Environmental Economics – Lecture 2

Emission control: Targets

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Perman et al (2011) ch 5

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Review last lecture

1. Overview and Organisation
2. Environment $\leftrightarrow$ Economy
3. Efficient and optimal allocation of goods
4. Public goods and the Free-rider problem
5. Externalities and the Coase theorem

Key concepts last lecture

- Markets allocate goods efficiently under ideal conditions but need not be optimal from a social point of view
- Efficiency for private goods: $MRUS^A = MRUS^B = MRT$
- Public goods are goods that are both non-excludable and non-rivalrous
- Efficiency for public goods: $MRUS^A + MRUS^B = MRT$
- Public good implies presence of externality
- Externality does **not** imply existence of public good
- Uncorrected externalities lead to inefficiencies

Preview this lecture

1. The efficient level of emissions
2. Benefits and damages from emissions
3. Different types of pollution problems

The efficient level of emissions

Trade-off between benefit and damages from emission.

Standard solution: M^* defined by $B'(M) = D'(M)$

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The efficient level of emissions

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Standard solution: M^* defined by $B'(M) = D'(M)$

- Marginal benefits from emission are decreasing (linked to marginal utility of consumption)
- Marginal damage from emission is increasing (gradually reduced ecosystem services or increased valuation of unspoiled nature)

Benefits from emissions

- Consumers have preferences for a private good y and a public good E (environmental quality).
- Firms competitively produce the private good y. Production causes emissions M that reduce E.
- Firms can exercise (costly) effort to reduce emissions:
  - End-of-the-pipe cleaning
  - Changed technology, cleaner inputs, increased diligence
  - Reduced production

Benefits from emissions

Figure: The solution to pollution is dilution?

Benefits from emissions

[Notation: Aggregate emissions M are sum of emissions m_j from all firms $j = 1, 2, ...$]

- For each firm j, suppose that inputs can be separated into those that are used for producing y and those that are used for reducing m.
- Production and emissions linked by a function $y_j = f(m_j)$.
- As if emissions are an input to production:
  - For a given y, m can only be reduced at the cost of increasing other inputs
  - If all other inputs are fixed, y can only be increased by increasing m.
- Let $\hat{m}_j$ be j's emissions when no effort to reduce emissions. Furthermore: $f(m_j) \geq 0, f'(m_j) \geq 0, f''(m) \leq 0$ and $f(0) = 0, f'(\hat{m}) = 0$.

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Benefits from emissions and costs of abatement

Firm's benefits from emission are the avoided costs of abatement.

- Abatement is the emission reduction compared to the baseline scenario: $a_j = \hat{m}_j - m_j$
- Abatement cost loss due to reduced output (keeping the other inputs fixed): $c_j(a_j) = f(\hat{m}_j) - f(m_j)$
- Marg. abatement cost equals marg. productivity of emissions:

$$\frac{\partial c_j(a_j)}{\partial a_j} = \frac{\partial [f(\hat{m}_j) - f(m_j)]}{\partial m_j} \frac{\partial m_j}{\partial a_j} = -f'(m_j)(-1) = f'(m_j)$$

- c is increasing and convex, defined on $[0, \hat{m}_j]$ with $c(0) = 0$ and $c(\hat{m}_j) = f(\hat{m}_j)$.

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Benefits from emissions

The firm's objective is to maximize profits:

$$\pi(m_j) = f(m_j) - b_j - \tau m_j$$

where:

- the price of the (numeraire) good is normalized to 1
- b are the (fixed) costs of the other inputs to production
- τ is the price per unit of emission that the firm has to pay

Without regulation, $\tau = 0$ and $m_j^* = \arg\max \pi = \hat{m}_j$

Damages from emissions

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Damages from emissions

Obtain a measure of damages from emissions through consumer's preferences for E, measured in unit of the consumption good y.

