Introduction to Cost-Benefit Analysis

Lecture 1

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CBA: Introduction

Practical Details

- Class: every Tuesday from 12 to 16, room U25A.
- Slides and other material will be put up on blackboard after the class.
- Some of the lectures (partially) based on textbook "Cost-Benefit Analysis", Boardman et al., 4^{th} edition. Only optional reading.
- Course divided in two parts: first part - theory and concepts, second part - project.
- Projects to be conducted in groups of 4 or 5 students. Not graded but to be taken seriously.
- Exam will be easy and predictable, so no worries on that side!

CBA: Introduction

Practical Details

- My background: graduated as a civil engineer originally, then moved to economics. Ph.D. from Ecole Polytechnique in France. Now associate professor in the department of economics at SDU.
- My research is theoretical and deals mostly with issues related to voting procedures and resource allocation.
- If interested, welcome to ask about my research or check my website:

https://sites.google.com/site/rafaeltreibich/

CBA: Introduction

Lecture 1

- Motivation and Examples.
- Basic Principles.
  - Decision Rules.
  - Timing.
  - Standing.
- Three main challenges: Uncertainty, Comparability and Aggregation.
- Willingness to Pay.
  - Definition.
  - Influencing Factors.
  - Willingness to Accept.
  - Measurement.
- Aggregating individual benefits.
- CBA approach: the 9 steps of CBA.

CBA: Introduction

Motivation

- Should Denmark build a new bridge between Jutland and Zealand? Should Odense build a second lightrail?
- Should higher education expand, or water supplies be improved?
- How fast should we consume non-renewable resources and what are the costs and benefits of protecting the environment?
- These are the type of questions on which cost-benefit analysis (CBA henceforth) has something to say.
- Any public project or policy that has implications for society at large can be analysed with the tools of CBA.

Question: What other projects could be the object (or not) of CBA? Think about a project that is related to your studies.

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Examples

Civil Engineering:

- Bridge Construction: Evaluating the costs of materials, labor, and maintenance against the benefits of reduced travel time, increased safety, and potential economic development.
- Flood Control Systems: Assessing the costs of building dams or levees against the benefits of protecting communities and farmlands from flooding.

Mechanical Engineering:

- Public Transportation: Assessing the costs and benefits of introducing energy-efficient buses or trains in public transportation systems.
- Robotics in Public Services: Evaluating the costs of implementing robotic systems in public services like waste management against the benefits of increased efficiency.

CBA: Introduction

Examples

Electrical Engineering:

- Smart Grid Implementation: Evaluating the costs of upgrading a city's electrical grid to a smart grid against the benefits of improved energy efficiency and reliability.
- Solar Power Plant: Assessing the costs of land, materials, and maintenance for a solar power plant against the benefits of renewable energy production and reduced greenhouse gas emissions.

Environmental Engineering:

- Wastewater Treatment Plant: Comparing the costs of building and operating a new wastewater treatment plant against the benefits of improved water quality and public health.
- Recycling Facility: Evaluating the costs of setting up a new recycling facility against the benefits of waste reduction and potential revenue from recycled materials.

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Examples

Software Engineering:

- E-Government Systems: Comparing the costs of developing digital platforms for public services against the benefits of increased accessibility and efficiency.
- Cybersecurity for Public Infrastructure: Evaluating the costs of implementing advanced cybersecurity measures in public infrastructure against the benefits of reduced risk of cyber-attacks.

Chemical Engineering:

- Water Purification Systems: Assessing the costs of implementing advanced water purification technologies in public water supply against the benefits of improved water quality.
- Pollution Control: Evaluating the costs of installing emission control systems in public facilities against the benefits of reduced air pollution.

CBA: Introduction

Examples

Healthcare:

- Hospital Construction: Comparing the costs of building a new hospital against the benefits of improved healthcare services and increased capacity.
- Vaccination Program: Evaluating the costs of a large-scale vaccination program against the benefits of herd immunity and reduced healthcare costs.

Education:

- School Building: Assessing the costs of constructing new educational facilities against the benefits of improved learning environments and educational outcomes.
- Digital Learning Platforms: Evaluating the costs of implementing digital learning platforms in public schools against the benefits of enhanced learning experiences and educational reach.

And many more, the list of topics and projects where CBA can be conducted is endless.

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CBA: Introduction

Basic idea

- The basic notion is very simple: implement a project if the benefits exceeds the costs.

Project's net benefits = Benefits - Costs.

- Implicit **opportunity cost** of implementing a project is to abandon the status quo.
- Costs and benefits must always be measured **relative** to the costs and benefits incurred under the status quo.

Decision rule:

- If *only one* project under consideration: implement project if the net benefits are positive.
- If *several* projects under consideration: implement the project which yields the largest net benefits if positive; If all projects yield negative net benefits, keep status quo.

CBA: Introduction

Timing

- The broad purpose of CBA is to help social decision making and to make it more rational.
- Cost-Benefit Analysis (CBA) is often conducted at different stages of a project to serve various purposes.
- We generally distinguish between ex-ante, ex-post and midway CBA.

