Lecture 6

ECON4910 Environmental Economics

Previous lectures:

How to solve an environmental externality

- Cost effectiveness
- Different types of pollution
- Different types of instruments
  - Taxes, quotas, lisences, subsidies, bargaining

Public goods and services implies missing markets

- Market failure: negative externalities are not corrected or taken into account when the market value is missing for these goods

This lecture:

- **Ch. 11** Cost-benefit analysis

«How to choose between different investment projects, a tool for decision making»

- **Ch. 12** Valuing the environment

«How to measure and incorporate the natural environment in cost-benefit analysis»

- **Ch. 13** Irreversibility, risk and uncertainty

«How can we handle uncertainties and the risk of irreversible outcomes in cost-benefit analysis»

CHAPTER 11

Cost-benefit analysis

Cost-benefit analysis

Definition:

- Cost–benefit analysis (CBA) is a systematic approach to estimate the short and long term consequences
  - measuring *all costs* and *all possible profits and benefits* from an investment project proposal
  - taking into account both quantitative and qualitative factors
  - sometimes called benefit–cost analysis (BCA)
- CBA, is the social evaluation of *marginal* projects, correcting for a potential market failure
- ECBA: Environmental impacts of projects/policies are often externalities, both negative and sometimes positive
- CBA seeks to attach *monetary values* to external effects so that they can be taken account of, along with the effects on ordinary inputs and outputs

How shall the regulator / the policy makers rank different investment projects?

Economists: Follow the efficiency criteria

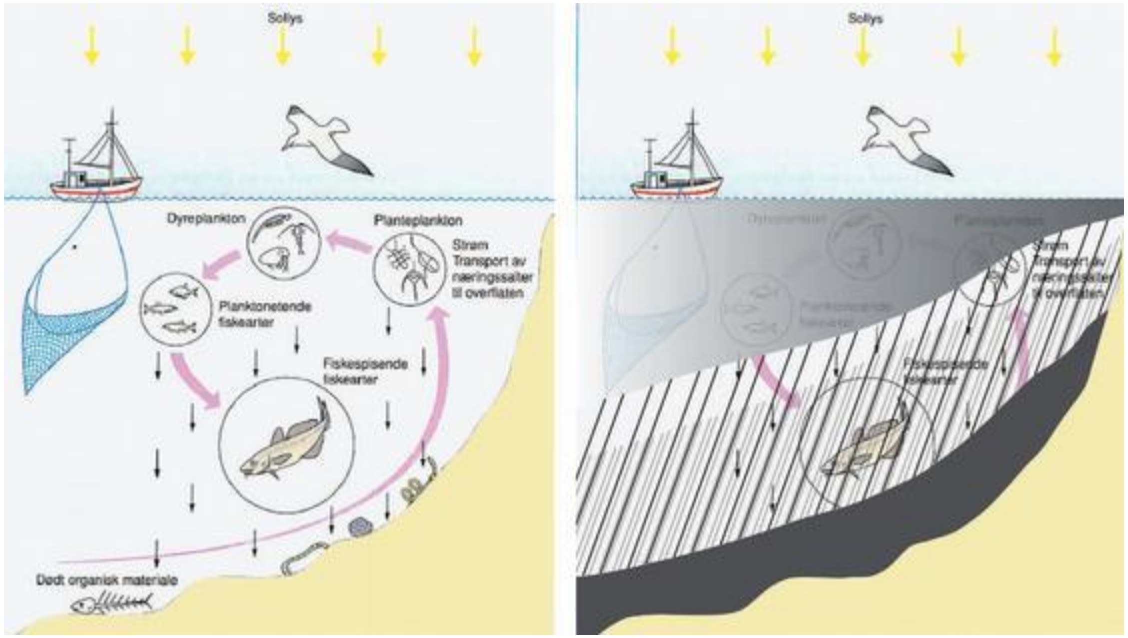
Choose the most cost efficient project

Example:

- Consider a fjord in Norway, the Førde fjord, with a small local community.
- There are scare local labor opportunities, and the regulator want to support industry that create job opportunities, maintaining the local life of its citizens.

Consider a case where the local cornerstone company in the fjord is a mining industry. To expand and create job opportunities the industry need permission to dump mineral waste into the fjord. A cheep and easy solution benefitting the economic activity in the area.

However, this would have future consequences for the fishing industry and the local ecosystem in the fjord



The consequences of dumping mineral waste into the fjords
Source: The Norwegian institute of marine research

What should the regulator do?

- Let an independent and neutral party, the analyst in the Norwegian Environmental Agency, perform a cost-benefit analysis, comparing the

  - The economic benefits of establishing a local industry
  - The future environmental damages to the ecosystem and biodiversity

The decision and consideration is a political task

How should one incorporate the environmental and biological consequences of Førde fjorden in a CBA?

Problem:
The market do not provide any direct information about the valuation on *changes* in the provision of environmental goods and services.

The environment is a public good without a market, such that there do not exist any market prices.

How do one perform environmental valuation?
How do one calculate the price of a clean fjord?

A simple definition of a CBA

- The regulator should choose the project with largest positive expected net present value: $E[NPV] > 0$
- **Net benefits**, at time t:

$$NB_t = B(x) - c(x)$$
$$= \sum_{i=1}^{n} WTP_t - c(x)$$

The sum of what all relevant agents want to pay, minus the costs

- **Net present value**:

$$NPV = \sum_{t=1}^{T} \beta^t \, NB_t$$

The sum of all discounted net benefits over a project's time horizon.

Challenging aspects

- What is the projects time horizon? – it might be infinite
- How do we measure agent’s willingness to pay for goods and services without market prices?
- Who are the relevant agents? – should we gather and count every affected agent, what about the valuation of non-users?
- How do we sum net benefits and the willingness to pay for public goods?

