{2}}{2 C''} - \frac{\sigma_{\mathrm{BC}}^{2}}{C''},$$

- where $\sigma_{BC}^2 = E\{B - E[B]\} \times E\{C - E[C]\}$, the covariance of benefits and costs

$$\Delta_{pq} \approx \frac{\sigma_C^2}{C''}\left[\frac{B''}{2C''} + \frac{1}{2} - \frac{\rho_{BC}\sigma_B}{\sigma_C}\right]$$

- where ρ_{BC} is the correlation (coefficient) between benefits and costs
- σ_B is the standard deviation of benefits and the standard deviation of σ_C costs
- When there is statistical dependence between benefits and costs, benefit uncertainty does matter in our choice of the optimal instrument
- It is always the case that a positive correlation tends to favor the quantity instrument

- is it reasonable to suggest that benefit uncertainty is significant in the environmental arena, particularly relative to cost uncertainty?
- is it reasonable to assume that in many cases, the marginal benefits and marginal costs of environmental protection are indeed correlated?
- is there any reason to believe that these factors are likely to be sufficiently important to overwhelm a "conventional analysis" of efficient instrument choice, based on the simpler relative-slopes rule?
- Examples: Weather (sunny day)
    - marginal cost of ambient concentration reduction would increase
    - marginal benefits of ambient-reduction would also increase
- Negative correlation?

- In the presence of simultaneous uncertainty in both marginal benefits and marginal costs and some statistical dependence between them, benefit uncertainty can make a difference for identifying the efficient policy instrument.
- A positive correlation tends to favor the quantity instrument
- A negative correlation favors the price instrument

The Net Benefits of Incentive-Based Regulation: A Case Study of Environmental Standard Setting

Wallace E. Oates; Paul R. Portney; Albert M. McGartland

The American Economic Review, Vol. 79, No. 5. (Dec., 1989), pp. 1233-1242

Introduction

- decentralized, incentive-based (or IB) policies are more efficient than centralized, command-and-control (or CAC) approaches

- IB policies will accomplish the same goals as their CAC counterparts, but at less cost to society
- **However IB fails to consider improvements that exceed the standards**
- Empirical Evidence..
- data on the costs and benefits of controlling a common air pollutant, total suspended particulates (or TSP), in Baltimore.
- They estimate the MC and MB associated with a variety of alternative air quality standards which take the form of maximum permissible concentrations.

- Suppose that we have a specific *"region"* in which there are m sources of pollution

- Environmental quality is defined in terms of pollutant concentrations at each of n "receptor points" in the region.
  - Measure environmental quality by a vector $Q = (q_1, q_2, ..., q_n)$ whose elements indicate the concentration of the pollutant at each of the receptors.
- The dispersion of emissions from the m sources in the region is described by an $m \times n$ matrix of unit diffusion (or transfer) coefficients:

$$D = \begin{matrix} . \\ . \\ ...d_{ij}... \\ . \\ . \end{matrix}$$

- d_{ij} indicates the increase in pollutant concentration at

- Denote by e_i the level of emissions by source i, then the pattern of waste emissions in the region is:
  - $E = (e_1, e_2, ..., e_m)$.
- The levels of pollution at the various receptor points can then be determined by mapping the vector of emissions through the diffusion matrix:
  - $ED = Q$
- Abatement Cost Function $C_i(e_i)$
- Standard:maximum permissible level of pollutant concentration at any receptor point in the region.
- **CAC:**the agency might specify abatement technologies for the sources
- Such a control program would result in a specific vector of emissions from sources, E_C,. And this vector would map through the diffusion matrix into a vector Q_c, of pollutant concentrations.

- **IB strategy:** *it seeks that vector of emissions (E_1) that can attain the standard at the minimum aggregate abatement cost*
-

$$
\begin{aligned}
& \min \sum C(e_i) \\
s.t.\ ED & \leq Q^* \\
E & \geq 0
\end{aligned}
$$

- IB, by definition, achieve the standard at a cost less than (or equal to) CAC program
- the IB vector will entail higher levels of emissions and higher levels of pollutant concentrations at nonbinding receptor points than will the CAC solution.
- The levels of both benefits and control costs associated with a particular standard will, in consequence, tend to be higher under a CAC than under an IB.

- They used a model developed by McGartland (1983,1984) which reflects the technological control possibilities, associated particulate reduction efficiencies, and costs for about 400 actual sources in Baltimore.
- Marginal Costs:
- $C_i'(e_i/IB)$:reflects, for each possible standard considered. the least-cost combination of control options across all particulate sources that ensures attainment at all receptors.