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Timing

Ex-ante CBA: before the project is started or implemented.

Purposes:

- **Feasibility Assessment**: Determines whether the project is viable and worth pursuing before it starts.
- **Resource Allocation**: Helps in deciding how to allocate resources most efficiently among competing projects.
- **Risk Analysis**: Identifies potential risks and uncertainties to be managed during project implementation.
- **Stakeholder Engagement**: Provides a basis for engaging with stakeholders by presenting a clear picture of expected costs and benefits.

CBA: Introduction

Timing

Ex-post CBA: at the end of a project, as a way to evaluate whether the project turned out to be profitable.

Purposes:

- **Outcome Evaluation**: Measures the actual costs and benefits realized by the project after its completion.
- **Accountability**: Holds project implementers accountable for delivering the promised benefits.
- **Lessons Learned**: Provides valuable insights and lessons that can be applied to future projects.
- **Policy Recommendations**: Can inform policy by demonstrating what works and what doesn't in a real-world setting.

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Timing

Midway CBA: during the completion of a project.

Purposes:

- **Performance Monitoring**: Assesses whether the project is on track to meet its objectives and deliver the expected benefits.
- **Course Correction**: Adjust parts of the project or abandon the whole project altogether if the evaluation of future benefits/costs has drastically evolved.
- **Resource Re-Allocation**: Helps in reallocating resources if necessary, based on the project's performance to date.
- **Transparency and Accountability**: Keeps stakeholders informed about the project's status and ensures accountability.

CBA: Introduction

Timing

When conducting a CBA midway, one may wonder whether to account for past expenditures.

- **Sunk costs** are expenditures that have already been incurred and cannot be recovered. These costs are independent of any future events or decisions. In other words, once the money is spent, it's gone, regardless of what happens next.
- In CBA, the focus is on assessing future costs and benefits to make informed decisions. Sunk costs should not influence this assessment because they are irrelevant to future costs and benefits.
- **Sunk Cost Fallacy**: tendency to continue investing in a project based on the amount of resources already invested, rather than evaluating it based on its current and future value. Sunk cost fallacy can also come from an emotional attachment to the project because of the effort and time invested in it.
- When evaluating the continuation of a project, only **incremental** (future) costs and benefits should be considered. Sunk costs should be excluded from the analysis.

CBA: Introduction

Timing

Examples of projects that were (inefficiently) completed because of sunk costs:

- **Concorde airplane**: despite escalating costs and growing evidence that the project would not be economically viable, both France and UK continued to invest in it, partly because they had already invested so much.
- **Sydney Opera House**: as costs ballooned to over AUD 100 million and construction took 14 years, the project continued partly because of the large investment already made.
- **U.S. Military Involvement in Vietnam**: despite mounting casualties and costs, with little sign of a decisive victory, the U.S. continued its involvement partly due to the significant resources already committed.

CBA: Introduction

Timing

Examples of projects that were (efficiently) terminated despite sunk costs:

- **Superconducting Super Collider (US)**: Initiated in the 1980s, it was intended to be the world's largest and most energetic particle accelerator. Around 2 billion had been spent on the project before it was canceled in 1993 due to budget overruns and doubts about its scientific value.
- **Berlin airport**: The Berlin-Brandenburg Airport was intended to replace both Tegel and Schönefeld airports in Berlin. The original plan was abandoned, and the project underwent significant revisions, despite billions of euros already spent on its construction. It eventually opened in 2020, nine years behind schedule.

CBA: Introduction

Standing

- Whose benefits? Society's as a whole. Here we take the point of view of a benevolent social planner.
- Different ways of defining society: region, country, world? This is what we call the **standing** of the project.

Question: think back to your example of a CBA project. What would be the standing for that project?

- The issue of standing is often contentious. Countries tend to overlook the effect of their projects on the welfare of other countries. This is unfortunate because it is often in everyone's interest to adopt a wider standing.
- The following example shows why it can be beneficial for every country to account for the effect of their projects/policies on the rest of the world, even if they do not care about each other's welfare.

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Standing

The choice of standing as a Prisoner's dilemma:

- Assume countries $i = 1, \ldots, N$ are considering whether to implement a given project (e.g. reduce carbon emissions).
- For each country i, implementing the project costs C, yields benefit B to citizens in country i and benefits $b < B$ to citizens in each of the $n-1$ other countries.
- We say the project of country i has a positive externality on the remaining countries.
- Assume $B < C < B + (n-1)b$ and each country cares only about its own citizens' welfare.
- Each country then chooses not to implement the project because the cost outweighs the benefits.
- Is this outcome optimal?

CBA: Introduction

Standing

- If all countries were to implement the project together, they would each get a net benefit of $B + (n-1)b - C > 0$, and would therefore be strictly better off.
- It is in countries' own self interest to adopt a broad standing and account for other countries' welfare, provided they all do so.
- **Difficulty:** each country always has an incentive to free ride and benefit from other countries implementing the project while not doing so itself.
- As a result, broader standings are rarely observed in practice.
- Instance of the so-called Prisoner's dilemma.

