Lecture 2
Pollution control

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Econ 4910 - Environmental Economics - UiO

January 25, 2017
Review

Last lecture:
- Market failures
- Characterizing the pollution problem
- Determining the pollution target

This lecture: How should we design policy to meet the target?
How should we solve environmental problems?

- Will the market voluntarily solve the problem?
- Solved by democratic voting?
- Solved by binding contracts?

Involves ethical considerations:
- Who bears the cost?
- Who should pay the cost?
- Time aspect: shifting the cost on future generations?
The target and the instrument

The target: the emission target should be set such that the aggregate marginal benefit from emissions equals the aggregate marginal damage

\[ \sum MB = \sum MD \]

The instrument: should be cost-efficient.

*The cost of achieving a given reduction in emissions will be minimized if and only if the marginal costs of emission reduction are equalized for all emitters*
Cost efficiency

The use of cost-effective instruments is necessary to achieve an economically efficient allocation of resources.

- Suppose a list is available of all instruments which are capable of achieving a pollution abatement target.
  - If one particular instrument can attain that target at lower real cost than any other, then that instrument is cost-effective.

- Using a cost-effective instrument involves:
  - Allocating the smallest amount of resources to pollution control, conditional on a given target being achieved.
  - It has the minimum opportunity cost.
Least cost theorem

The least cost theorem = Equi-marginal principle

- A necessary condition to achieve abatement at least cost.
- The marginal cost of abatement (MAC) is equalized over all polluting firms.
- Focus on abatement effort: polluters that can abate at least cost should abate the most.
- This result is known as the least-cost theorem of pollution control.
Abatement

Emission reduction compared to Business as Usual (BaU)

\[ y = f(m) \]

\[ a_i = \hat{m} - m_i \]
Abatement cost

\[ c_i(a_i) = f(\hat{m}) - f(m_i) \]

Abatement is costly due to

- Reduced inputs decreases production
- Lost output gives less consumption
- Reduces utility (but emission reduction increases utility)
Example

The social planner will minimize total abatement cost for all firms, given the targets:

$$\min_{\mathbf{m}} \sum_{i=1}^{n} \mathbf{c}_i(a_i) \quad \text{s.t.} \quad M \leq M^*$$

where $c_i(a_i) = f_i(\hat{m}_i) - f_i(m_i)$ and $\sum_{i=1}^{n} m_i = M$, gives:

$$\mathcal{L} = \sum_{i=1}^{n} (f_i(\hat{m}_i) - f_i(m_i)) + \lambda \left( \sum_{i=1}^{n} m_i - M^* \right)$$

Show that the least cost theorem holds, i.e., the shadow value of emission reduction should equal across all firms
Example

Example: Two firms with different marginal abatement cost

- Production $y_i = f_i(m_i)$
- Abatement $a_i = \hat{m}_i - m_i$
- Cost of abatement: $c_i(a_i) = f_i(\hat{m}_i) - f_i(m_i), \ c'_i(a_i) > 0$
Least cost theorem

Conclusion:

- A least-cost control regime implies that the marginal cost of abatement is equalized across firms undertaking pollution control.
- A least-cost solution will in general not involve equal abatement effort by all polluters.
- Where abatement costs differ, cost efficiency implies that relatively low-cost abaters will undertake most of the total abatement effort, but not usually all of it.
How to solve the environmental problem
Solutions to the environmental problems

The environmental impact of economic activity can be looked at in terms of *insertions into* and *extractions from* the environment:

1. **Externalities: Pollution emissions**
   - Find the efficient level of emissions
   - Internalize the price of the externality

2. **Environmental degradation: Natural resource depletion**
   - Find the efficient level of extraction
   - Internalize the true cost of extracting
   - Option values: the value of preserving threatened natural resources so that they might be available for future use
Two-sided problem

Two different angels when solving the problems

- **Demand side policy**
  - Reduce demand of the damaging good/input
  - Economic incentive based instruments
  - Command and control

- **Supply side policy**
  - Limiting the supply of the damaging good/input
  - Conservation contracts
  - International agreements
Instruments
Evaluate different instruments to the cost-effective criteria
### Criteria when choosing environmental policy

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Brief description</th>
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<tbody>
<tr>
<td>Cost-effectiveness</td>
<td>Does the instrument attain the target at least cost?</td>
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<td>Long-run effects</td>
<td>Does the influence of the instrument strengthen, weaken or remain constant over time?</td>
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<td>Dynamic efficiency</td>
<td>Does the instrument create continual incentives to improve products or production processes in pollution-reducing ways?</td>
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| Ancillary benefits              | Does the use of the instrument allow for a ‘double dividend’ to be achieved?  
| Equity                          | What implications does the use of an instrument have for the distribution of income or wealth?                                                    |
| Dependability                   | To what extent can the instrument be relied upon to achieve the target?  
| Flexibility                     | Is the instrument capable of being adapted quickly and cheaply as new information arises, as conditions change, or as targets are altered?          |
| Costs of use under uncertainty  | How large are the efficiency losses when the instrument is used with incorrect information?                                                        |
| Information requirements        | How much information does the instrument require that the control authority possess, and what are the costs of acquiring it?                      |
Instruments

Instruments for achieving pollution abatement targets:

1. Voluntary approaches
2. Command and control
3. Economic incentive based instruments
1. **Voluntary approaches**

Market based approaches, without governmental interfering.