The dynamic aspect

When comparing projects that involve different people living in different time periods

Challenges:

- Will preferences stay the same over time and across generations?
    - If there are less healthy environment in the future, will they value a stable climate and a rich biodiversity more than us?
- How much richer/poorer will the future generations be?
    - Should we employ expensive mitigation investments today when future generations probably have better technology and are richer than us?
- How to evaluate future benefits and costs?
    - These decisions depends our choice of discount rate. For long-lived stock pollution, such as climate change, the choice of policy is extremely sensitive to the choice of discount rate.

The dynamic aspect

Given that CBA is concerned with consequences over time, and based in welfare economics, a key idea is *intertemporal efficiency*

Intertemporal efficiency requires the satisfaction of 3 conditions

Equality of individuals' consumption discount rates ${r_t}^A = {r_t}^B = r_t$
Equality of rates of return to investment across firms $\delta_i = \delta, i \in N$

Equality of the common consumption discount rate with the common rate of return $\delta^t = r_t$

Choosing a unique intertemporal efficient allocation require a social welfare function

Pareto optimality: An allocation is efficient if it is impossible to make one individual better off without thereby making the other worse off.

→ Moral-philosopical aspect: Pareto optimality is only an efficiency criterion, does not say anything about how we should allocate resources or the initial distribution.

Social welfare functions

In economics we assume that social welfare can be represented by a function of all individual's utility.

$$W = w(u_1(x_1, E), u_2(x_2, E), \dots, u_n(x_n, E))$$

x_i ~ private consumption of a private good

E ~ consumption of a public environmental good

n ~ number of induviduals

The welfare function weight all utility functions in the economy, based on a common understanding of what determines a good society.

Consider the utilitaristic approach:

$$W = w(u_1(x_1, E) + u_2(x_2, E) + \cdots + u_n(x_n, E))$$

Taking the total derivative: finding the effect on social welfare from an investment project/policy

$$dW = \sum_{i=1}^{n} \left[\omega_i \, {}^{\partial u_i}\!/_{\partial x_i} \, dx_i + \omega_i \, {}^{\partial u_i}\!/_{\partial E} \, dE\right]$$

$$dW = \sum_{i=1}^{n} \omega_i \, {}^{\partial u_i}\!/_{\partial x_i} \left[dx_i + \frac{\partial u_i/\partial E}{\partial u_i/\partial x_i} dE\right]$$

$$dW = \sum_{i=1}^{n} \omega_i \, {}^{\partial u_i}\!/_{\partial x_i} \left[-c_i + WTP_i\right]$$

$$dW = \sum_{i=1}^{n} \widetilde{\omega}_i NB_t$$

The welfare weight, $\widetilde{\omega}_i$, values the Net Benefit for each consumer. Choosing an utilitaristic welfare function yield $\widetilde{\omega}_i = 1$. The welfare weight is a pure normative choice by the analyst, be aware!

For an individual the marginal rate of substitution determines the net willingness to pay. Can we then interpret a welfare change as the *aggregate* marginal willingness to pay?

→ only if we assume that everyone has the same marginal utility of the numeraire good.

Further reading:

- Brekke, Kjell Arne. 1997. The numeraire matters in cost-benefit analysis. *Journal of Economic Literature*. 64(1): 117-123.

- Nyborg, Karine. 2014. Project evaluation with democratic decision making: What does cost-benefit analysis really measure? Memorandum 08/2014, Department of Economics, Oslo

- Nyborg, Karine. 2000. Project analysis as input to public debate: Environmental valuation versus physical unit indicators. *Ecological Economics* 34 (3), 393-408

Do everyone have the same marginal utility of money? Depends on how much money you already have:

$$\partial u_{poor}/\partial x_{poor} > \partial u_{rich}/\partial x_{rich}$$

An additional dollar if you are rich gives less initial utility gain.

Standard CBA often use the same weight for everyone, setting $\widetilde{\omega}_i = 1$

$$\widetilde{\omega}_i = 1 = \omega_i \, \partial u_i/\partial x_i$$

$$\omega_i = \frac{1}{\partial u_i/\partial x_i}$$

$$\omega_{poor} < \omega_{rich}$$

This welfare function implies that the society should put less weight on the interest of an agent with high valuation of money. Give more to those that already have more, Is this faire?

→ We are the analysts providing neutral and independent research.

The dynamic aspect

Welfare across time

- The function W maps contemporaneous utility levels for the whole sequence T

$$W = U_t(c_t, E_t) + \beta U_{t+1}(c_{t+1}, E_{t+1}) + \cdots + \beta^{T-1} U_T(c_T, E_T)$$

$$W = \sum_{t=0}^{T} \beta^t U_{t+1}(c_{t+1}, E_{t+1})$$

$\beta\sim$ The discount **factor**, by which future values are multiplied to obtain the NPV

where $\beta = \frac{1}{1-r}$, and r~ the discount **rate**, often referred to as the interest rate.