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Standing

Examples of projects that were criticized for a narrow standing:

Ilısu Dam (Turkey, 2018): inefficiently implemented.

- Project: A hydroelectric dam on the Tigris River.
- Narrow Standing: Focused on meeting Turkey's energy needs.
- Criticism: The dam has been criticized for reducing water supply to downstream countries like Iraq and Syria, exacerbating water scarcity issues in those regions.

Helsinki-Tallinn Tunnel (Finland and Estonia): inefficiently rejected.

- Project: A proposed undersea tunnel connecting Helsinki, Finland, and Tallinn, Estonia.
- Issue: High costs have been a significant barrier.
- Potential Positive Externality: The tunnel could significantly boost trade, tourism, and economic integration in neighbouring countries.

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- Three main challenges: Uncertainty, Comparability and Aggregation.

CBA: Introduction

Three main challenges

- Straightforward principle, so what's the big deal about CBA?
- Measuring costs and benefits may prove very difficult. Why?
- Three main issues: **uncertainty, comparability and aggregation**.

CBA: Introduction

Three main challenges: Uncertainty

- Even if the social planner knows exactly how much material and labour is required to build a certain infrastructure, he does not know how the prices for materials and labor will evolve over time.
- ***Predictions*** about future benefits and how the project will affect citizens even more challenging. How to know exactly how many people will use a new subway if it opens next year? How to know how many will do in 10 years?
- Measuring costs and benefits will thus require extensive ***technical*** analysis to assess and quantify the impact of the project.
- Unreasonable (and dangerous) to aim for exact predictions, wiser to look for ***intervals*** and try to evaluate the quality of the prediction.

Question: what would be the most challenging aspects of your projects to predict?

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Three main challenges: Comparability

- Even if we believe our estimates of such benefits and costs are reliable, very difficult to make these benefits and costs **commensurable**.
- How to compare saving 10 min in commuting everyday with an increase in 5% of air pollution (whatever that means!) or an increase in 50*dkk* in montly local taxes?
- Need to **monetize** the various costs and benefits so as to make them commensurable.
- Reducing very heterogeneous benefits and costs to a single dimension (money) seems rather questionable. However, it is unavoidable if we want to reach meaningful conclusions.
- Otherwise, impossible to say whether A is better than B, unless A is better than B in all dimensions!

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Three main challenges: Comparability

Why is it difficult to monetize benefits/costs?

- **Intangible Benefits and Costs**: Some benefits or costs don't have a direct monetary value, making them difficult to quantify.Examples: intrinsic value of cultural heritage, aesthetic value of a landscape, or spiritual value of a religious site.
- **Non-Market Goods and Services**: Many goods and services that are crucial for public projects don't have market prices. Examples: clean air, biodiversity.
- **Irreplaceable Assets**: Some assets, once lost, cannot be replaced, making their valuation particularly challenging. Examples: endangered species or unique historical artefacts.
- **Valuing Human Life**: placing a monetary value on human life is ethically challenging and methodologically complex. Different methodologies can yield different results, and there's no universally accepted approach.

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Three main challenges: Comparability

Why is it difficult to monetize benefits/costs?

- **Moral and Ethical Concerns**: Beyond the value of life, there are other moral and ethical concerns that are hard to monetize. How do you place a monetary value on the benefit of a more just society or the cost of discrimination?
- **Valuing Future Generations**: Even without considering discount rates, how do we value benefits or costs that will be experienced by future generations, especially when those generations cannot voice their preferences?
- **Social and Cultural Values**: Some costs and benefits are deeply tied to social or cultural values that are difficult to monetize. Examples: religious sites.
- **Valuing Time**: The value of time varies based on individual preferences, activities, and contexts. Assigning a monetary value to time is complex due to factors like opportunity costs, subjective value, variability across individuals and activities, and cultural differences.

Question: in what respect would it be difficult to compare some of the benefits (and costs) of your projects?

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Three main challenges: Aggregation

- First level of aggregation: from **individual** to **social** welfare.
- General approach will consist in simply adding up the individual benefits or costs, but may not always be appropriate.
- Second level of aggregation: **intertemporal** welfare.
- The costs and benefits associated to a given project realize at different times. Should we simply add all these costs and benefits over the lifetime of the project to decide whether to implement it or not?
- No! Costs and benefits which accrue later in time should be discounted. Why?

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- Willingness to Pay.
  - Definition.
  - Influencing Factors.
  - Willingness to Accept.
  - Measurement.

CBA: Introduction

Willingness to pay: Definition

- Even though costs might be difficult to measure and predict in practice, they are rather straightforward conceptually because they are usually monetary (can you think of an example of a cost that is not monetary?).
- Benefits are more challenging because most of them are non monetary.
- So how should we monetize individual (non-monetary) benefits/costs?
- In order to do so, we must find out how the decision would affect the welfare of each individual concerned.
- To do so we will rely on the individual's own evaluation of his welfare, either directly or indirectly.
- Central concept: **willingness to pay**.

