Cost-benefit analysis

A microeconomic foundation

Overview

- Introduction
- A framework
- Allocative efficiency and social surplus
- Social surplus — Consumers and producers surplus
- Cost of public fund

What is a cost-benefit analysis?

- It is a policy assessment method that quantifies in monetary terms the value of all consequences of a policy to all members of society.
    - It can be applied to a variety of contexts, including policy/law, project, program, regulations, any government intervention.
    - It focuses on social costs and social benefits.
    - It can either be prospective or retrospective.
- Examples—Building of a transportation project, developing a mine for mineral extraction for industrial production/export.

Examples

- Hardanger Bridge (Hardangerbrua) is one of the world's longest suspension bridges.

  —Approved 2006, construction began 2009, opened 2013

  —The bridge replaced ferries across the Hardangerfjord in Vestland county, drastically reducing travel time and improving regional connectivity.

- CBA relevance:
  Costs: Very high construction expenses (over NOK 2.3 billion), technical challenges, environmental concerns (landscape impact in a sensitive fjord area).
  Benefits: Shorter travel times, improved accessibility for local communities, better logistics for businesses, tourism growth.

- Debate—Supporters stressed regional development and long-term gains. Critics pointed to limited traffic volumes (compared to Denmark's Great Belt Bridge). The project went ahead, financed partly by tolls.

- Other examples—
  Norwegian high-speed rail proposals (where CBAs often show costs outweighing benefits due to low population density).

Primary questions

- **Whose costs and benefits count?**
  – Define the perspective: government, society as a whole, or specific groups (e.g., commuters, firms, taxpayers).

- **What is the proper counterfactual?**
  – Compare the project to the next-best alternative (e.g., continuing with ferries vs. building a bridge).

- **Who are impacted?**
  – Transport market, labour market, product and service markets, land and housing market, public finance and capital market, environment, landscape/aesthetic value.

- **How to value non-market goods?**
  – Consider how to assign value to intangibles like environmental impacts, cultural heritage, safety, or time savings.

- **How should time be treated?**
  – Decide on the appropriate **discount rate** for future costs and benefits (a contentious issue in climate and infrastructure CBAs).

- **What uncertainties and risks matter most?**
  – Identify how sensitive results are to assumptions (construction costs, traffic growth, economic multipliers).

Historical development

- Sir **William Petty (1623–1687)** is sometimes considered a proto-originator of cost–benefit thinking, though not in the modern formal sense.
    - In *Political Arithmetick* (1676), Petty argued that state decisions should be guided by "number, weight, and measure" rather than vague opinion.
- In his classic paper *On the Measurement of the Utility of Public Works* (1844), **Jules Dupuit** introduced the idea of comparing costs and benefits of public projects (like bridges, roads, canals). He laid the conceptual foundation by quantifying consumer surplus, which remains central to CBA today.
- In *Principles of Economics* (1890), **Alfred Marshall** refined and formalized Dupuit's ideas.
- In the United States, CBA became formalized in the 1930s with the **Flood Control Act of 1936**, which required that *"benefits to whomever they accrue be in excess of the estimated costs"* before approving federal projects. This was the first time CBA was applied systematically to public decision-making.

