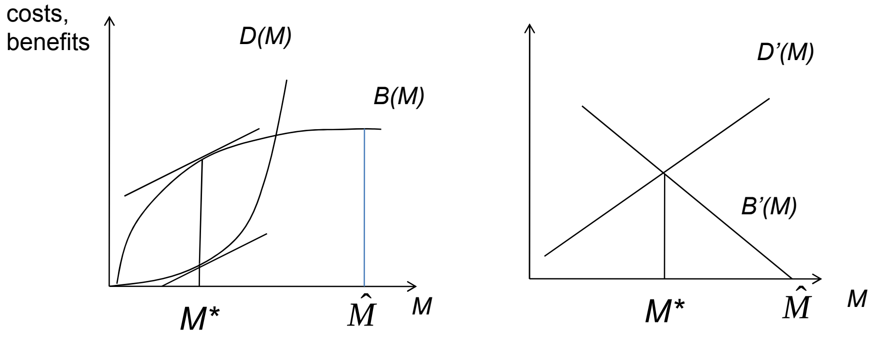
Lecture 2

ECON 4910, Environmental Economics
Spring 2011

- More on the benefits of pollution
- The damages of pollution
- Pareto optimality and the market

Benefits and damages, uniformly mixing flow pollutant



Social optimum: $B'(M^*) = D'(M^*)$

The benefits of pollution

- If the production function may differ between firms, equations from last time can be written

(1) $y_j = f_j(m_j)$ — Firm *j*'s production of *x*

(2) $\pi_j = f_j(m_j) - b_j - \tau m_j$ — Firm *j*'s profit

(3) $f_j'(m_j) = \tau$ — 1.o.c. for profit max.

(4) $B(M) = \sum_j f_j(m_j)$ — Aggregate benefits

where m_j is firm *j*'s emissions, b_j is *j*'s fixed costs, τ = unit price of emissions, $M= \sum_j m_j$ = aggregate emissions.

- If $\tau = 0$: Every firm j emits $\hat{m}_j$, where $f_j'(\hat{m}_j) = 0$.

What is B'(M)?

- B'(M): The change in maximum possible private good production if total emissions increase marginally

$$\partial B(M)/ \partial m_j = \partial \sum_j f_j(m_j)/ \partial m_j$$
$$= f'_j(m_j)$$

  - If marginal productivity differs, *j* will matter
  - Different $f'_j(m_j)$:
- B(M): The *maximum possible* private good production, given aggregate emission level M
  - Implies: emissions efficiently distributed along B(M), i.e.:

    $f'_j(m_j) = f'_k(m_k)$

    $B'(M) = f'_j(m_j) = f'_k(m_k)$
  - If $f'_j(m_j) \neq f'_k(m_k)$, we are *off* the B(M) curve

Marginal production and abatement

- $f_j'(m_j)$ = the marginal productivity of emissions
  = lost x production in firm *j* if m_j is reduced 1 unit
- Firm j's marginal abatement cost:
  the cost, in units of x, of 1 reducing m_j 1 unit
  $= f_j'(m_j)$
- $f_j'(m_j)$ can be interpreted both as the
  marginal productivity of emissions
  marginal abatement cost

Benefits and damages of pollution

- Aggregate benefits: Production of *x*
  - Measurement unit: *x*
  - ”Benefits”: Consumers have preferences for *x*.
- Aggregate damages of pollution
  - To compare: must be measured in units of *x*
  - How to define and measure ”damages”?
  - Key: Consumers have preferences for E.

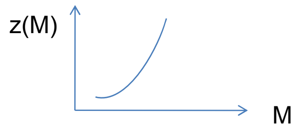
Damages of pollution

- Environmental quality *E:* a pure public good
  - visibility, water quality
- Environmental quality (physical units):

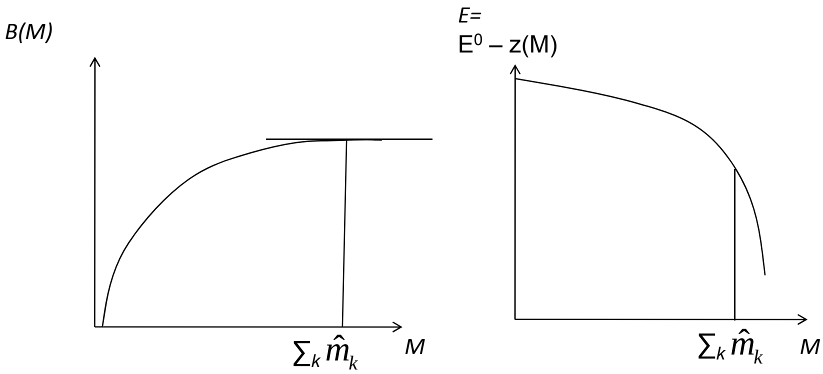
(5) $$E = E^0 - z(M) = E^0 - z(\sum_k \hat{m}_k)$$

for $k = 1,\ldots,K$, where K = # of firms, E^0=initial env. quality, and z(M) = physical damages