An intertemporal welfare function of a representative agent living in all periods

or

An intertemporal welfare function of non-overlapping generations

Environmental CBA

- Finding efficient allocation of a project using CBA we need to
  - Specify a welfare function $W = \sum_{t=1}^{T} \quad w_{t+1}(u_1(x_1, E), u_2(x_2, E), \ldots, u_n(x_n, E))$
  - Determine the time period T
  - Measure individual marginal utility $\frac{\partial u_i / \partial E}{\partial u_i / \partial x_i} = WTP_i$
  - Settle who the relevant agents are $i \in N$
  - Determine the discount rate β

Choice of discount rate

There is disagreement about the discount rate that should be used in CBA

This matters because the result of the NPV test can be very sensitive to the number used for the discount rate

$$NPV = \sum_{t=1}^{T} \left(\frac{1}{1+r}\right)^{t} NB_t$$

Especially if the project *lifetime* is long (often with environmental consequences)

Lifetime: The longest lasting consequence, not when the project stops yielding

	Time Horizon			
	Years			
Discount rate %	**25**	**50**	**100**	**200**
0.5	88.28	77.93	60.73	36.88
2	60.95	37.15	13.80	1.91
3.5	42.32	17.91	3.21	1.03
7	18.43	3.40	0.12	0.0001

The table present a value of $100 in the future at various discount rates

At high discount rates the value diminishes and becomes negligible

Academic debate: Stern vs Nordhaus

The academic disagreement on discount rates is not only arguments about empirical matters, but major debates on conceptual issues.

Professor Nicholas Stern and Professor Simon Dietz (Grantham and LSE)

- The discount rate are based on ethical considerations, weighs the welfare interests of present and future generations, taking into account the risk of catastrophes
- Not based on individual market behavior, but how societies should behave
- The Stern Review (2007)
- Average discount rate for climate change damages is approximately 1.4%

Professor William Nordhaus (Yale University)

- Uses a discount rate consistent with today's marketplace real interest rates and savings rates (the opportunity cost of capital, reflecting the rate at which people are willing to exchange current for future consumption)
- Directly connected to actual market behavior, can be empirically estimated
- Developed the computer-based climate model 'DICE' (1993)
- Uses a discount rate around 4.3%

The discount rate has implications for how aggressive recommended climate policy should be

Is there here a groundbreaking interpretable difference, between finding the ideal and actual policy to the moral acceptable and desirable policy.

Objections to environmental cost-benefit analysis

- CBA is based in welfare economics which is *consequentialist* and *subjectivist*, essentially it accepts that the natural environment should be subject to *consumer sovereignty*
- Consumer sovereignty can be rejected as a proper guide on the grounds of
  - inadequate information about consequences
  - insufficiently deliberative
  - lacking self-knowledge
  - preference shaping
- Do we accept that only human interests count? Or should we take into account the interests of other living entities
- Does the valuation methods actually deliver the necessary information?
- There is no guarantee that the subjective assessment of their utility losses by individuals will be large enough to stop a project that threatens sustainability.
- ECBA should therefore be restricted in its application

CHAPTER 12

Valuing the environment

- **International Initiative**
  - TEEB: *The Economics of Ecosystems and Biodiversity*, launched by the European Commission in 2007
  - Global initiative focused on "making nature's values visible"
  - Mainstream the values of biodiversity and ecosystem services into decision-making at all levels
  - Motive: establish an objective global standard basis for natural capital accounting
  - Estimate: The costs of ecosystem damage are expected to be 18% of global economic output by 2050

- **Norway's initiative**
  - NOU 2013:10. *Naturens goder – om verdier av økosystemtjenester*. Norges offentlige utredninger. Miljøverndepartementet, Oslo.
  - Norwegian Pollution Control Authority, 2010. *Verdsetting av marine økosystemtjenester: Metoder og eksempler.* Norwegian Environmental Agency, Oslo
  - Kostnadsberegningsutvalget. 1997. *Nytte-kostnadsanalyser. Prinsipper for lønnsomhetsvurderinger i offentlig forvaltning.* FIN, NOU 1997:27, Oslo

Purposes of environmental valuation

- Inclusion of environmental impacts in cost benefit analysis of projects/policies
- Determination of targets for environmental quality standards
- Accounting for environment impacts in measuring national economic performance
- In the USA, fixing compensation by those the courts hold responsible for environmental damage

Valuing the environment

Valuation in theory: Environmental benefits/damages should be valued as the marginal willingness to pay or the marginal willingness to accept