Basic steps

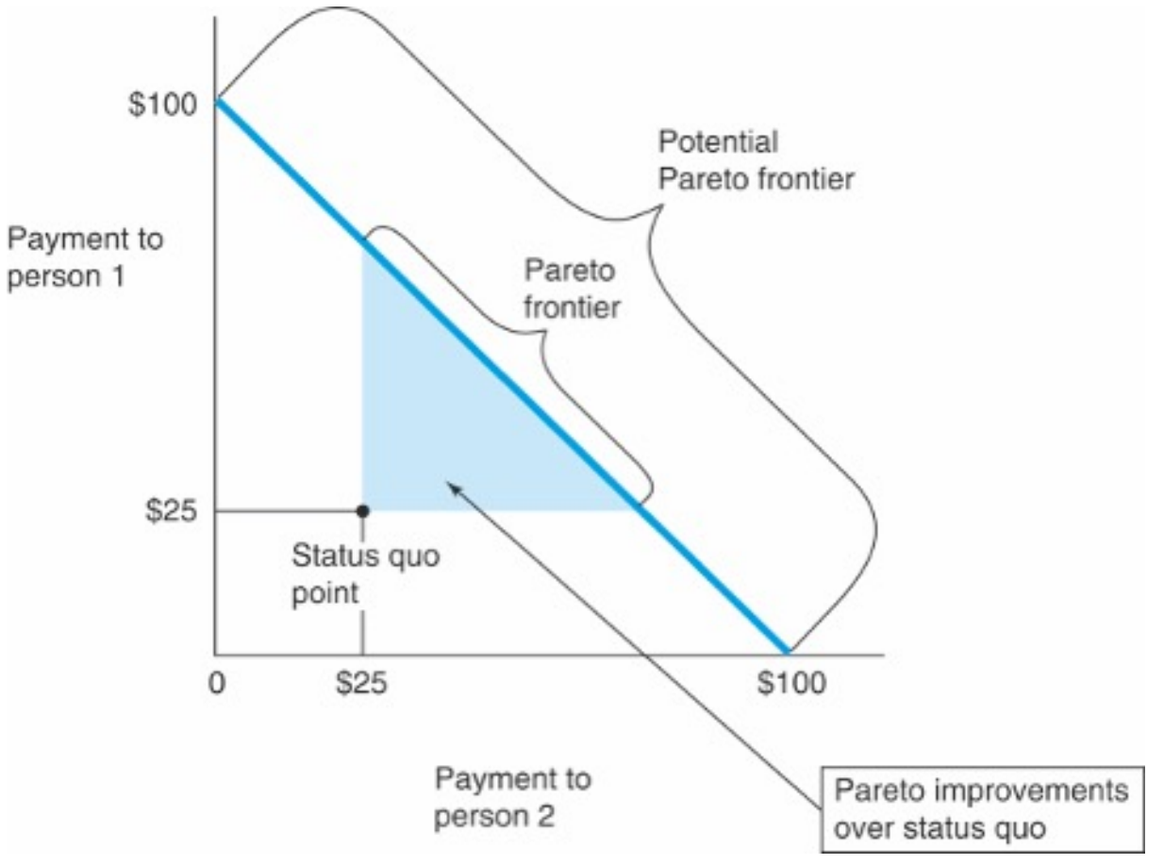
- Purpose of the study—To achieve **allocative efficiency**. But what might have caused inefficiency at the first place?
- Specify alternatives
- Identify impacted sectors—Primary, secondary, inputs, non-traded goods
- Quantify impacts over *the life of the project*
- Express them in monetary values
- Proper discounting of potential future impacts
- Perform sensitivity analysis
- Make a recommendation

Conceptual foundation

- CBA is aimed at providing a framework to assess relative efficiency of policy alternatives

- How do we measure efficiency?

- A simple and intuitive starting point can be the concept of **Pareto efficiency**.



- An allocation of resources is Pareto efficient if no other allocation can make one person better off without making anyone worse off.

- Unfortunately, it does not narrow down the choices among alternatives significantly. However, observe that the potential for improvement depends on where the status quo is.

Aggregate (net) benefit and Pareto efficiency

- Compare two alternatives, A and B, and suppose the aggregate/net benefits (aggregated over all impacted groups) under A is bigger than that under B.

- However, it might be possible that certain groups prefer A to B while others prefer B to A.
  - So, A does not *Pareto dominate* B.
    Can A be a better choice in such a case?

- *If a policy has positive net benefits, then it is possible to find a set of transfers, or side payments, that makes at least one person better off without making anyone else worse off.*

Kaldor-Hicks Criteria

- Adopt only policies that have positive net benefits. Reasons for adopting it:
    - It is feasible.
    - Society maximizes aggregate wealth.
        - If different policies have different winners and losers, then, in aggregate, costs and benefits will average out over the entire population.
        - It is possible to do redistribution wholesale rather than within each separate policy.

How to quantify efficiency?

- If benefits are given in monetary terms like our example of dividing 100 dollars, the problem would have been simple.

- Real policies affect individuals in ways that are not always simply visible in monetary terms.

- Economists generally hold the view that consumers derive utility from consumption and have preferences over alternative choices.

- Measuring utility—It isn't quantified in monetary units, and it is not directly observable.

- We have heterogenous preferences, a change in policy can affect us differently because of our preferences.

- Collective preference—How can we then express the collective preference of the entire group?