- Let E and M be connected via some function z such that $E = E_0 - z(M)$ (where z is increasing and convex)
- How much would consumer pay for marg improvement of E?
  - Differentiate $U_i = u(y_i, E)$ keeping U_i fixed:

$$dU_i = \frac{\partial u}{\partial y_i} dy_i + \frac{\partial u}{\partial E} dE = 0 \quad \Leftrightarrow \quad -dy_i = \frac{u'_E}{u'_{y_i}} dE$$

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- However, interested in emissions M: substitute $dE = -z'(M)dM$
- Let $dM = 1$ so that our measure for $MWTP_i$ is $z'(M)\frac{u'_E}{u'_{y_i}}$

Damages from emissions

From individual $MWTP$ to aggregate $D(M)$:

- Is measurement possible?
  (discussed in Lecture 5)
- Is aggregation possible?
  ($MWTP_i > MWTP_j$ could be caused by differences in the valuation of y)
- Here focus on efficiency and suppose zero income / distribution effects.
- $D'(M) = z'(M) \sum_i \frac{u'_E}{u'_{y_i}}$

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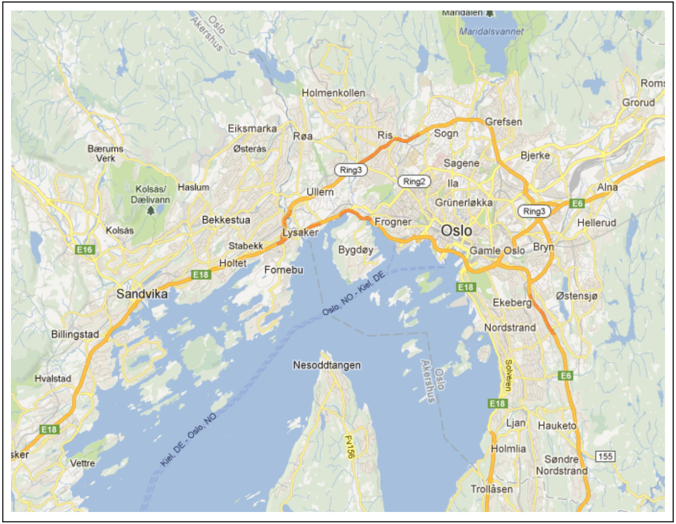
We know that efficiency requires $B'(M) = D'(M)$:

- $B'(M) = \frac{\partial \sum_j f(m_j)}{\partial m_j} = f'(m_j)$
- $D'(M) = z'(M) \sum_i \frac{u'_E}{u'_{y_i}}$

The market solution is $f'(m_j) = \tau$

- Task of regulation: $\tau = z'(M) \sum_i \frac{u'_E}{u'_{y_i}}$

Discussion: Where to put a waste treatment plant?



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Different types of pollution problems

- In the model so far, environmental quality was impacted directly by emissions and there was no time dimension: The "static flow pollution" model
- Often, emissions accumulate to form a stock of some stock A of a harmful substance. Damages are then a function of A.
  (a) If the stock dissolves quickly, no need to take time into account: "short-lived stock pollutant"
  (b) If the stock dissolves slowly: explicit dynamic modeling necessary: "long-lived stock pollutant" (Lecture 9)
- Even in case (a), the distinction between stock and flow may matter when:
  - space matters
  - there are non-convexities in the damage function

Different types of pollution problems

Short-lived stock pollutants: Are emissions "uniformly mixing"?

- If yes, model stock as $A = kM$
- If not, damages depend on relative position of the I "sources" and J "receptors". Model stock as $\mathbf{A}_{I\times 1} = \mathbf{T}_{I\times J}\mathbf{M}_{J\times 1}$
- Objective is now: $\max NB = \sum_i B_i(m_i) - \sum_j D_j(A_j)$

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- Substitute: $\max NB = \sum_i B_i(m_i) - \sum_j D_j\left(\sum_i t_{ji} m_i\right)$

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- Substitute: $\max NB = \sum_i B_i(m_i) - \sum_j D_j\left(\sum_i t_{ji} m_i\right)$
- Efficiency condition is: $B_i'(m_i) = \sum_j D_j'(A_j) t_{ji}$

Key concepts this lecture

- The emission target should be set such that the aggregate marginal benefit from emission equals the aggregate marginal damage from emission.
- Equivalently, the marginal abatement costs should equal the total willingness to pay for a marginal improvement of environmental quality
- Pollution can be classified as flow- or stock pollution. The latter can be short-lived or long-lived, uniformly mixing or non-uniformly mixing.

Preview next lecture

Emission control: Instruments Perman et al (2011) ch 6

- Criteria for choosing emission control instruments
- Voluntary approaches
- Command-and-control measures
- Incentive-based instruments