ECONOMICS OF POLLUTION CONTROL

OVERVIEW OF
COST-EFFECTIVE POLICIES FOR POLLUTION CONTROL

Tables and Figures
To Accompany Lectures
Economics of Pollution Control

I. Introduction: The Temporal and Spatial Dimensions

II. Efficient allocation (optimal level) of pollution control

III. The market and pollution control

IV. Criteria for good pollution-control policies

V. Cost-effective policies for uniformly-mixed flow pollutants

   A. Efficient vs. cost-effective allocation
   B. Cost-effective pollution-control policies
   C. Technological standards
   D. Performance standards
   E. Emission charges (taxes)
   F. Tradable permits
      1. Cap-and-trade
      2. Emission reduction credits

VI. Cost-effective policies for non-uniformly mixed pollutants

   A. Single-receptor case
   B. Multiple-receptor case

VII. Comparison of charges & permits

   A. Responsiveness to: econ growth, inflation, tech change
   B. Distributional differences
   C. Conditions of uncertainty
   D. Visibility and efficiency
   E. Transaction and administrative costs
   F. Strategic behavior

VIII. Alternative solutions to environmental problems
Environmental Pollution: 
The Temporal Dimension

Let $E_t =$ Emissions of Pollutant at time $t$

$D_t =$ Decay of Pollutant at time $t$

$S_t =$ Stock of Pollutant at time $t$

\[
S_t = S_0 + \sum_{i=1}^{t} E_i - \sum_{i=1}^{t} D_i
\]

\[
\frac{dS}{dt} = \dot{S} = E_t - D_t
\]

A “Pure Stock Pollutant”: $D_t = 0$ (climate?)

A “Pure Flow Pollutant”: $D_t = E_t$ (noise?)
Environmental Pollution:  
The Spatial Dimension

• Relevant variable: degree of mixing of pollutant in receiving body (airshed, watershed, etc.)

• Local Pollutant  
  • Greatest damage near emission source  
  • Example: carbon monoxide

• Regional Pollutant  
  • Greatest damage far from emission source  
  • Example: SO₂ and acid rain

• Global Pollutant  
  • Damage distributed globally regardless of location of source  
  • Example: CO₂ and climate change
Efficient Level of Pollution Control

Total Benefits and Cost

P $ B

Q* Pollution Control

P $ MC

Q* Pollution Control

C

MB
The Market and Pollution Control

Marginal Social Cost = MPC + Marginal Damages

Marginal Private Costs (Supply)

Marginal Damages

Marginal Benefits (Demand)

$ q^* \rightarrow q'$ Quantity of Steel
Other Economic Criteria

• Economic efficiency criterion — benefit-cost analysis
  • Difficult, in part because of need for benefit assessment
• More modest criterion: *cost-effectiveness* — does policy accomplish given purpose in the least costly way?
  \[
  \min_{\{q_i\}} \sum C_i(q_i) \\
  s.t. \sum q_i \geq \bar{Q}
  \]
• Compare with efficiency criterion:
  \[
  \max_{\{q_i\}} \sum \left[ B_i(q_i) - C_i(q_i) \right] \Rightarrow q_i^* 
  \]
• Question:
  \[
  \sum q_i^* \neq \bar{Q}
  \]
• “Beware of designing fast trains to the wrong station”
• Both criteria -- efficiency & cost effectiveness -- focus on aggregate, but who gets the benefits, who pays the costs?
• Another key criterion: distributional equity
More Criteria for Selecting Environmental Policy Instruments

1. Achieve stated goals/standards?
2. Cost-effective?
3. Provide government with information it needs?
4. Monitoring and enforcement possibilities?
5. Flexible in the face of change (in tastes, technology, or resource use)?
6. Dynamic incentives for research, development, adoption, and diffusion of better pollution-control technologies?
7. Equitable distribution of financial and environmental impacts?
8. Purpose and nature of policy understandable to general public?
9. Feasible, in terms of enactment and implementation?
Cost-Effective Pollution Control Allocation (for a uniformly-mixed, flow pollutant)
Cost-Effectiveness

\[
\min_{\{r_i\}} C = \sum_{i=1}^{N} c_i(r_i)
\]

s.t. \[\sum_{i=1}^{N} [u_i - r_i] \leq \bar{E}\]
\[0 \leq r_i \leq u_i\]