CBA: Introduction

Willingness to pay: Definition

- An individual's willingness to pay measures how much her welfare would change if the project were implemented. That is, it measures how much she would be willing to pay to acquire the benefits or to avoid the costs related to the projects.
- To simplify assume an individual's utility depends on her level of consumption and whether the considered project is implemented or not.
- Denote by $u_i = u_i(x_i, P)$ individual i's utility (her level of welfare), where:
  - x_i denotes individual i's consumption (or income).
  - $P = 1$ means that the project is adopted and $P = 0$ means that it is not.
- Then the individual's willingness to pay for the project is given by the quantity Δ_i such that:

$$u_i(x_i - \Delta_i, 1) = u_i(x_i, 0)$$

CBA: Introduction

Willingness to pay: Definition

- Here the WTP Δ_i reflects individual i's net benefit from the project.
- So the individual is indifferent between keeping the status quo and paying Δ_i for the project to be adopted.
- If the WTP is positive then the individual is favorable to the project, if it is negative then she is opposed (she needs to get an additional payment to keep the same utility after the project has been adopted and paid for).
- The exact value of the WTP tells us by exactly how much.

CBA: Introduction

Willingness to pay: Definition

Exercise: Imagine a specific event that you would very much like to attend, perhaps a World Cup match, or a concert from your favorite band.

1. What is the most you would be willing to pay for a ticket to the event?
2. Imagine that you won a ticket to the event in a lottery. What is the minimum amount of money that you would be willing to accept to give up the ticket?
3. Imagine that you had an income 50% higher than it is now, but that you didn't win a ticket to the event. What is the most you would be willing to pay for a ticket?
4. Do your answers suggest any possible generalizations about willingness to pay?

CBA: Introduction

Willingness to pay: Influencing Factors.

Various factors may influence a person's WTP for a specific good/project: economic, psychological, contextual, etc.

- **Income Level**: Higher income often correlates with higher WTP, as people have more disposable income to allocate towards goods and services.
- **Price of Substitutes/Complements**: Availability and pricing of substitute or complements goods can impact WTP for a specific product (e.g., if gas prices go up, WTP for cars might go down).
- **Urgency**: In situations of immediate need, WTP can increase significantly.
- **Social Norms**: Cultural norms and societal values can shape what is considered a "reasonable" price for certain goods.

CBA: Introduction

Willingness to pay: Influencing Factors.

Various factors may influence a person's WTP for a specific good/project: economic, psychological, contextual, etc.

- **Peer Influence**: Friends, family, and social circles can influence individual WTP, particularly for lifestyle or luxury goods.
- **Time Sensitivity**: WTP can vary depending on the timing, such as seasonal changes, time of day, or during sales.
- **Geographical Location**: WTP can differ based on location due to factors like cost of living, availability, and local competition.
- **Information Availability**: More (or less) information can either increase or decrease WTP. For example, knowing a product's ethical sourcing may increase WTP.

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Willingness to pay: Willingness to Accept

A dual concept to the WTP is the Willingness to Accept (WTA): minimum amount an individual is willing to accept to part with a good or service, or to endure something undesirable.

- **Endowment Effect**: Studies show that WTA is often higher than WTP for the same good due to the endowment effect, where people value things more highly when they own them.
- **Compensation for Loss**: WTA is often used in contexts where people are being asked to give up existing benefits or rights (e.g., property rights, environmental quality).
- **Policy and Regulation**: Like WTP, WTA is also used in cost-benefit analyses to assess the impact of policies that may result in losses for certain groups.

CBA: Introduction

Willingness to pay: Measurement.

The willingness to pay cannot be observed directly. How can we measure it?

- **Surveys and Questionnaires**: Structured interviews or written questions are used to directly ask individuals about their maximum willingness to pay for a specific good or service.
- **Experimental Methods**: Participants are placed in a controlled setting where they bid on goods in auctions or make choices in simulated markets. These experiments can be conducted in a lab, online, or in a field setting.
- **Conjoint Analysis**: Participants are presented with a series of choices involving different combinations of product attributes. Statistical techniques like logistic regression or machine learning algorithms are then used to estimate the value placed on each attribute.

- **Market Data**: Transaction data from real markets is used to build the associated demand curve (quantity sold as a function of price). Such demand curve can then be used to infer the distribution of WTP in the population.

- **Travel Cost Method**: used primarily to estimate the economic value of recreational sites or natural resources that are not traded in markets. It involves collecting data on the costs incurred by visitors to travel to a site, including transportation, accommodation, and other related expenses.

Both of these methods rely on either observing or estimating a lower bound for the WTP of each individual.

- Market Data: the WTP is at least as large as the price the consumer pays to purchase the object.

- Travel Cost Method: the WTP is at least as large as the estimated cost of travelling to the recreation site.

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Willingness to pay: Surveys.

Pros:

- **Broad Coverage**: Can be administered to a large and diverse population, either in person, online, or via telephone.
- **Flexibility**: Can be tailored to capture WTP for a wide range of goods and services, from public goods like parks to private goods like electronics.
- **Qualitative Insights**: Open-ended questions can provide deeper understanding of the factors influencing WTP.