Welfare function

- Let us first address the collective preference problem.
- Social welfare function: A function that incorporates everyone utility in a "fair" way; for example

$$W(U_1, U_2) = U_1 + U_2.$$

- A change in welfare can then be expressed as $dW = \sum_{i=1}^{2} \frac{\partial W}{\partial U_i} dU_i$
- A direct application of the utility maximization principle from consumer theory gives us

$$dU_i = \sum_{j=1}^{m} \frac{\partial U_i}{\partial M_i} p_j dx_{ij}$$

- Therefore, change in welfare is given by

$$dW = \sum_{i=1}^{2} \sum_{j=1}^{m} \frac{\partial W}{\partial U_i} \frac{\partial U_i}{\partial M_i} p_j dx_{ij} = \sum_{i=1}^{2} \sum_{j=1}^{m} \beta_i p_j dx_{ij}$$

- This observation is important—It establishes a link between change in welfare and change in demand (which is also expressed in terms of its market value).

Willingness to pay

- How can we measure change in demand for goods for which no market is yet active, or even for goods which are not even tradable?

- Let us first think about a good with a market.
  The inverse market demand, where the price is represented as a function of quantity , can be interpreted as a Marginal Benefits (MB) curve: it indicates the maximum amount someone is **willing to pay** for the marginal unit of a good.

- Willingness to Pay (WTP) is a general concept that can be applied not only to a single consumption good but also in the context of broader policies. And, it can be *extended* to situations even in absence of an active market.

    - For example, it is the payment that one would have to make or receive under the policy so that one would be indifferent between the status quo and the policy with the payments.

- The algebraic sum of the WTP values is the appropriate measure of the net benefits of the impacts of a policy.

Opportunity costs of resources

- In addition to providing utility/value to consumers, a policy/project also requires employment of inputs.

- How can we measure efficient employment of resources?

- The **opportunity cost** of using an input to implement a policy is its value in its best alternative use.

- Opportunity cost measures the value of what society must forgo to use the input to implement the policy.

A policy approval rule

- If we can aggregate benefits (in terms of their willingness to pay) of users from all impacted markets and opportunity costs of all resources employed, we can come out with some simple numbers to measure the net impact of a policy.

- Measuring social surplus serves that objective.

$$SS = SS_O + SS_I + SS_S + SS_E$$

where O, I, S, E, for example, represents various markets of outputs, inputs, secondary goods and services, external non-marketed goods etc.

- A simple approval rule would be the change in social surplus

$$\Delta SS = \Delta SS_O + \Delta SS_I + \Delta SS_S + \Delta SS_E$$

must be positive, or the highest if multiple alternatives exist with positive change in social surplus.

Social surplus

- If we focus on a specific market, we can decompose the aggregate surplus based on how much value it creates and the cost it incurs to create those value

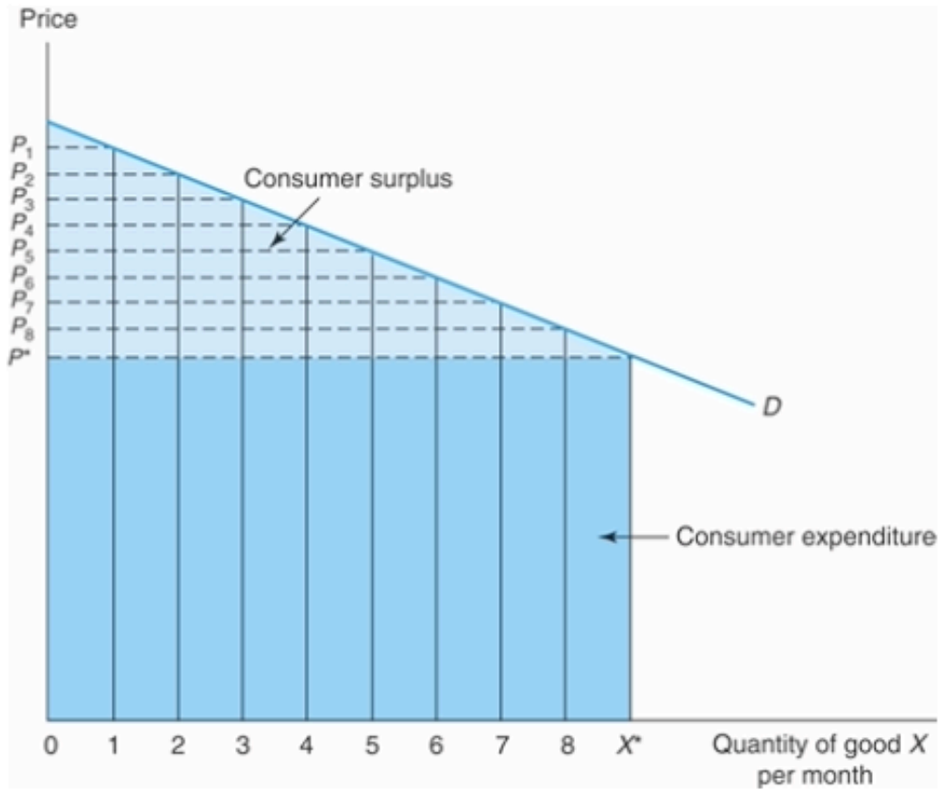
- We typically split it in two parts, one attributing to the **consumers** (who benefits from the value) and one attributing to the **producers** (who may profit by diverting some of the benefits)