If the cost functions are convex, then necessary and sufficient conditions are: (Kuhn-Tucker)

\[
\frac{\partial c_i(r_i)}{\partial r_i} - \lambda \geq 0
\]

\[
r_i \left[ \frac{\partial c_i(r_i)}{\partial r_i} - \lambda \right] = 0
\]

...among others

Thus, in a cost-effective allocation, all sources that exercise control, must experience the same marginal abatement costs.
Alternative Environmental Policy Instruments

1. Command-and-Control Approaches

   a. Technology Standards
      i. Good News: low monitoring costs
      ii. Bad News: wrong goal, not c/e, no tech chg

   b. Performance Standards
      i. Uniform Emission Standard (not c/e)
      ii. Uniform Ambient Standard (not c/e)
      iii. Non-uniform standard
           (1) Can be c/e in principle
           (2) But gov’t lacks information; politics

2. Economic-Incentive Approaches

   a. Pollution Charges
      i. Emissions/ambient fee (tax)
      ii. Deposit-refund system

   b. Tradeable Permits
      i. Cap-and-trade system
      ii. Emission-reduction-credit system
Pollution Charges

\[ MC_1 \]

\[ MC \text { $/ton} \]

\[ T \]

\[ 0 \quad 5 \quad 10 \quad 15 \]

\[ \text{Pollution Control In Tons} \]

\[ \text{Tax Paid} \]

\[ \text{Tax} \]

\[ \text{Pollution} \]

Additional Tax Paid > Additional Control Costs Avoided

(If I control more)

Area ABCD = Tax Paid

Area 0AD = Control Cost

\[ \begin{align*}
\text{Additional Tax Paid} & < \text{Additional Control Costs Avoided} \\
\text{(If I control less)}
\end{align*} \]

Firms want to minimize sum
Pollution Tax

$\text{$/ton}$

Pollution Control In Tons

$T$

MC\textsubscript{1}

MC\textsubscript{2}
Pollution Charge

Let \( e_i = u_i - r_i \)

The single firm’s problem is given by:

\[
\min_{\{r_i\}} \left[ C_i(r_i) + t \cdot (u_i - r_i) \right]
\]

s.t. \( r_i \geq 0 \)

The result for each source is:

\[
\frac{\partial C_i(r_i)}{\partial r_i} - t \geq 0
\]

\[
 r_i \cdot \left[ \frac{\partial C_i(r_i)}{\partial r_i} - t \right] = 0
\]

\( r_i \geq 0 \)

- Each firm controls at a level such that its abatement costs are equal to the tax rate.
- Hence, marginal abatement costs are equated among firms.
Incentives for Technological Change Under Conventional and Market-Based Instruments

**Performance Standard, \( Q_{\text{max}} \)**

\[
\begin{align*}
\text{T} & \quad \text{Pollution Control} \\
\text{MC}_{\text{w/o}} & \quad \text{MC}_{\text{w/t}} \\
\text{Cost Savings w/t}
\end{align*}
\]

**Emissions Tax, T**

\[
\begin{align*}
\text{T} & \quad \text{Pollution Control} \\
\text{MC}_{\text{w/o}} & \quad \text{MC}_{\text{w/t}} \\
\text{Cost Savings w/t} & \quad \text{Zero emissions}
\end{align*}
\]
Issues Facing Tax Approach

1. Government: information requirement
   a. Iterate up or down?
   b. Forget quantity, set tax where MB=MC

2. Private sector: costs may be greater under tax than with command-and-control

3. Environmental advocates: Taxes make costs visible; will result in low level

4. Politics: The t-word
Firm #2 will buy permits (control less) at price < C
Firm #1 will sell permits (control more) at price > A
Cap-and-Trade System