Cons:

- **Response Bias**: Social desirability, strategic behavior, or lack of understanding can lead to inaccurate responses.
- **Non-Response**: Low response rates can skew the results and reduce representativeness.
- **Cost and Time**: Requires resources for design, administration, and data analysis.

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Willingness to pay: Experiments.

Pros:

- **Real Choices**: Participants make choices with real or hypothetical money, providing a direct measure of WTP.
- **High Accuracy**: Controlled settings allow for the isolation of specific factors affecting WTP.
- **Behavioral Insights**: Captures real decision-making processes and can be designed to test specific behavioral hypotheses.

Cons:

- **Limited Scope**: Usually involves a small, non-representative sample.
- **Complexity**: Requires careful experimental design, including control groups and randomization.
- **Ethical Concerns**: Must ensure informed consent and consider the ethical implications of the experiment.

CBA: Introduction

Willingness to pay: Market Data.

Pros:

- **Real Transactions**: Based on actual market behavior, providing a robust measure of WTP.
- **Large Data Sets**: Can analyze extensive transaction data, often from multiple sources.
- **Objective**: Uses observed behavior, reducing the risk of self-reporting bias.

Cons:

- **Data Availability**: Requires access to detailed, accurate transaction data.
- **Confounding Factors**: Prices in real markets are influenced by many variables, such as supply conditions, advertising, and seasonality.
- **Limited to Market Goods**: Not applicable for estimating WTP for non-market goods like environmental quality.

We will study in detail the Market Data approach in the second lecture.

CBA: Introduction

Willingness to Pay: Travel Cost Method

- How to evaluate the benefits of non-market goods such as National Parks?
- In 1947, a famous economist called Hotelling proposed a solution in a letter addressed to the director of the National Park Services in the US.
- The idea was to use data on how far each visitor comes from (and her associated travel cost), and other relevant cost factors, to estimate the cost incurred for visiting the national park.
- This provides a lower bound on each visitor's WTP, that can then be used to back out the distribution of WTP in the population.

CBA: Introduction

Willingness to Pay: Travel Cost Method

- Assume that the cost of travelling x kms is given by function $c(x)$.
- Say for example that 2% of the visitors located 100 km from the park take the trip, while 5% of the visitors located 90 km from the park take the trip.
- Then we can infer that 3% of the population has a willingness to pay between $c(90)$ and $c(100)$.
- Indeed, there is 3% of the population who are not willing to visit the park when the cost is $c(100)$ but who are willing to visit the park when the cost is $c(90) < c(100)$.
- Using the complete travel cost information, we can recover the complete distribution of WTP for visiting the park.

CBA: Introduction

Willingness to Pay: Travel Cost Method

Pros:

- **Real Expenditures**: The method is based on actual expenses incurred by individuals, providing a real-world measure of WTP.
- **Applicable to Public Goods**: Particularly useful for valuing non-market goods like natural parks, beaches, and cultural sites.
- **Straightforward Data Collection**: Often, data can be collected through simple surveys or interviews with visitors, making it relatively easy to implement.

CBA: Introduction

Willingness to Pay: Travel Cost Method

Cons:

- **Variable Opportunity Cost**: individuals may have different opportunity costs for the use of their time. The cost of traveling includes both the direct cost of transportation *and* the indirect opportunity cost of not earning money.
- **Distinguishing sublocations**: the estimation of willingness to pay used in the travel cost method is for entire site access. It does not allow to distinguish among different locations within the park.
- **Exclusion of complementary goods**: the travel cost method does not account for the costs involved in purchasing complementary goods which may be required in order to enjoy accessing the amenity.
- **Multi-purpose or multi-activity journeys**: individuals may visit multiple recreation sites on a single trip. In this case the cost incurred in travelling reflect the value of all the recreation sites taken together.

CBA: Introduction

Willingness to Pay: Travel Cost Method

Group Discussion:

- What other type of non-market benefit could be evaluated using a similar approach to the travel cost method?
- How would you implement the method and what kind of data would the method require?

CBA: Introduction

Willingness to Pay: Travel Cost Method

Other examples:

- **Cultural Events or Festivals**: TCM could be used to assess the value of cultural festivals or parades that are free to the public.
- **Public Libraries**: TCM can help estimate the value that communities place on library services.
- **Historic Sites**: Sites of historic or cultural significance often don't have admission fees but do attract tourists and visitors. TCM can be used to estimate the value people place on preserving these sites.
- **Beaches**: TCM can be used to estimate the value of beach access to local residents and tourists.
- **Public Museums**: Many museums are publicly funded and offer free admission. The TCM can be used to estimate how much visitors value these cultural experiences.

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CBA: Introduction

Aggregating individual benefits.