Valuation in practice: 5 techniques

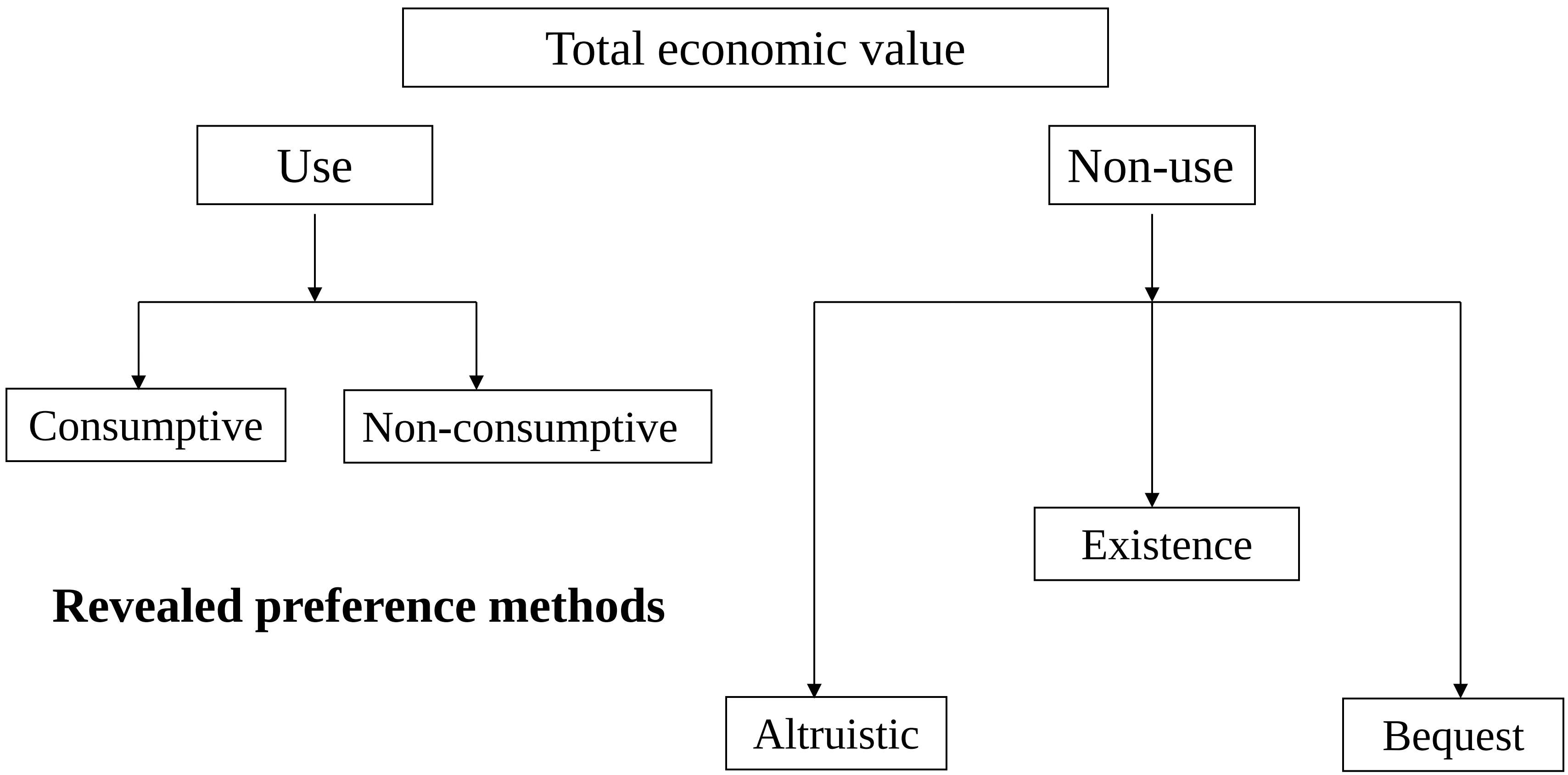
Stated preference method: *our preferences over nature*

1. Contingent valuation (CV)

Revealed preference methods: *our use of nature*

2. Choice experiments
3. The travel cost method (TC)
4. Hedonic pricing
5. Production function-based techniques

Categories of environmental benefits



Revealed preference methods

Stated preference methods

Indirect use – carbon fixation, micro-climate regulation

Environmental valuation theory

How to find monetary measures for environmental quality changes

Two approaches

- Willingness to pay (WTP)
  - The amount you are willing to pay for an improvement in environmental quality
- Willingness to accept (WTA)
  - The compensation you accept for a reduction in environmental quality
- WTP is constrained by the individual's budget, WTA is not bounded by income

Assume that quantity/quality of an environmental good (*e*) can be treated as an argument in a well-behaved utility function

$$u = u(y, e)$$

Where (*y)* is income (expenditure on all private goods) and the environmental quality (*e*) cannot be individual chosen

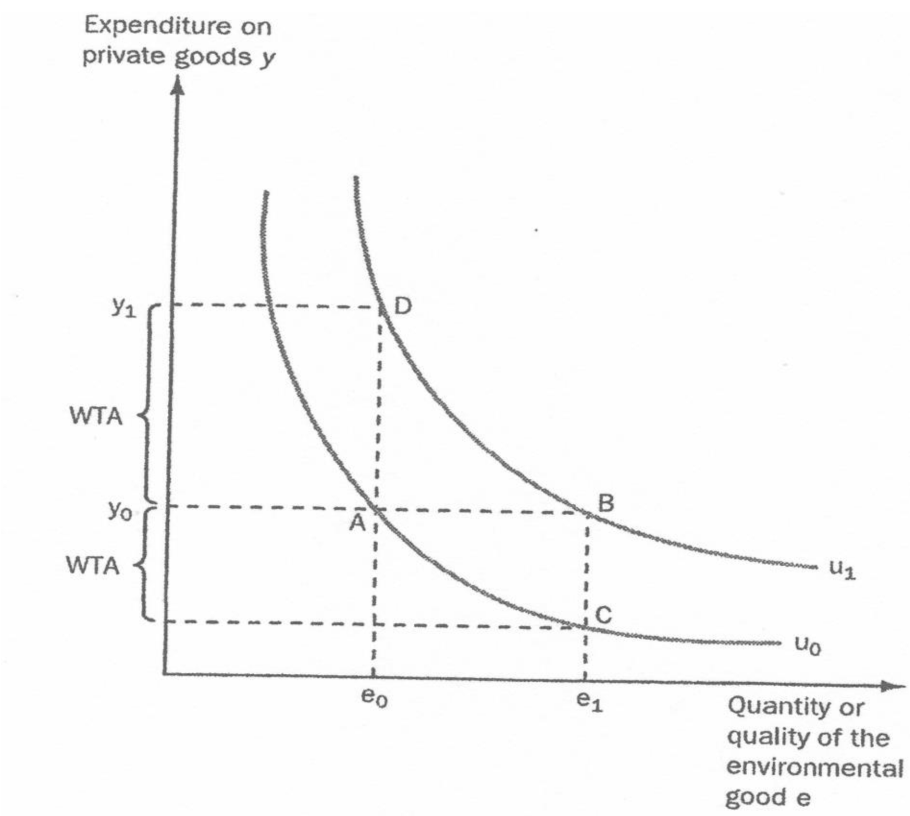


Figure 12.1 Measuring changes in welfare for an environmental good

$e_0 \rightarrow e_1$

At A, WTP for e improvement = BC is the Compensating Surplus

At A, WTA in lieu of e improvement = DA is the Equivalent Surplus

$e_1 \rightarrow e_0$

At B, WTP to avoid deterioration = BC is the Equivalent Surplus

At B, WTA compensation for decline = DA, is the Compensating Surplus

	Compensating surplus (CS)	Equivalent surplus (ES)
Improvement	WTP for the change occurring	WTA compensation for the change not occurring
Decline	WTA compensation for the change occurring	WTP for the change not to occur