- M = a uniformly mixing flow pollutant
  - impact on E depends on the sum of instant emissions, not on location or history
- Assume z increasing and convex: z'> 0, z''≥ 0
  - marginal physical damages increasing in M



Emissions and environmental quality; no regulation, production to consumption externality



If $\tau = 0$, and firms max. profits, we will have

$$E = E^0 - z(\sum_k \hat{m}_k)$$

because no firm will abate.

The damage function D(M)

- Damages to what, or whom, valued how?
  - How important is the physical damage z(M)?
  - To be directly compared to the benefits B(M): must be measured in units of x
- Key: Consumers' preferences
  - How much x will consumers give up to improve E?
  - *Marginal willingness to pay for environmental benefits*
  - Two elements: Physical damage, valuation

> Note:
>
> Damages of pollution M = reduced environmental benefits *(***benefits of E**)
>
> B(M) function: Economic benefits (**benefits of M**)

Preferences

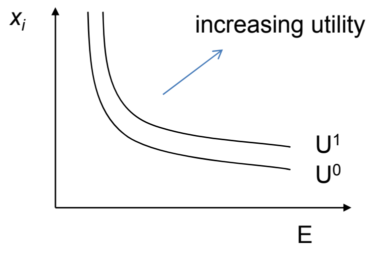
- Consider a single consumer *i*
- *i*'s preferences:

  (6) $U_i = u_i(x_i, E)$

  where u_i = *i*'s utility function (preferences may differ from others'), and x_i = *i*'s private good consumption
- Assume u_i is
  - Increasing: $u'_{ix} > 0$, $u'_{iE} > 0$
  - Quasiconcave: Indifference curves curved towards origo (the more *i* has of x, the more x is she willing to give up to get more E – & vice versa)

Utility

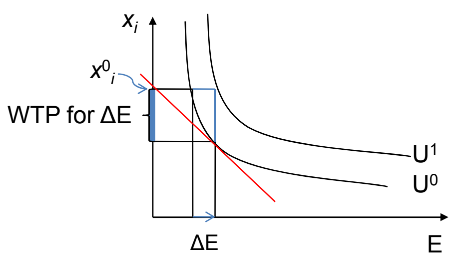
- We cannot measure utility (”utils”) directly
- We know: increasing consumption of one good, keeping the other fixed, will increase utility (non-satiation).



- If we increase E and keep x_i fixed, U_i increases
- Can we measure this increase in units of x_i?

Willingness to pay

- Consider a discrete change in E, ΔE
- E is a public good
  - If provided, *i* gets ΔE regardless of who provided/who paid
  - Consider only env. benefits, disregard costs here.
- When E increases: How much *x* could we take from the consumer and still keep her at U^0?



- Benefit measure of ΔE: The amount of x the consumer would be willing to pay to get ΔE
- On the margin: WTP for increased E = Required compensation for red. E = marg. rate of substitution

Formal derivation of MWTP

- Marginal WTP: How large change in *x* would exactly offset the utility change of a marginal change *dE*?
- Utility: $U_i = u_i(x_i, E)$
- Differentiating, assuming utility is kept constant:
- $dU_i = u'_{ix}dx_i + u'_{iE}\,dE = 0$

  $-\,u'_{ix}dx_i = u'_{iE}\,dE$

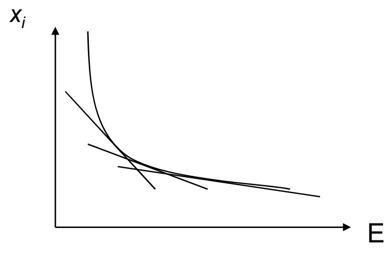
  $-dx_i = (u'_{iE}/u'_{ix})dE$
- The max. amount of *x* you can take away without leaving *i* worse off = marginal rate of substitution times the change in E
- Let dE = 1 ⟶
- $\text{MWTP} = u'_{iE}/u'_{ix}$

WTP for changes in what?