- So, let's assume we know how the project is going to impact each of us, and that we can summarize these benefits in a single number (one for each individual).
- The second step is to deduce the change in social welfare implied by all the changes in individual welfare.
- We'll then be able to decide whether the project is worthwhile as a whole for society.
- So how should we proceed to aggregate these individual benefits in a measure of social welfare? Should we simply add the net benefits of all individuals?
- This is a difficult question. But let's try to think a bit more about how to approach the problem.

CBA: Introduction

Aggregating individual benefits

- Assume for example that we want to maximize the sum of individuals' utilities. This is what we call the ***utilitarian*** approach.
- Each individual counts for the same in society's objective function.
- Let's assume, as previously, that each individual's utility depends on her level of consumption and whether the project is adopted or not.

$$u = u_i(x_i, P), \quad \text{where} \quad \frac{\partial u_i}{\partial x_i} > 0 \text{ and } \frac{\partial^2 u_i}{\partial x_i^2} < 0.$$

- Here, we are implicitly assuming that the WTP Δ_i reflects the net benefit of implementing the project (how much the individual values the project accounting for its cost).
- The concavivity of the utility function reflects the assumption of decreasing marginal utility.

CBA: Introduction

Aggregating individual benefits

- Society's welfare then writes as the sum of these utilities:

$$W(\boldsymbol{x}, P) = \sum_{i \in N} u_i(x_i, P)$$

- A project is socially desirable if the social welfare associated to the adoption of the project $W(\boldsymbol{x}, 1)$ is larger than the welfare associated to the status quo $W(\boldsymbol{x}, 0)$.
- The corresponding variation in social welfare writes:

$$\begin{aligned} \Delta W(\boldsymbol{x}) &= \sum_{i \in N} u_i(x_i, 1) - \sum_{i \in N} u_i(x_i, 0) \\ &= \sum_{i \in N} u_i(x_i, 1) - u_i(x_i - \Delta_i, 1) \end{aligned}$$

- Criteria: adopt the project if $\Delta W(\mathbf{x}) > 0$.

CBA: Introduction

Aggregating individual benefits

- Usual approach in CBA: adopt the project if the sum of willingness to pay is positive, $\sum_{i \in N} \Delta_i > 0$. Is that criteria always appropriate?
- If $\Delta_i << x_i$, then first order approximation yields:

$$\Delta W(\mathbf{x}) \approx \sum_{i \in N} \frac{\partial u_i}{\partial x}(x_i, 1)\Delta_i$$

- In theory, one should not necessarily give the same weight to everyone's willingness to pay.
- For example, if i and j have the same utility function, but j is richer than i, $x_i < x_j$, then:

$$\frac{\partial u_i}{\partial x}(x_i, 1) > \frac{\partial u_j}{\partial x}(x_j, 1)$$

so that i's WTP should be weighted more than j's WTP.

CBA: Introduction

Aggregating individual benefits

- Adding individuals' WTPs may not always be appropriate, especially if the project impacts poor people differently than rich people.
- Note that if income were optimally distributed,

$$\max_x \sum_{i \in N} u(x_i, 1) \quad \Leftrightarrow \quad \frac{\partial u_i}{\partial x}(x_i, 1) = \frac{\partial u_j}{\partial x}(x_j, 1) \; \forall i, j$$

  then it would be appropriate to weight each individual's Δ equally.
- This assumption, however, will not be satisfied in general.

CBA: Introduction

Aggregating individual benefits

- Why focus on the $\sum_{i \in N} \Delta_i$ as a measure of social welfare?
- One answer is that as long as $\sum_{i \in N} \Delta_i > 0$, it is in theory possible to compensate losers in such a way that everyone's welfare increases. In that case, there is no ambiguity, the project is indeed desirable.
- However, nothing guarantees that such redistribution of the benefits will indeed take place. In practice, it often does not happen.
- This discussion shows why adding the sum of Δ_is may sometimes be problematic.
- It also raises the problem of how to exactly measure the impact of a given policy on the individual welfare of each person in society.
- We have assumed here one single dimension. But how to even arrive at the quantity Δ_i if a project impacts our lives along various (possibly non financial) dimensions?

CBA: Introduction

Aggregating individual benefits

- Usual CBA approach: rely on market prices. If the projects increases i's consumption of good A by Δ_i^A and i's consumption of good B by Δ_i^B, then the resulting change in utility is assumed to be:

$$p_A \Delta_i^A + p_B \Delta_i^B$$

- However, the individual's increase in utility is actually equal to:

$$u_i(x_i^A, x_i^B, 1) - u_i(x_i^A - \Delta_i^A, x_i^B - \Delta_i^B, 1) \approx \frac{\partial u_i}{\partial x_i^A}\Delta_i^A + \frac{\partial u_i}{\partial x_i^B}\Delta_i^B$$

- So implicit assumption is that prices reflect how much individuals value corresponding goods (at the margin):

$$p_A = \frac{\partial u_i}{\partial x_i^A} \quad \text{and} \quad p_B = \frac{\partial u_i}{\partial x_i^B}$$

- But not always the case: difference between market prices and shadow prices.