1. Contingent valuation

- Survey-based valuation technique
  - Which involves asking a representative sample about their WTP or their WTA for environmental goods and services.
  - Revealed preference method
  - Best suited for capturing use-values

- Application:
  - Benefits of improving air/water quality
  - Benefits of wilderness areas
  - Benefits of outdoor recreation opportunities

The steps involved in conducting a CV study:

1. Creating a survey (questionnaire)
   - Explain the purpose of the exercise, Describe the problem, Questions about respondent's knowledge and attitudes, Statement of payment vehicle, Reminders about substitutes and income constraints, Ask about WTP
   - Different methods produce different results,
     - **Open ended**: ask 'what is your maximum WTP for...?' Avoids giving respondents cues, but difficult for them
     - **Bidding game**: the respondent is asked if WTP a sequence of increasing amounts until says 'no'.
     - **Dichotomous choice:** single or double, the respondent answer yes/no to whether he is willing to pay a given amount for a public good provision

2. Choosing an appropriate survey technique.
   - Face-to-face interviews, mail surveys or telephone survey

3. Identifying the population of interest and developing a sampling strategy.
   - The sample should be representative of the target population - the group liable to be affected, well defined for use values, not so for non-use values.
   - Tropical forests, the candidate population is potentially the whole global population.

4. Analysing the responses to the survey.

5. Aggregating the WTP or WTA over the population of interest

CV – reliability and validity

- CV surveys are ought to be reliable if
    - the same survey applied to a different sample of respondents, or the same sample of respondents at a later date, should yield similar results.
    - Surveys designed and undertaken by different researchers but purporting to measure the same thing should also produce similar results.

- Should we rely on peoples responses to questions about research design, and therefore hypothetical changes in the environment?

- Would people actually pay what they say if the case was not hypothetical?
    - Interviewer bias, stating high WTP to please the interviewer
    - Information bias – individual’s WTP reflects inadequacy of their knowledge

- Political bias
    - How much are you willing to pay to save the world from climate change?
    - Reflecting that the responses are largely symbolic in nature – ‘warm glow’ effects

- Part – whole bias
    - The challenge of identifying a *particular* value attached to one *particular* thing which is embedded in a collection of similar things. The embedding effect

- The problem of aggregation
    - How much are you willing to pay to save this waterfall?
    - How much are you willing to pay to save these 50 waterfalls?

Exxon Valdez oil spill in 1989 in the coast of Alaska

The largest oil spill in US waters until the 2010 BP oil spill in the Gulf of Mexico

The most devastating human-caused environmental disaster occurring in a vulnerable wilderness area

- In 1991 the US District Court settled the compensation to approximately $1 billion in damages, and $2 billion in restoration efforts.
- In anticipation of legal action against the ship's owners, the Government of Alaska commissioned a team of economists to conduct a CV study to estimate the damages from the oil spill.
  - Carson et al (1995) estimated total WTP for the escort ship programme of $2.75 billion. The damage was estimated to be $4.9 billion in lost economic value of non-users, survey non-Alaskans
  - Hausman et. al (1995) estimated the recreation damages to be $3.8 million, the economic loss of actual visiting the area
- Key explanation for the thousand-fold difference: Inclusion of *non-use values*
- Stated preference methods came under intense examination
- When pricing wilderness areas non-use values may be the largest component,
- Accounting only direct impacts (lost production, health effects, damaged fisheries, displaced recreation) may result in comparatively small losses.

2. Choice experiments (CE)

- Another type of stated preference survey based valuation technique
- Respondents are presented with a number of discrete alternatives – competing environmental projects- and asked to state which they prefer
    - CV: How much are you willing to pay for a small reduction in the probability of a fatal oil spill?
    - CE: Respondents are introduced to three accident scenarios with attributes: health effects, damaged tidelands, fishing ports, recovery period, and cleanup costs. Respondents are asked to choose the one accident that they thought is most likely to occur, and which they regard as the worst
- CE is growing in popularity because
    - can deal with non-use values
    - control of the experimental design is with the researcher
    - avoids yea and nay-saying
    - monetary values implicit – no WTP question
    - can calculate WTP even if attribute levels change
    - WTP values can be transferred across project analyses

3. The travel cost method (TC)

- The TC method is a *revealed* preference technique for estimating use values,
- Travel costs incurred visiting a site vary
    - The recreational benefits of environmental resources – national parks, forests, reserves, fishing and hunting sites
    - Access to these places is typically free, but visitors pay an implicit price incurred in their travel costs to the site (both time and tram tickets, gas)
- TC assumes weak complementarity – if the site is too expensive for an individual to visit, changes in the condition and availability of the site do not affect the individual's utility.
- TC cannot obtain non-use values regarding a site not visited.
- TC can be used to estimate value of *changes in quality of a site*