- $C_i'(e_i / CAC)$:adopted the basic spirit of the regulatory strategy used in Baltimore:
  - all sources were categorized and similar sources grouped together
  - marginal costs for additional control were estimated for each source category
  - when additional controls were required to reduce particulate levels, the source category with the lowest cost-per-ton was targeted for further regulation;
  - all sources within that category were required to adopt the same technology regardless of their individual costs or location.

- Marginal Benefits:
- To estimate the MB associated with alternative standards, they identified the **"exposed population"** of the Baltimore metropolitan area to one of the 23 receptors in the area (ranging from as few as 3,800 people assigned to one receptor to more than 180,000 at another)
- They calculated marginal benefits from successively tighter TSP standards for four different categories:
  - reduced premature mortality,
  - reduced morbidity,
  - reduced soiling damages to households,
  - and improved visibility

- The changes in TSP levels that would accompany successively tighter standards were first translated into physical improvements:
    - fewer sick days, fewer "statistical" lives lost, reduced soiling, and increased visibility
    - They monetized these physical improvements using recent studies

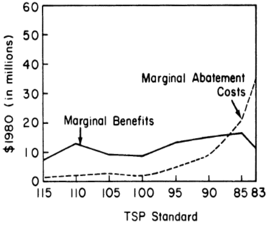
- 

FIGURE 1. LEAST-COST CASE

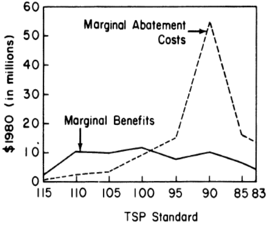


FIGURE 2. COMMAND AND CONTROL CASE

- by equating $MC = MB$, the IB approach would give us a more stringent standard than the CAC regime.

- However:The source of the confusion is the natural inclination to associate **air quality standards** with **air quality levels**.
  - an air quality standard maps into a vector of pollutant concentrations and the mapping itself depends upon the regulatory regime.
- IB would lead us to select the more stringent standard for air quality, but it does not necessarily follow that this would actually result in better air quality
- Thus, the same standard on the horizontal axis in our figures will produce a different vector of air quality under our two regulator systems.

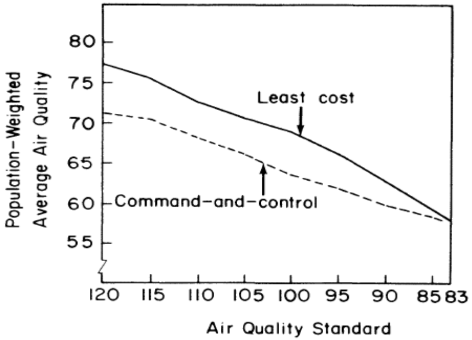
- 

FIGURE 3. POPULATION-WEIGHTED AVERAGE AIR QUALITY UNDER THE LEAST COST AND COMMAND AND CONTROL SYSTEMS

- First result: although the IB regime results in a more stringent "optimal" standard, there is really little difference in overall air quality under the "optima" of our two systems.

- This calculation is more problematic:

TABLE 3—A COMPARISON OF THE CUMULATIVE NET BENEFITS UNDER THE TWO SYSTEMS (MILLIONS OF 1980 DOLLARS)

1. *Incentive-Based Case: Net Benefits from Moving from a Standard of 120 $\mu g/m^3$ to the "Optimal" Standard of 90 $\mu g/m^3$*	
Cumulative MB	\$66.17
Cumulative MC	20.97
Cumulative Net Benefits	\$45.20
2. *Command & Control Case: Net Benefits from Moving from a Standard of 120 $\mu g/m^3$ to the "Optimal" Standard of 100 $\mu g/m^3$*	
Cumulative MB	\$33.86
Cumulative MC	15.41
Cumulative Net Benefits	\$18.45
3. *Adjustment of Net Benefits Under the CAC System*	
Cumulative Net Benefits Under CAC	\$18.45
Less: Baseline Control Costs in Excess of IB Case	7.81
Plus: Baseline Benefits in Excess of IB Case	28.67
Adjusted Cumulative Net Benefits	\$39.31

- The difference between the cumulative net benefits under the two systems is quite small. As Table 3 shows, the cumulative net benefits under the IB outcome exceed those under the CAC case by only about $6 million when evaluated at their respective "optima."

- Some sensitivity analysis using upper and lower bounds for our benefits estimates suggests that the "optimal" standard under both systems is quite sensitive to our choice of benefits measures.

- IB policies designed to achieve prescribed regulatory standards at least cost may not be so obviously superior to CAC approaches as has been supposed.

- When we take into account real-world regulatory institutions that require uniformity of fees, incentive-based programs may not clearly dominate well-designed CAC measures