# Environmental Economics – Lecture 6

## Cost-Benefit Analysis

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Perman et al (2011) ch. 10 and 13

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# Review last lecture: Valuation

1. Theory
   - Categories of environmental benefits
   - WTP and WTA
2. Practice
   - Stated preference methods (in part. "contingent valuation")
   - Revealed preferences: Travel cost method, Hedonic pricing, Production function based techniques

# Preview this lecture

1. Choosing $A$ over $B$ or a heuristic definition of CBA
2. Cost-benefit analysis in a static and certain world
   - Tests for marginal and non-marginal projects
   - CBA and social welfare functions
3. Dynamic aspects
4. Accounting for uncertainty, risk, and irreversibility

# A heuristic definition of cost-benefit analysis

Carry out a project if $\mathrm{E}[NPV] > 0$

- $NPV$ = Net-Present Value = $\sum_0^T \delta^t NB_t$
- $NB_t$ = Net-Benefits at time $t$ = $\sum_i^N WTP_i - C$

In politics, relevant question is whether $NPV^A > NPV^B$.

# Choosing $A$ over $B$

- Formidable moral-philosophical problem.
- The Pareto-principle is nice, but impracticable: There will almost always be some that lose from a policy choice.
- Alternative: Kaldor-Hicks criterium (recall lecture 1): "Situation $A$ is better than situation $B$ iff there is some *hypothetical* distribution of resources that *could* make everyone better of under $A$ than under $B$".
- Drawback: Ignores distributional aspects!
- Advantage:
  1. Gives complete ordering
  2. Guide the way to actual Pareto improvement
  3. In random draw over many similar projects, it makes everyone better-off *on average*
  4. Focus on increasing the pie, rather than fighting over how to allocate it

# Marginal project in a time-less and risk-less word

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This rests on a first-order Taylor approximation:

- Choose some vector $\mathbf{X}$ close enough to $\mathbf{Q}$. Production possibility set is: $\{\mathbf{X} | \mathbf{PX} \leq \mathbf{PQ}\}$
- Now $\mathbf{Y} = \mathbf{X} + \mathbf{\Delta Q}$
  and $\{\mathbf{Y} | \mathbf{PY} = \mathbf{P}(\mathbf{X} + \mathbf{\Delta Q}) \leq \mathbf{PQ} + \mathbf{P\Delta Q} = \mathbf{PQ} + NB\}$
- PPF has been pushed out if and only if $NB > 0$

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Does not hold for non-marginal projects

# CBA and social welfare functions

Define social welfare function: $W = w\big(U_1(x_1, E), ..., U_N(x_N, E)\big)$

Project: environmental improvement $dE$ at cost per person of $C_i = -dx_i$

$$dW = \sum_i w_i \left( \frac{\partial U_i}{\partial x_i} dx_i + \frac{\partial U_i}{\partial E} dE \right)$$

$$= \sum_i w_i \frac{\partial U_i}{\partial x_i} \left( -C_i + \frac{\partial U_i / \partial E}{\partial U_i / \partial x_i} dE \right)$$

$$= \sum_i w_i \frac{\partial U_i}{\partial x_i} (WTP_i - C_i)$$

- If welfare weights $w_i \frac{\partial U_i}{\partial x_i}$ are the same for all, standard CBA ranks projects according to social welfare

# CBA and social welfare functions

- $w_i$ are a purely normative choice
- $\frac{\partial U_i}{\partial x_i}$ (marginal utility of an extra unit of income) are descriptive, but not observable
- The assumption that $w_i \frac{\partial U_i}{\partial x_i}$ is the same for all cannot be verified.