CBA: Introduction

Aggregating individual benefits

- We have taken here the sum of individuals' utilities as a measure of social welfare. But is it the only appropriate measure of social welfare?
- Other measures of social welfare may be more appealing depending on one's views about distributive justice.
- What could be other possible measures of social welfare?
- Rawlsian Social Welfare:

$$SW = \min_{i \in N} u_i(x_i, P)$$

- How would our previous conclusions about evaluating the impact of a project on social welfare would be affected?

CBA: Introduction

Lecture 1

- Motivation and Examples.
- Basic Principles.
  - Decision Rules.
  - Timing.
  - Standing.
- Three main challenges: Uncertainty, Comparability and Aggregation.
- Willingness to Pay.
  - Definition.
  - Influencing Factors.
  - Willingness to Accept.
  - Measurement.
- Aggregating individual benefits.
- CBA approach: the 9 steps of CBA.

CBA: Introduction

The basic steps of CBA

The 9 basic steps of CBA:

1. Specify the set of alternative projects.
2. Decide whose benefits and costs count (standing).
3. Identify the impact categories, catalogue them, and select measurement indicators.
4. Predict the impacts quantitatively over the life of the project.
5. Monetize all impacts.
6. Discount benefits and costs to obtain present values.
7. Compute the net present value of each alternative.
8. Perform sensitivity analysis.
9. Make a recommendation.

CBA: Introduction

The basic steps of CBA

Assume the region of Fyn is considering whether to build a new highway between Odense and Nyborg.

First Step: Specify the alternatives.

- Many possible variables to set: How many lanes? What type of Road surface? What exact path? etc... Each combination of all these variables defines a possible highway.
- The variations are endless. Important to limit ourselves to a reasonable number of possible candidates to choose from.

CBA: Introduction

The basic steps of CBA

Second Step: decide whose benefits and costs count.

- The *standing* of the project defines whose benefits and costs should be included in the CBA.
- For example, the region of Fyn might choose to look at the problem from a regional perspective, accounting only for the impact of the highway on Fyn residents.
- Alternatively, the region of Fyn might choose to account for the benefits on the rest of Denmark or even the world.
- Controversial decision: funding agencies often take the narrower perspective (only care about their voting constitutents), but the global perspective usually makes more sense.

CBA: Introduction

The basic steps of CBA

Third Step: Identify the impact categories, catalogue them, and select measurement.

Here, on the benefits side, we would get (among others):

- Time saved and reduced vehicle operating costs for travelers on the new highway.
- Accidents avoided (including lives saved) due to drivers switching to a shorter, safer new highway.
- Reduced congestion on alternative routes.
- Benefits accruing to new travelers.

CBA: Introduction

The basic steps of CBA

The cost impact categories would be:

- Construction costs.
- Additional maintenance.
- Toll collection and toll booth construction and maintenance.

CBA: Introduction

The basic steps of CBA

- From a CBA perspective, analysts are interested only in project impacts that affect the utility of individuals with standing.
- In order to treat something as an impact, we have to know there is a cause-and-effect relationship between some physical outcome of the project and the utility of human beings with standing.
- There are no particular difficulties in specifying measurement indicators of each impact in the highway example.
- For example, the number of lives saved per year, the number of person-hours of travel time saved, and the value of gasoline saved are reasonably intuitive indicators.
- More difficult to define measurement indicators when the impact on the environment is accounted for.

CBA: Introduction

The basic steps of CBA

Fourth Step: Predict the impacts quantitatively over the life of the project.

- The proposed highway project, like almost all projects, has impacts that extend over time. It is therefore necessary to quantify all impacts in each time period.
- In particular here, we would have to make predictions regarding traffic, time saved and lives saved over the life of the project.
- Prediction is especially difficult when projects are unique (similar projects haven't been implemented in the past), have long time horizons, or relationships among variables are complex.

CBA: Introduction

The basic steps of CBA

Fifth Step: Monetize all impacts.

- Before we can aggregate the various costs and benefits related to the projects, we first need to make them commensurable.
- We do so by attaching a monetary value to each of the impacts.
- In the highway example, we have to monetize each unit of time saved, lives saved, and accidents avoided.
- For this, we need the monetary value of an hour saved by each type of traveler, the value of a life saved, and the value of an avoided accident.

CBA: Introduction

The basic steps of CBA

Sixth Step: Discount benefits and costs to obtain present values.

- For a project that has impacts that occur over years, we need a way to aggregate the benefits and costs that arise in different years.
- In CBA, future benefits and costs are discounted relative to present benefits and costs in order to obtain their present values (PV). The need to discount arises for two main reasons.
- First, there is an opportunity cost to the resources used in a project.
- Second, most people prefer to consume now rather than later.

CBA: Introduction

The basic steps of CBA

Seventh Step: Compute the net present value of each alternative.

- The net present value (NPV) of an alternative equals the difference between the PV of the benefits and the PV of the costs:

$$NPV = PV(Benefits) - PV(Costs)$$

- The basic decision rule for a single alternative project (relative to the status quo) is simple: adopt the project if its NPV is positive.
- When there is more than one alternative to the status quo and all the alternatives are mutually exclusive, then the rule is also simple: select the project with the largest NPV (if positive, otherwise keep status quo).