- We have derived a benefit measure in units of *x* for changes in *environmental quality*
- If price of *x* = 1: MWTP is a monetary measure
- How about WTP for marginal *pollution* changes?
- Recall eq. (5): $E = E^0 – z(M)$ $z' > 0$
  - The higher M, the greater loss of E
- $dE = -z'dM$
- $MWTP_i = (u'_{iE}/u'_{ix})dE = -(u'_{iE}/u'_{ix})z'dM$
- MWTP for dE = MWTP for dM multiplied by (- z')

Properties of MWTP

- MWTP= the amount of x the consumer can give up in exchange for a marginal increase in E, keeping U_i constant
- $MWTP_i = (u'_{iE}/u'_{ix})dE = -(u'_{iE}/u'_{ix})z'dM$
- **For a *given* U_i,** (u'_{iE}/u'_{ix}) decreases with E, due to quasiconcavity

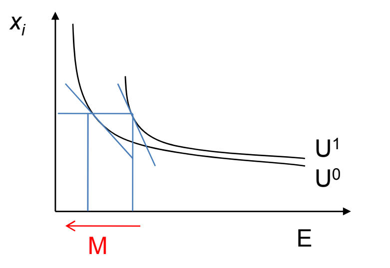


  – conversely, (u'_{iE}/u'_{ix}) is increasing in M
- If the utility level is allowed to change: Depends on the utility function

Marginal damages for i: increasing in M?

- Damage for *i,* one unit increase in M:

  $-MWTP_i = (u'_{iE}/u'_{ix})\, z'$



- This damage could be increasing or decreasing in M
  – requires more specific assumptions on the utility function.

Aggregate marginal damages

- Possible definition of D(M): Total consumer value of physical damages
- Usually: More relevant to consider small changes than elimination of all pollution
  - Properties of D'(M) more interesting than D(M) itself
- Consumer *i*: Marginal damage of increased M, measured in *x*:

  $MWTP_i = (u'_{iE}/u'_{ix})z'dM$
- *n* consumers, same change
- Sum of ind. damage, units of x: $\sum_n MWTP_i = z'dM \sum_n (u'_{iE}/u'_{ix})$

  (Change in E: $z'dM$; Valuation: $\sum_n (u'_{iE}/u'_{ix})$)
- Let dM=1, and let this be our measure of D'(M):

  $D'(M) = z' \sum_n (u'_{iE}/u'_{ix})$

Increasing marginal damage

- Is D'(M) increasing in M?

  $D'(M) = z' \sum_n (u'_{iE}/u'_{ix})$
- z'(M) depends on M
  - We know: z(M) increasing and convex: z'>0, z''≥0
  - z''≥0 means: z' is increasing in M
- (u'_{iE}/u'_{ix}) depends on M
  - Not necessarily increasing in M
- If $\sum_n (u'_{iE}/u'_{ix})$ is constant or increasing (or: not ”too decreasing”) in M: D'(M) is increasing
  - will assume that this holds

  ⇒ D'(M) increasing in M

Aggregation and conflict of interests

- Controversial & difficult:
  - Aggregating from individual to social damages
- Private goods:
  - Low valuation -> consumer buys less
  - In equilibrium: equal MSB for all (= product price)
  - Public goods: Same supply for all
  - u'_{iE} / u'_{ix} (MSB) will differ
  - Low valuation: cannot choose to buy less; must 'agree'
  - Hard to separate efficiency from distributional concerns!
- $MWTP_i > MWTP_j$ may not mean $dU_i > dU_j$
  - *i* is willing to give up more *x* for increased *E* than *j* is
  - but: x may be more important for j than for i

To focus on efficiency:

- Return to this later (CBA). For now:
  - Assume that any unwanted distributional effects can be costlessly compensated – and thus disregarded in the efficiency analysis.
- Requires:
  - Perfect information (preferences are known) & feasible lump-sum transfers (costless side payments)
- If this is not satisfied:
  - Separating efficiency from distribution in economies with public goods is NOT trivial.