- The producers' ability to divert benefits may create inefficient employment of resources

- Challenges
  - Quantification of impacts
  - Presence of impacted agents/factors in multiple markets
  - Characterizing demand and supply in **inefficient** markets
  - Dealing with time and uncertainty

Consumer surplus

- Recall that WTP can be represented by the inverse demand curve.
- We can measure the consumer surplus as the area under the market demand curve over and above the consumer expenditure.



- The net benefits are called consumer surplus.

Which demand curve?

- Consumer surplus is a close approximations of the WTP for (the benefits of) a policy change.

- Recall from microeconomic theory—We typically deal with two types of utility-maximizing demand.

    - **Uncompensated or Marshallian demand**: Utility-maximizing demand for a given fixed level of income.

    - **Compensated or Hicksian demand**: Expenditure-minimizing demand for a given fixed level of utility.

- For CBA purposes, as an approximation of WTP, it is important to measure the change in consumer surplus on a Hicksian compensated variation demand curve.

Compensating variation

- The maximum amount of money that consumers would be willing to pay to avoid a price increase is the amount required to return them to the same level of utility that they enjoyed prior to the change in price, an amount called **compensating variation**.

- To get the compensating variation, analysts often estimate the market demand by directly asking consumers about their willingness to pay for a change.

- The Marshallian demand curve, however, is sometimes the only one that is usually available. Computing consumer surplus on a Marshallian demand curve will be different than a Hicksian compensated variation demand curve because the income effect will be inappropriately included.

- Measuring the effect of price changes from Marshallian demand gives us a measure of **equivalent variation**, which is the amount of money that, if paid by a consumer, would cause him or her to lose just as much utility as a price increase.