4. Hedonic pricing (HP)

- The hedonic price method is widely-used revealed preference valuation technique.
- HP is usually applied to the property market within which many environmental goods are implicitly traded. Households reveal their preferences for these goods through their decision about where to locate.
- HP has been widely used to value household preferences for noise nuisance, air quality, physical separation from locally-undesirable land uses and the value of a statistical life.
- A Norwegian study by
  - Barton et. al (2015) *Naturen i Oslo er verdt milliarder. Økonomisk verdsetting av utvalgte urbane økosystemtjenester fra grønnstruktur*. NINA Rapport 1113. Oslo
  - Estimated the WTP to recreation in a park in Oslo by HP: 1 billion NOK
  - Recreation in the nature surrounding Oslo was estimated to 2,3-13,3 billion NOK

CHAPTER 13

Irreversibility, risk and uncertainty

Risk and uncertainty

- The risk/uncertainty distinction is not always made in economics, Knight (1921)

- Risk:
  - where probabilities can be assigned to each possible consequence, (state of the world, state of nature)
  - Risk aversion: determines whether one wants to gamble for uncertain gains or avoid potential losses by excepting lower expected returns

- Uncertainty:
  - where all possible consequences can be enumerated, but probabilities cannot be assigned
  - Ambiguity aversion: An agent that is ambiguity averse would rather choose the lottery with known distribution of outcomes rather than the lottery with unknown probabilities.

- Radical uncertainty - where all possible consequences of a decision cannot be enumerated
  - The climate problem

Irreversibility effect in CBA

- Irreversible changes pose a challenge to conventional benefit cost analysis when the consequences of these changes are not fully understood and cannot be priced with certainty at the time of action.

- In the presence of irreversibility, postponement of a project can be optimal even if the expected NPV is positive.
  - A shortcoming of conventional CBA

- Hanemann (1989) formalized a value corresponding to the irreversibility effect commonly known as

The Arrow–Fisher–Hanemann–Henry quasi-option value

Traeger (2014) *On option values in environmental and resource economics.* Resource and Energy Economics, 37:08, 242-252

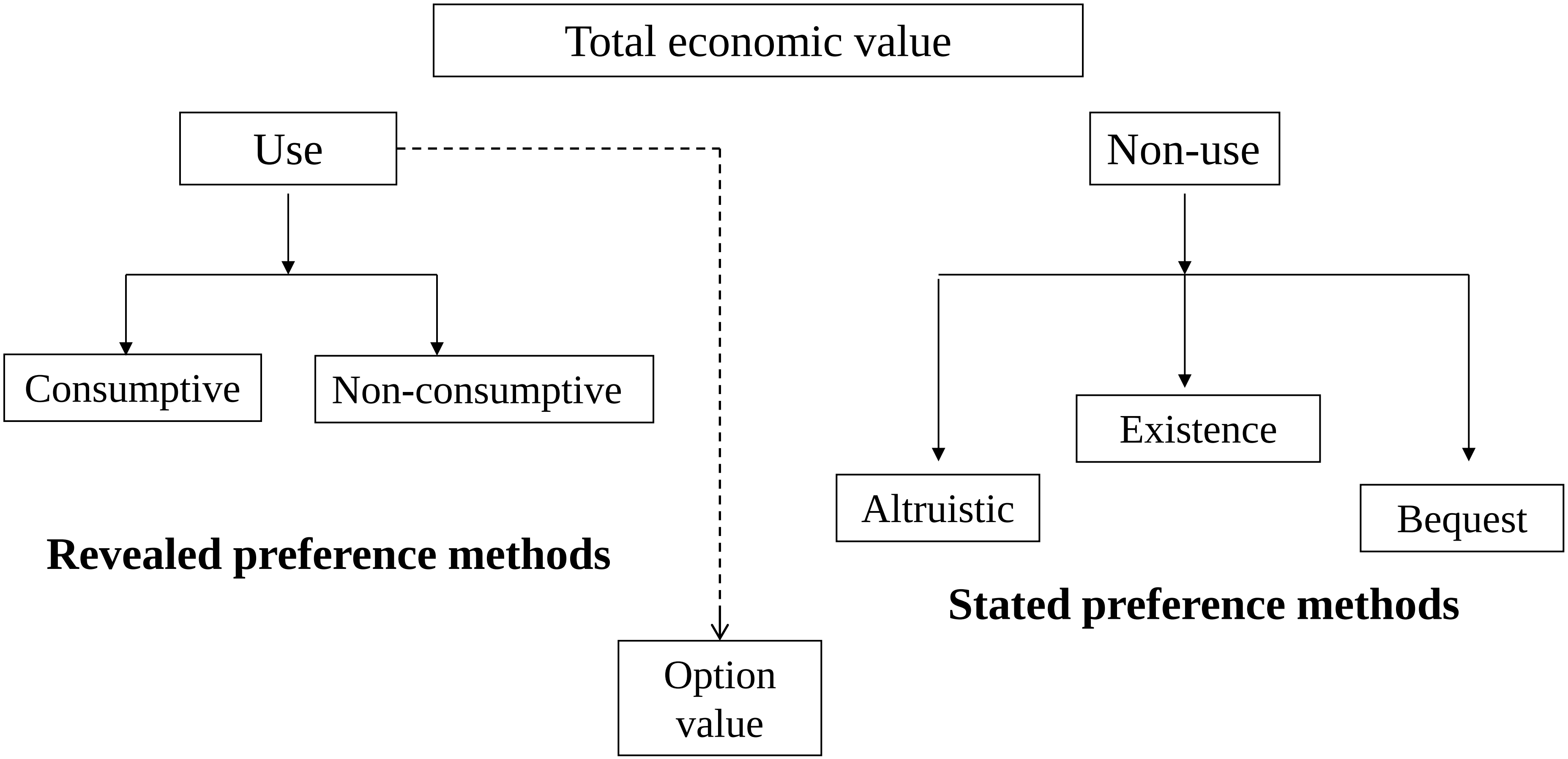
Option values

- In cost–benefit analysis and social welfare economics, the term *option value* refers to the *value* that is placed on private WTP for maintaining or preserving a public good or service even if there is little or no likelihood of the individual actually ever using it.

