

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., 4th 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!

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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.

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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.

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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.

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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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Basic idea

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

$$\text{Project's net benefits} = \text{Benefits} - \text{Costs}.$$

- ▶ 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.

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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 $i = 1, \dots, N$ 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:

Ilisu 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.**

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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 50dkk 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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 - ▶ Influencing Factors.
 - ▶ Willingness to Accept.
 - ▶ Measurement.

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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**.

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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:

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

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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.

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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?

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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.

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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.