- The market solves the problem alone

Example: Consider a hypothetical world without transaction costs

→ Focus on property rights

With a firm that pollutes and a victim that is hurt

1. If the firm has the p.r. the victim can pay the firm to reduce the emissions

2. If the victim has the p.r. the firm can compensate the victim for the damages

→ Gives same level of emissions

*If both parties are free to bargain, the final amount of emissions will be independent of the initial allocation of property rights.*
Introducing Coase

However, transaction costs/bargaining power are always present and positive (and often quite high)

→ Focus on hinders to the bargaining approach

Consider a case where the victim has the p.r.

1. If the firm bears the transaction cost: Willing to pay less in compensation

2. If the victim bears the transaction cost: Requires more in compensation

→ Gives different level of emissions

*In presence of transactions costs/bargaining power, the final amount of emissions depends on the initial allocation of property rights*
The Coase theorem

How externalities are corrected with bargaining and contracts

- Coase (1960) explored the likelihood of bargaining solutions to inefficient allocations of resources.
- Parties involved in an externality situation may reach an efficient solution by bargaining among themselves.

The Coase theorem:

*Where there are complete comp. markets with no transactions costs, then an efficient set of inputs and outputs will be selected, regardless of how property rights are divided.*

Necessary assumptions:

- Well defined and enforceable allocation of property rights.
- No transactions costs.
Environmental problems

- Public externalities: Bargaining may lead to some abatement
  - every consumer is willing to pay some to avoid emissions but not enough to reach the social optimum
  - The environment is a public good, causing free-rider problems

Liability

- The juridical system may lead to efficient bargaining outcomes
  - An implicit assumption in the discussion of Coase
  - Enforcement of the contract
  - Specifying property rights

The environmental problem is not solved by voluntary approaches, but lessons from the Coase theorem are useful in developing climate treaties and conservation contracts.
The challenges with climate change

- Global: The absence of supra-national sovereign institutions
  - Difficult to legally enforce the Coasian-bargaining solutions
  - International environmental treaties

- Uniformly mixing: How can we determine whose emissions are causing what damages?
  - Whom should be compensating who?

- Time horizon: Damage appear long time after the relevant pollutants were discharged.
  - How to track down those who are liable? Those responsible - individuals or firms - may no longer exist
  - Even if one could identify the polluting part appropriately, it is not clear whether an ex post liability should be imposed.
2. Command and control

The dominant method of reducing pollution has been the use of direct controls over polluters.

→ Commonly known as *command and control instruments*.

- Examples: prohibitions and restrictions

Pros:

- Certainty of outcome
- Ability to get desired results very quickly.

Cons:

- Will not usually be cost-efficient
  - Necessary to know the shape of each polluter’s MAC function
  - Emission control must be calculated for each firm
- Lack good dynamic incentives
- Achieves the target, but to a higher cost
Command and control examples

- Control quantity or the mix of inputs
  - Require the use of some particular inputs, and restrict (prohibit) the use of others

- Technology controls
  - Require the use if special methods, or standards

- Output quotas
  - A ceiling on product outputs

- Emissions licences
  - A ceiling on emission

- Location control
  - Regulate the admission to specific locations

Can you think of some environmental problems where command and control is a suitable instrument?
Example: Command and Control

Firms differ in technology, but faces the same cap $\bar{m}$. Each firm maximize profit given the command and control-cap imposed by the government:

$$\max_{m_i} \pi_i = f_i(m_i) - K_i \quad \text{s.t.} \quad m_i \leq \bar{m} \quad (3)$$

Set ut the Lagrangian:

$$\mathcal{L} = f_i(m_i) - K_i - \lambda_i(m_i - \bar{m}) \quad (4)$$

The shadow value is no longer equal for all firms:

$$f'_i(m_i) = \lambda_i \quad (5)$$

This instrument is not cost effective, solution:

- If the government has all information about each firm’s marginal abatement cost function, an individual cap can be imposed on all firms. This would be a cost effective instrument. (Is this feasible?)
Command and control

- Controls sometimes blur the pollution target
- Administration of the instrument.
- Although control-based instruments may be lacking in cost-effectiveness terms, they can be very powerful
  - capable of achieving large reductions in emissions quickly
  - particular if the abatement technology is available
- Control instruments have certainly resulted in huge reductions in pollution levels, compared with what would be expected in their absence.
3. Economic incentive instruments

Incentive-based instruments work by altering the structure of pay-offs that agents face, thereby creating incentives for individuals or firms to *voluntarily* change their behavior.