- Commonly used to justify investments in wildlife areas, national parks or land conservation

- Recognized as an element of *total economic value (TEV)* of environmental resources
  - TEV: The sum of *use* and *non-use* values

Categories of environmental benefits



Revealed preference methods

Stated preference methods

Future use of known and unknown benefits

Option values relate to the potential future availability of ecosystem services

Option values

- Global warming, alterations of ecosystems, and sunk investments all imply irreversible changes with uncertain future costs and benefits
- Option values measure how irreversibility and uncertainty change the value of preserving an ecosystem or postponing an investment
- Quasi option values captures the value of learning under preservation / postponed investment

Example

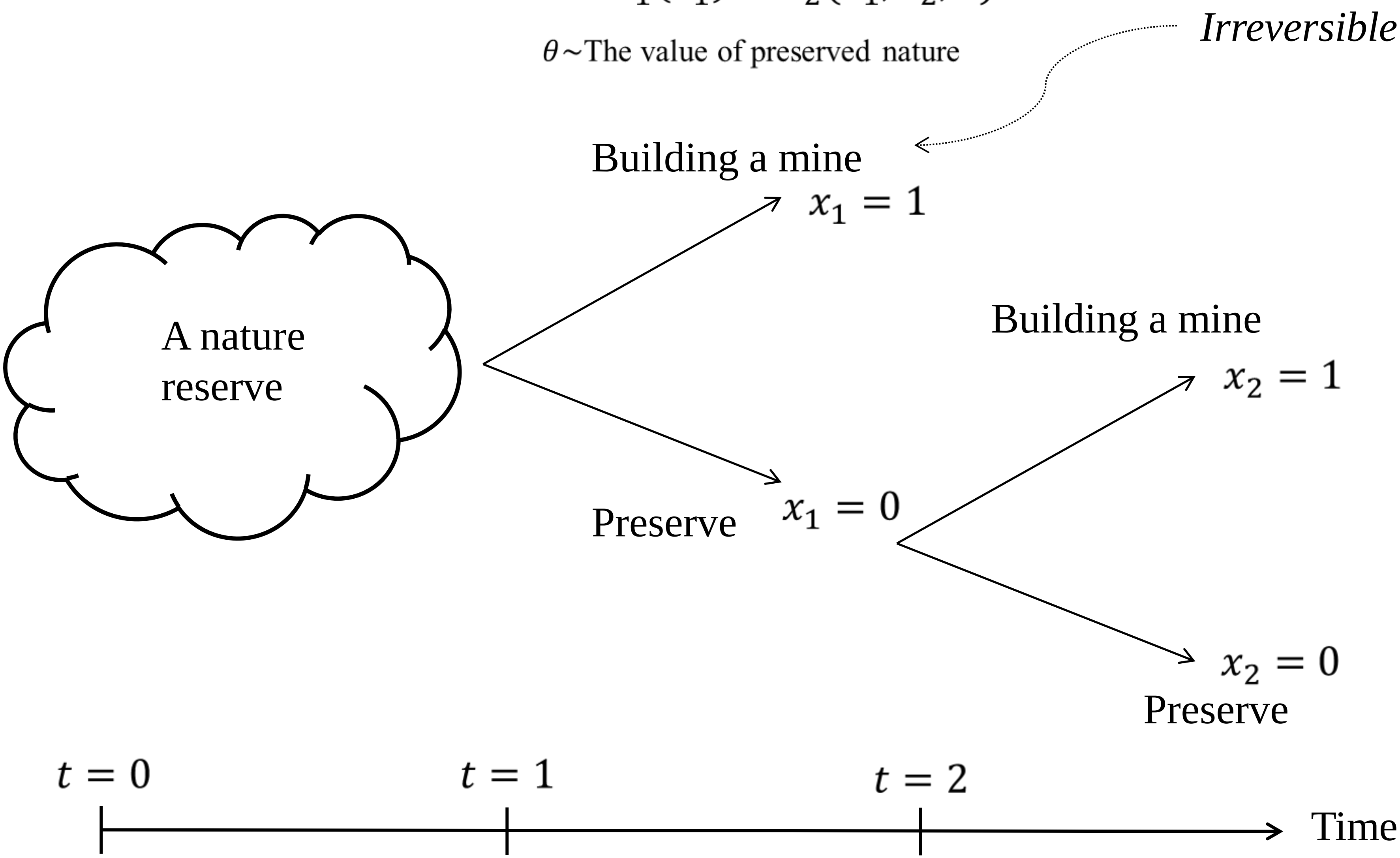
Option value, Net present value, Quasi option value

- Consider a rich wilderness area (the rain forest, the cost in Alaska, the Norwegian fjord?)
- and an investment choice of building a mine.
- When the mine is build, the nature and ecosystem in that area is lost forever.
- How would future generations and users value this resource?
- The investment is irreversible.
- But the mine gives economic benefits today.
- Can we price this action optimally in the time of action when the future value of a nature reserve is unknown?
- How to determine this trade-off?