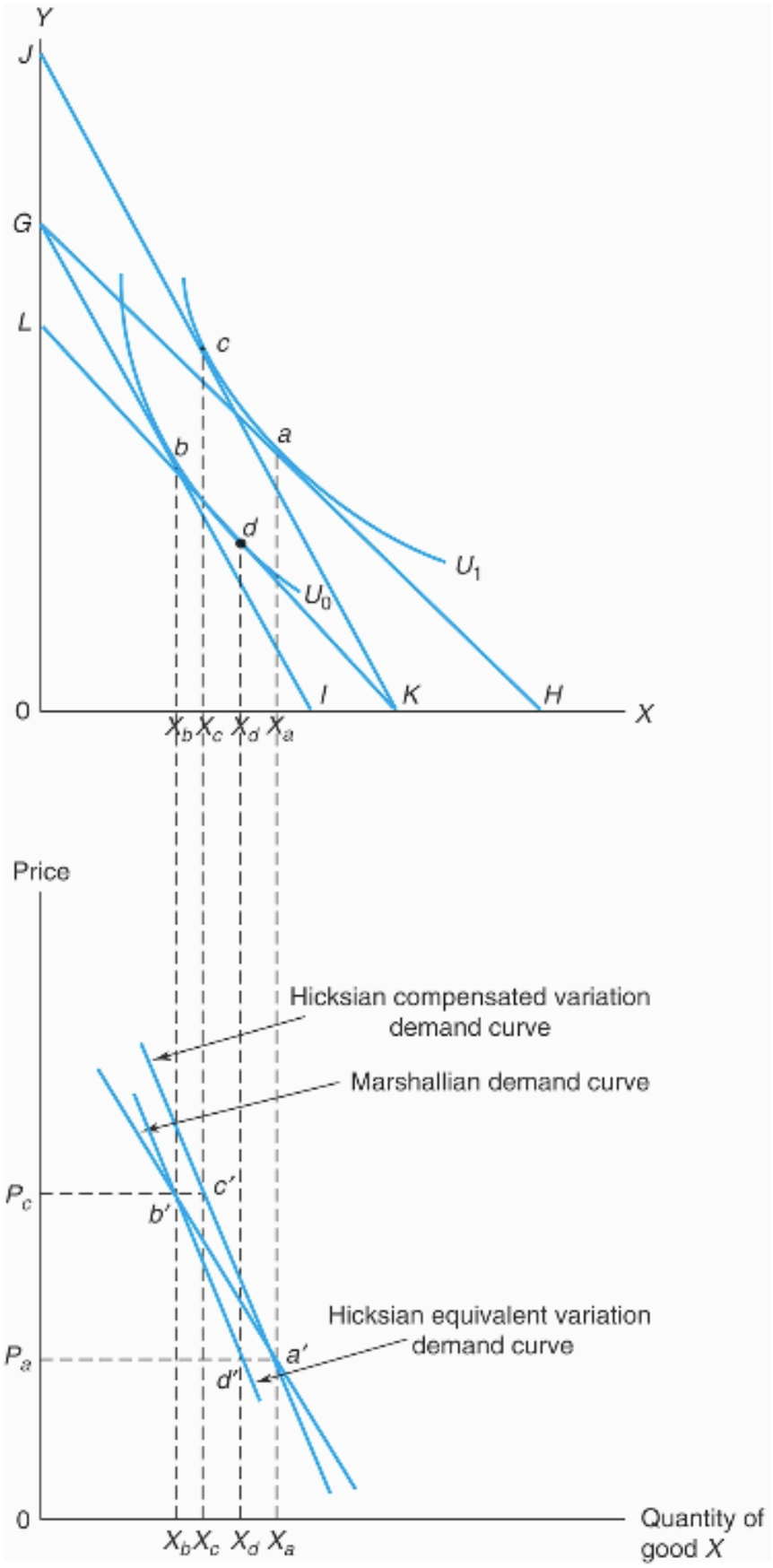


Figure 2: Compensated and uncompensated demand

Quantifying the change in consumer surplus

- If the demand curve is linear:

$$\Delta CS = -(\Delta P)(X^*) - (1/2)(\Delta X)(\Delta P)$$

- If we do not know the shape of the demand curve, we can focus on the measure of elasticity.

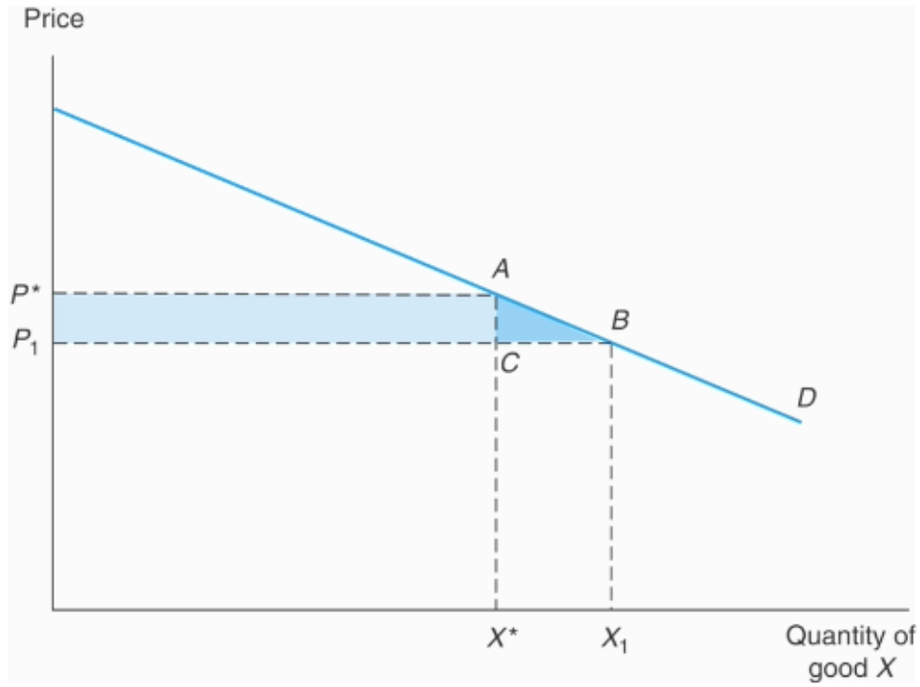


Figure 3: Change in consumer surplus

$$E_d = (dX/dP)/(X/P)$$

- The following is an approximation for the change in consumer surplus for demand curves which exhibit (close to) constant elasticity.

$$\Delta CS = -X^*\Delta P - E_d X * (\Delta P)^2/2P^*$$

Producer surplus

- Producer surplus is the supply-side equivalent of consumer surplus.
- It is the difference between total revenues (a rectangle bounded by P^* and X^*) and total variable costs.