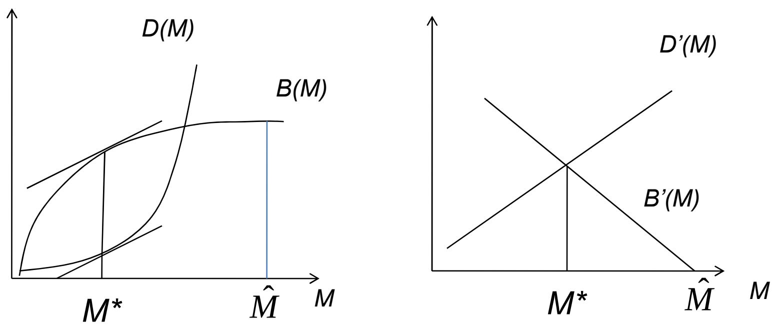
Maximizing net benefits

- In the specific model,
  - $B'(M) = f_j'(m_j)$ (which is equal for every j)
  - $D'(M) = z'(M)\sum_i(u'_{iE}/u'_{ix})$ (for all i = 1,…,n)
- We already know: Max net benefits requires B'(M) = D'(M)
- Hence, max net benefits imply
  $f_j'(m_j) = \sum_i(u'_{iE}/u'_{ix})z'(M)$
- That is,

  the **marginal abatement cost should equal the sum of marginal willingness to pay** to avoid pollution

- Samuelsonian condition for optimal provision of public goods
  Note: Hinges on our definition of benefits and damages

Max net benefits



Pareto efficiency

- *Pareto efficiency:* A situation in which no-one can become better off without someone else becoming worse off
- To characterize a Pareto optimal situation:

  Max U_i subject to $U_j = U_j^0$ (fixed) for every $j \neq i$,

  taking into account the production possibilities in the economy
- Generally - when conflicting interests:

  Pareto improvement ≠ increase in net benefits
  - If one person must pay for reduced M, while everyone gets environmental benefits, this one person may still lose
  - But net benefits, as defined here, may be positive

PO and net benefits

- Pareto optimality and net benefit maximization is **equivalent if no conflict of interest**
- With *costless lumpsum-transfers* and *perfect information*, compensations can (potentially) eliminate conflicts
- If $D'(M) < B'(M)$, and M increases:
  - value of increased x > marginal env. damage
  - losers may be compensated for less than winners' gain
  - The initial situation cannot have been PO
- If $D'(M) > B'(M)$, and M decreases:
  - value of env. improvement > value of decreased x
  - losers may be compensated for less than winners' gain
  - The initial situation cannot have been PO
- Pareto efficiency: $B'(M) = D'(M)$

First order conditions, PO

$$f'_k = f'_l$$

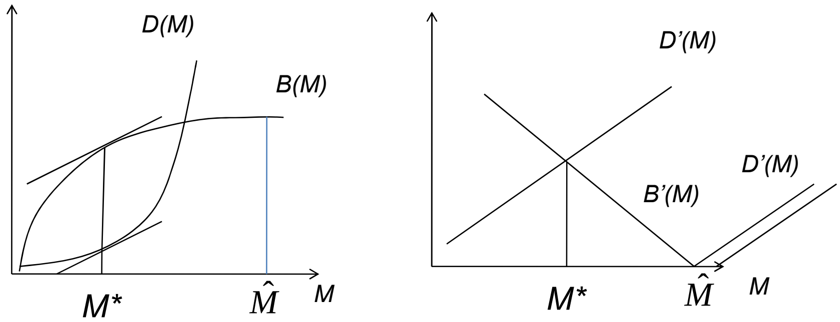
$$f'_k = \sum_{j=1}^{n} \frac{u'_{jE}}{u'_{jx}} z'$$

That is:
Marginal productivity (marginal abatement cost) should be equal for each firm
This marginal productivity should equal *the sum* of all marginal willingness to pay to reduce M.
In other words: The benefit of increasing M, in terms of more production of x, should equal the costs of increasing M, in terms of consumers' valuation of the reduced environmental quality.

The market

- Assume: Consumers consider M (and thus E) exogenously fixed
  - Consumers have no active role: passive recipients
- Pollution levels: determined by firms' profit maximization
- Market solution: If no regulation, M = $\sum_k \hat{M}_k$
- Is this Pareto efficient?

The market



Can B'=D' hold at $\sum_k \hat{M}_k$?

If D'(M) > 0 for every M > 0: *No*

Unregulated market outcome

- Profit max. producers: $f_j'(m_j) = 0$ (*)
- PO requirement: $f_j'(m_j) = z'\sum_i(u'_{iE}/u'_{ix})$ (**)
- (*) and (**) cannot hold simultaneously:
  - by assumption: u'_{iE} and $u'_{ix} > 0$
  - by assumption: $z'(M) > 0$
  - That is: D'(M) > 0 for every M > 0
- The market solution is not Pareto efficient: It gives too much pollution.

Next time

- Bargaining
- Policy instruments

- Readings: Perman et al., Ch.7