Let \( e_i = u_i - r_i \)
\( q_{0i} = \text{initial permit allocation} \)
\[ \sum_{i=1}^{N} q_{0i} = E_{\text{max}} \]

The single firm’s problem is given by:

\[ \min_{\{r_i\}} \left[ C_i(r_i) + p \cdot (u_i - r_i - q_{0i}) \right] \]

\[ \text{s.t. } r_i \geq 0 \]

The result for each source is:

\[ \frac{\partial C_i(r_i)}{\partial r_i} - p \geq 0 \]

\[ r_i \cdot \left[ \frac{\partial C_i(r_i)}{\partial r_i} - p \right] = 0 \]

\[ r_i \geq 0 \]

• The environmental constraint \( (E_{\text{max}}) \) is satisfied

• Marginal abatement costs are equated among firms, i.e., it is cost-effective.
Major Generic Issues for Cap-and-Trade Systems

1. Point of regulation (upstream, downstream, etc.)
   a. Input (example: carbon content of fossil fuels)
   b. Emissions (example: SO$_2$)
   iii. Ambient concentration (partial example: LA)
   iv. Exposure
   v. Risk

2. Allocation of allowances
   a. Free — how to allocate
   b. Auction — use of revenue (same as with tax)

3. Cost-containment mechanisms
   a. Banking
   b. Borrowing
   c. Safety-valve
   d. Linkage and offsets

4. Transaction costs
   a. Think about Coase
   b. Decreasing marginal transaction costs

5. Complications with non-uniformly mixed pollutants
   a. Ambient versus emissions
   b. Applies with CAT or tax
Experience with Cap-and-Trade Systems

- Leaded gasoline phasedown in 1980s A
- Criteria air pollutant trading (1974-) B
- Water-quality trading Inc
- SO$_2$/Acid Rain A-
- EU Emissions Trading Scheme B+
Comparing Charges and Tradeable Permits

1. Responsiveness to Change

A. Economic Growth – more and/or larger sources (particularly important in LDCs)
   - Fixed Supply of permits: demand increases, price rises, emissions unchanged
   - Fixed Tax: increase in aggregate emissions

B. General Price Inflation
   - Permits: higher nominal permit prices, constant real prices, no change in aggregate emissions or allocation.
   - Unit ($/ton) taxes (not ad valorem, % of price): real tax decreases, pollution levels increase.

C. Technological Change
   - Permits: marginal abatement costs decreases, permit price falls, but aggregate emissions unchanged.
   - Taxes: increase in control levels (decrease in aggregate emissions).
2. **Distributional Effects**

   - Taxes: higher costs for sources, transfer to government, property rights to gov’t (unless rebated).
   - Permits: lower costs for sources (unless auctioned)

3. **Uncertainty and Relative Efficiency** *(following slides)*

   - Weitzman analysis–relative slopes rule, only cost uncertainty matters
   - Simultaneous and correlated uncertainty
   - Empirical question

4. **Visibility to Public**

   - Taxes more transparent than permits, benefit-cost comparisons, lower public demand for regulation.

5. **Transactions Costs**

   - Permits: increase control costs directly and by reducing permit trades; also, costs are sensitive to initial allocation (for certain tc functions)
   - Taxes: administrative costs may be non-trivial

6. **Strategic Behavior**

   - Permits more susceptible, if concentration in permit market or product market.
Cost Uncertainty and the Choice of Policy Instrument

\[ |MC\ Slope| > |MB\ Slope| \Rightarrow \text{Price Instrument} \]
\[ |MC\ Slope| < |MB\ Slope| \Rightarrow \text{Quantity Instrument} \]
Benefit Uncertainty and the Choice of Policy Instrument
Simultaneous Benefit and Cost Uncertainty
And the Choice of Policy Instrument

- Positive Correlation favors Quantity Instrument
- Negative Correlation favors Price Instrument
## Alternative Solutions to Environmental Externalities

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