Unweighted utilitarianism:

- $W = U_1 + ... + U_N \quad \Rightarrow \quad w_i = 1$ for all $i$.
- If $\frac{\partial U_i}{\partial x_i} > \frac{\partial U_j}{\partial x_j}$: equal $w_i$ implies *larger* weight on $i$'s WTP than $j$'s.
- If $\frac{\partial U_i}{\partial x_i} > \frac{\partial U_j}{\partial x_j}$: standard CBA (equal weight on everyone's WTP) implies $w_j > w_i$
- Standard CBA systematically favors those who care little about money at the margin

# Dynamic aspects

- Comparisons between different people living at the *same* time is difficult: still harder to compare utility of different people living at *different* times!
- Especially worrisome when the points in time are far apart:
  - Will preferences stay the same?
  - Which discount rate to use?
  - How much richer will future generations be?
- Long-lived stock pollution problems are extremely sensitive to the discount rate.
  - At a 1% discount rate, we would be willing to pay ca. 370.000 NOK to avoid a damage of 1 million NOK in a century.
  - At a 3% discount rate we would pay up to 52 thousand NOK,
  - at a 10% discount rate, we would not even pay 73 NOK.

# Uncertainty, **risk**, and irreversibility

- Agent's expected utility is
  $\mathrm{E}[U] = pU(x, E_{good}) + (1-p)U(x, E_{bad})$
- Define the "option price" $OP_{\hat{p}}$ that an individual would pay to increase the likelihood that state *good* occurs from $p$ to $\hat{p}$ as:
  $\hat{p}U(x - OP_{\hat{p}}, E_{good}) + (1-\hat{p})U(x - OP_{\hat{p}}, E_{bad}) =$
  $pU(x, E_{good}) + (1-p)U(x, E_{bad})$
- Note that in book, $OP = OP_0$. They further differentiate:
  $OP = \mathrm{E}[CS] + OV$

# Uncertainty, risk, and **irreversibility**

Irreversibility is a "buzzword". People rather have the option to change course in the future: Introduce "quasi-option value" (following the notation in Traeger,REE, 2014 `http://dx.doi.org/10.1016/j.reseneeco.2014.03.001`):

Define the PV under anticipated learning by:

$$V^l(0) = u_1(0) + \mathrm{E}\left[\max_{x_2\in\{0,1\}}\left\{u_2(0,x_2,\tilde{\theta})\right\}\right]$$
$$V^l(1) = u_1(1) + \mathrm{E}\left[u_2(1,1,\tilde{\theta})\right],$$

the PV under the *p*ossibility of *p*ostponement:

$$V^p(0) = u_1(0) + \max_{x_2\in\{0,1\}}\left\{\mathrm{E}\left[u_2(0,x_2,\tilde{\theta})\right]\right\}$$
$$V^p(1) = u_1(1) + \mathrm{E}\left[u_2(1,1,\tilde{\theta})\right],$$

and the PV of a *n*ow or *n*ever decision:

$$V^n(0) = u_1(0) + \mathrm{E}\left[u_2(0,0,\tilde{\theta})\right]$$
$$V^n(1) = u_1(1) + \mathrm{E}\left[u_2(1,1,\tilde{\theta})\right]$$

# Uncertainty, risk, and **irreversibility**

Using these definitions, we see how the $NPV$ decision rule has to incorporate the $QOV$ while the "full value of sophistication" additionally incorporates the $SOV$. We have:

$$NPV = V^n(1) - V^n(0) > 0$$

$$QOV = (V^l(0) - V^l(1)) - (V^p(0) - V^p(1)) = V^l(0) - V^p(0)$$

$$FVS = V^l(0) - V^n(0) = \underbrace{V^l(0) - V^p(0)}_{QOV} + \underbrace{V^p(0) - V^n(0)}_{SOV}$$



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# **Uncertainty**, risk, and irreversibility

Decision rules under uncertainty

1. maximin
2. maximax
3. minimax regret
4. assign subjective probabilities

| | C | D | E |
|---|---|---|---|
| A Conserve the wilderness area as a national park | 120 | 50 | 10 |
| B Allow the mine to be developed | 5 | 30 | 140 |

# Preview next lecture: Behavioral aspects and experimental evidence

1. Private contributions to public goods (Nyborg & Rege, 2003)
   - Discuss theoretical predictions and empirical evidence for various alternative behavioral models
   - Special focus on the role of public policy ("crowding out" / "crowding in")

2. Evidence from lab-experiments (Noussair & van Soest, 2014)
   - What affects the propensity to cooperate?
   - How to design market institutions for environmental goods and services?