- Change the pay-off structure by changing relative prices
- Any instrument which manipulates the price system could also be regarded as an incentive-based instrument.

There are 3 main instruments:

1. Tax pollution emissions
2. Subsidies emission abatement
3. Enforce tradeable emission permits/quotas
Example: Incentive based instruments

Emission quota: \( q \) is the price of quotas

\[
\max_{m_i} \pi_i = f_i(m_i) - K_i + q(\bar{m} - m_i) \tag{6}
\]

Tax \( \tau \) on emissions

\[
\max_{m_i} \pi_i = f_i(m_i) - K_i - \tau m_i \tag{7}
\]

Subsidize abatement

\[
\max_{m_i} \pi_i = f_i(m_i) - K_i + s(\bar{m} - m_i) \tag{8}
\]

\( \Rightarrow \) Quotas and taxes equalize if \( q = \tau \) \( \Rightarrow \) Subsidies and taxes equalize if \( s = \tau \)
An economically efficient emissions tax

Marginal damage
$D'(M)$

Marginal benefit of emissions
$B'(M)$

emissions, $M$

The economically efficient level of emissions abatement

Marginal cost of abatement
$c'(a)$

Marginal benefit of abatement

$a^* = M^{BAU} - M^*$

abatement, $a$
Tradable emission permits

- Any emission increase in the system must be offset by an equivalent decrease elsewhere.
- There is a limit on the total quantity of emissions allowed.
- The regulator does not need to determine how quotas are allocated among firms, because they trade until the equilibrium is met.
- However, initial allocation must be determined.
  - Allocate the quotas for free = subsidizing
  - Firms have to bargain over quotas: may give distributional effects
Key result: Taxes/subsidies/quotas are cost-efficient policy instruments

- Gives the socially efficient aggregate level of pollution
- Achieve the target in a cost-effective way
- Marginal abatement cost is equal over all abaters
- Firms adjust their firm-specific abatement levels to equate their marginal abatement cost with the new cost structure.
- As the tax rate is identical for all firms, so are their marginal costs.

⇒ The government does not need to know each firm’s MAC function, only the aggregate MD and aggregate MB
⇒ Some emission reduction will be obtained, but the amount is probably unknown
⇒ In practice it is very difficult to measure external costs with a degree of accuracy — make reasonable estimates
Complicating the analysis

Closer to reality:

- What if the externality is global?
  - International cooperation
  - Carbon leakage
- What if the problem evolves over time?
  - Dynamic models
- What if the costs and benefits are unknown?
  - Estimate the value of the environment
- What if policy is not set by a benevolent social planner?
  - Use insights from political economy
Why is there still an environmental problem?

When we know the solution and the right instrument, why do we still have a huge environmental problem more alarmingly every year? Economists are not the ones implementing policies

- Environmental policy is decided by politicians
- Environmental policy is “unpopular”, or “unfair”
- Environmental policy is given less priority
- Environmental policy is subjected to pressure from interest groups (lobby groups)
- Environmental policy suffer from misleading information
- Environmental policy suffer from uncertainty
Alternative approaches:

Social norms as solutions by Nyborg et al. (2016) suggest:
- We are stuck in cycles of socially damaging behavior
- Formal institutions are at times unable to enforce the optima
- Then informal institutions (social norms), can be important
- Policy can support social norm changes
- Use knowledge from behavioral economics and psychology

Supply side policy by Harstad (2012) suggest:
- Carbon leakage originate from nonparticipating countries
- World prices decline when a coalition reduces its demand
- Nonparticipating countries is incentivized to extract more
  → The coalition should buy up resource deposits, such that further extraction is not longer possible
Policy update: Climate change

The worlds biggest polluters:

1. China: Taking the problem seriously, developing a quota system, reduced air pollution since 2011
2. USA: Scott Pruitt is the new leader of EPA
3. EU: The EU ETS covers 45% of the emissions
4. India: Developing green energy sources, but lack necessary infrastructure
5. Russia: A rhetorical shift, but little action?

Paris agreement

- Ratified by 117 countries in Marrakesh, November 2016

Norway

- Part of the EU ETS
- Norway issues licenses for Arctic drilling
References (Supplementary readings)