CBA: Introduction

The basic steps of CBA

Eighth Step: Perform sensitivity analysis.

- There may be considerable uncertainty about both the predicted impacts and the appropriate monetary valuation of each unit of the impact.
- For example, we may be uncertain about the predicted number of lives saved and about the appropriate monetary value to place on a life saved.
- We may also be uncertain about the appropriate social discount rate and about the appropriate level of standing.
- Sensitivity analysis consists in performing the CBA under various assumptions, so as to make sure that the recommendation is robust.

CBA: Introduction

The basic steps of CBA

Ninth Step: Make a recommendation.

- Generally, we should recommend adoption of the project with the largest NPV (including status quo, which NVP is zero).
- Sensitivity analysis might suggest that the alternative with the largest expected NPV is not necessarily the best alternative in all circumstances.
- Finally, it is important to note that CBA leads to recommendations, not decisions. CBA concerns how resources should be allocated; it is normative. It does not claim to be a positive (i.e., descriptive) theory of how resource allocation decisions are actually made.

Introduction to CBA

Lecture 1 exercises

The government is worried about the increased resistance to antibiotics, and is considering whether to monitor antibiotic prescribing by doctors.

Questions:

1. Step 1: What other projects might be considered?
2. Step 2: What should be the standing of the project?
3. Step 3: What are the major costs and benefits of the proposed policy?
4. Step 4: What indicators would you use to evaluate these costs and benefits?

Introduction to CBA

Lecture 1 exercises

- Analysts estimate the direct costs of enforcement of the monitoring policy to be 40 million, the time costs to doctors to be 220 million, and the convenience costs to patients to be 180 million (all annually).
- The annual benefits of the program are estimated to be 350 million in avoided resistance costs in the country, 70 million in other health related benefits in the country, and 280 million in avoided resistance costs in the rest of the world.

Questions:

1. Does the program have positive net benefits from the national perspective?
2. If not, what fraction of benefits accruing in the rest of the world would have to be counted for the program to have positive net benefits?

Introduction to CBA

Lecture 1 exercises

The city of Odense is worried about the growing number of serious bicycle accidents. The city is considering whether to implement an ordinance that would make wearing the helmet compulsory.

Questions:

1. Step 1: What other projects might be considered?
2. Step 2: What should be the standing of the project?
3. Step 3: What are the major costs and benefits of the proposed city ordinance from society's perspective?
4. Step 4: What indicators would you use to evaluate these costs and benefits?
5. Step 5: How would you monetize the cyclists' disutility from wearing a helmet?

Introduction to CBA

Lecture 1 exercises

Three mutually exclusive projects are being considered for a remote river valley:

- Project R, a recreational facility, has estimated benefits of 10 million and costs of 8 million.
- Project F, a forest preserve with some recreational facilities, has estimated benefits of 13 million and costs of 7 million.
- Project W, a wilderness area with restricted public access, has estimated benefits of 5 million and costs of 1 million.
- In addition, a road could be built for a cost of 4 million that would increase the benefits of project R by 8 million, increase the benefits of project F by 5 million, and reduce the benefits of project W by 1 million.

Introduction to CBA

Lecture 1 exercises

Questions:

1. Calculate the net benefit for each of the six possible projects.
2. What is the CBA recommendation?
3. Calculate the benefit-cost ratio for each of the seven possible alternatives. Which alternative yields the largest ratio. Compare to the CBA recommendation.
4. Assume the funding agency can spend at most 15 million. What project(s) does it choose to implement?

Introduction to CBA

Lecture 1 exercises

Net benefits:

- Project R: 2 million.
- Project F: 6 million.
- Project W: 4 million.
- Project R + road: 6 million.
- Project F + road: 7 million.
- Project W + road: 1 million.

CBA recommendation: Project F + road.

Introduction to CBA

Lecture 1 exercises

Benefits-cost ratio :

- Project R: $10/8 = 1.25$.
- Project F: $13/7 = 1.85$.
- Project W: $5/1 = 5$.
- Project R + road: $18/12 = 1.5$.
- Project F + road: $18/12 = 1.5$
- Project W + road: $6/5 = 1.2$.

Recommendation: Project F (alone).

Introduction to CBA

Lecture 1 exercises

- Not the same recommendation!
- Beware, CBA recommends project for which net benefits is the largest. May differ from project for which Benefits-Costs ratio is the highest.

Introduction to CBA

Lecture 1 exercises

Assume the funding agency can spend at most 15 million. What project(s) does it choose to implement?

- Budget constraint of 15 million. What are the combinations of projects for which the total cost is smaller than 15 million?
- Feasible combos: R,F,W (with or without road), R+F, F+W, R+W, F+W+road, R+W+road.
- Net benefits? Simply add up the net benefits of each project in the combo (beware of double counting the cost of the road).
- R+F: 8 million, F+W: 10 million, R+W: 6 million, F+W+road: 12 million, R+W+road: 11 million.
- CBA recommendation: F+W+road.