Irreversibility

$$U = u_1(x_1) + u_2(x_1, x_2, \theta)$$

$\theta \sim$The value of preserved nature



Define Quasi option value

Anticipated learning (Option value)

Wait: $x_1 = 0$ $\quad V'(0) = u_1(0) + E\left[\max_{x_2} u_2(0, x_1, \theta)\right]$

Build: $x_1 = 1$ $\quad V'(1) = u_1(1) + E[u_2(1,1,\theta)]$

Possibility of postponing (Simple option value)

Wait: $x_1 = 0$ $\quad V^{p\prime}(0) = u_1(0) + \max_{x_2} E[u_2(0, x_1, \theta)\ ]$

Build: $x_1 = 1$ $\quad V^{p\prime}(1) = u_1(1) + E[u_2(1,1,\theta)]$

Now or never (NPV)

Wait: $x_1 = 0$ $\quad V^{n\prime}(0) = u_1(0) + E[u_2(0,0,\theta)\ ]$

Build: $x_1 = 1$ $\quad V^{n\prime}(1) = u_1(1) + E[u_2(1,1,\theta)]$

Def: $NPV = \left(V^{n\prime}(1) - V^{n\prime}(0)\right)$

Def: $QOP = (V'(0) - V'(1)) - \left(V^{p\prime}(0) - V^{p\prime}(1)\right)$

Option price and option value

Consider an individual and a national park wilderness area.

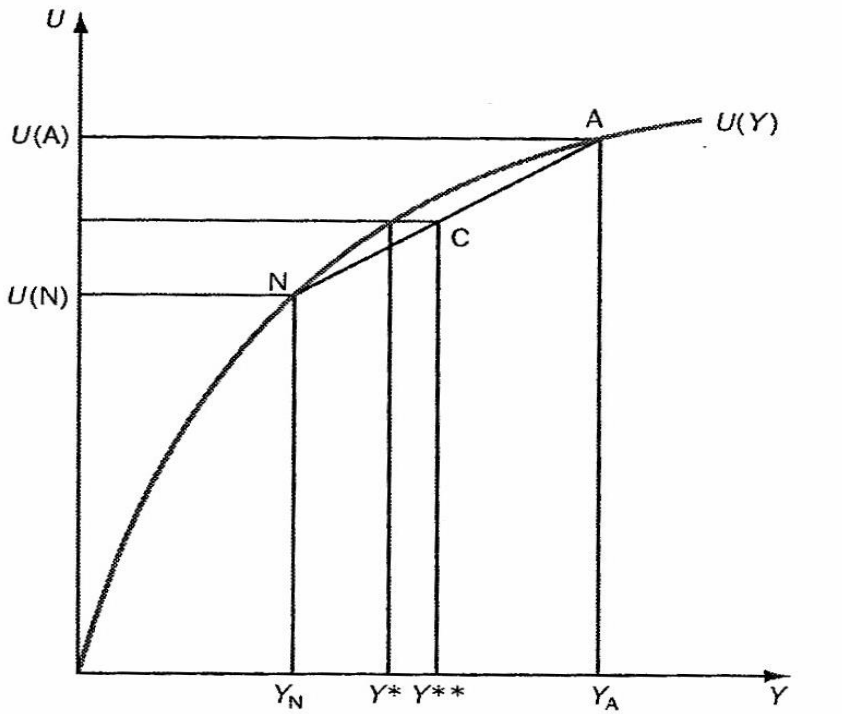


Figure 13.2 Risk aversion, option price and option value

A – available, the park is open

N – the park is closed

U(A) – utility for income Y_A, park open and wants to visit

U(N) – utility for income Y_A, park closed and wants to visit.

p_1 – probability of *N*,

$(1-p_1)$ – probability of *A*

NCA as p_1 varies

Y** is the expected value of the outcome and Y* is the certainty equivalent

Y_A – Y** is the expected value of the individual's compensating surplus, E[CS].

Y_A – Y* is the *option price*, the maximum that the individual would be willing to pay for an option that guaranteed access to an open park.

Option price and option value 2

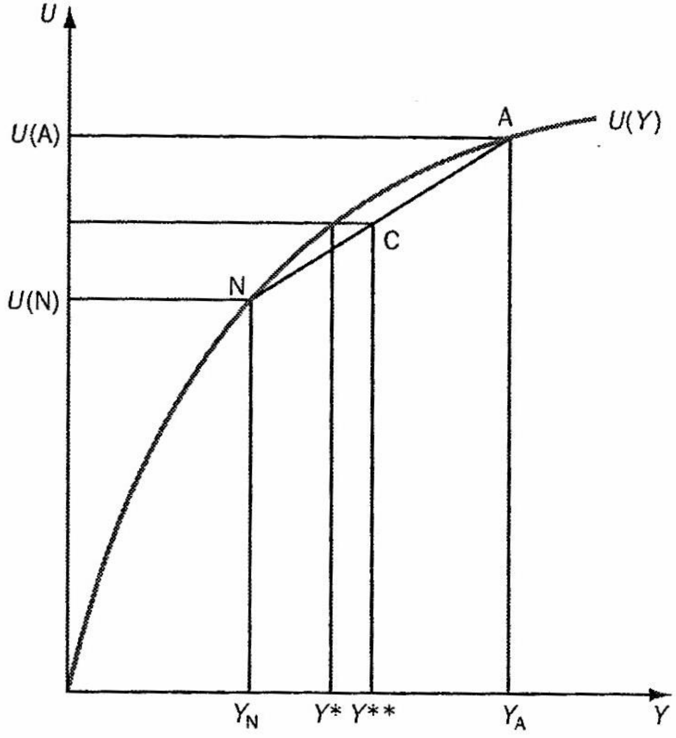


Figure 13.2 Risk aversion, option price and option value

U function, risk aversion, Y** > Y* has OP > E[CS].

OP = E[CS] + OV

with OV, option value, positive.

With risk neutrality, OV would be zero.

Option value is a risk aversion premium

E[CS] understates the benefit of keeping the park open as risk averse individuals would be willing to pay a premium to avoid risk