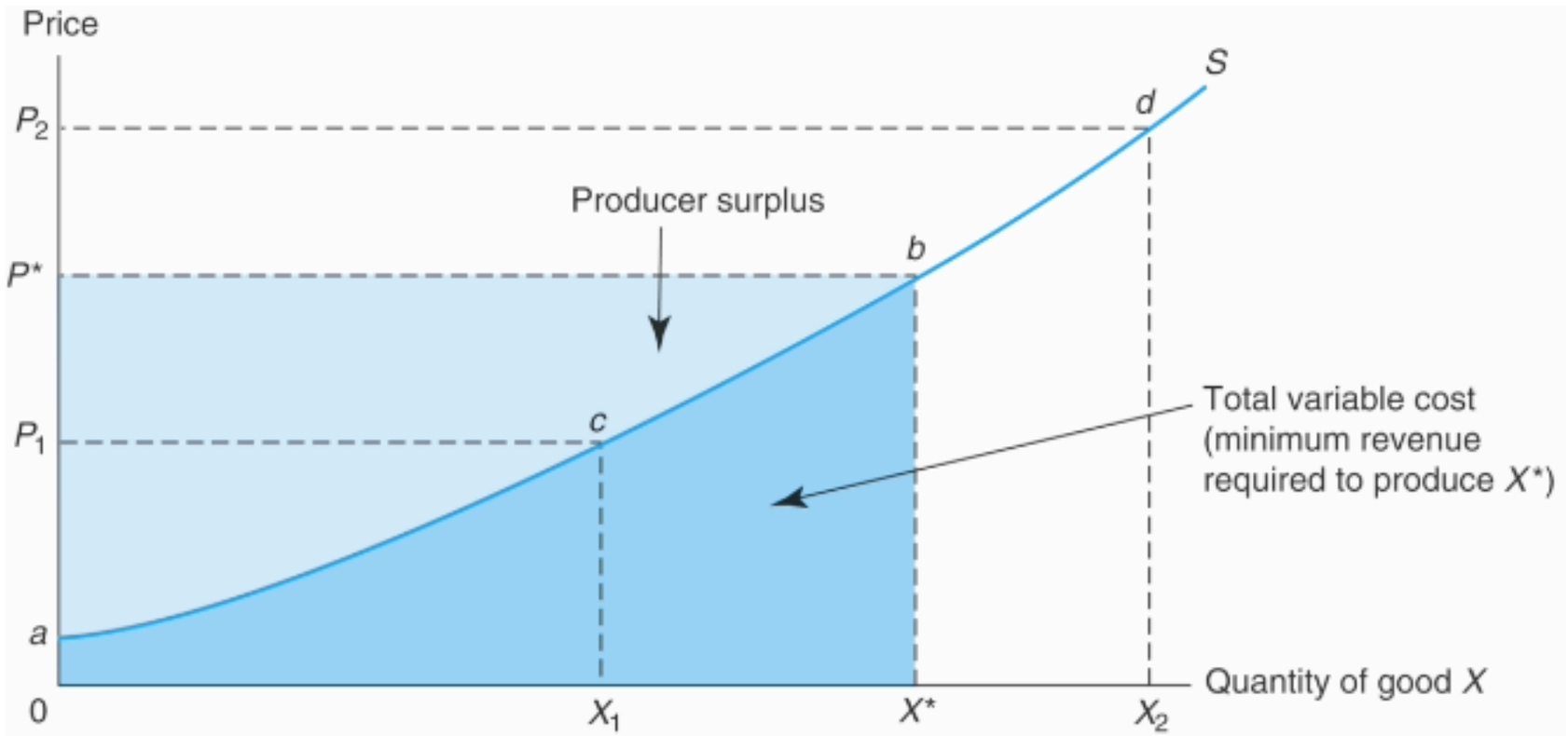


Figure 4: Producer surplus

Social surplus

- Consumer surplus plus the producer surplus equals social surplus.

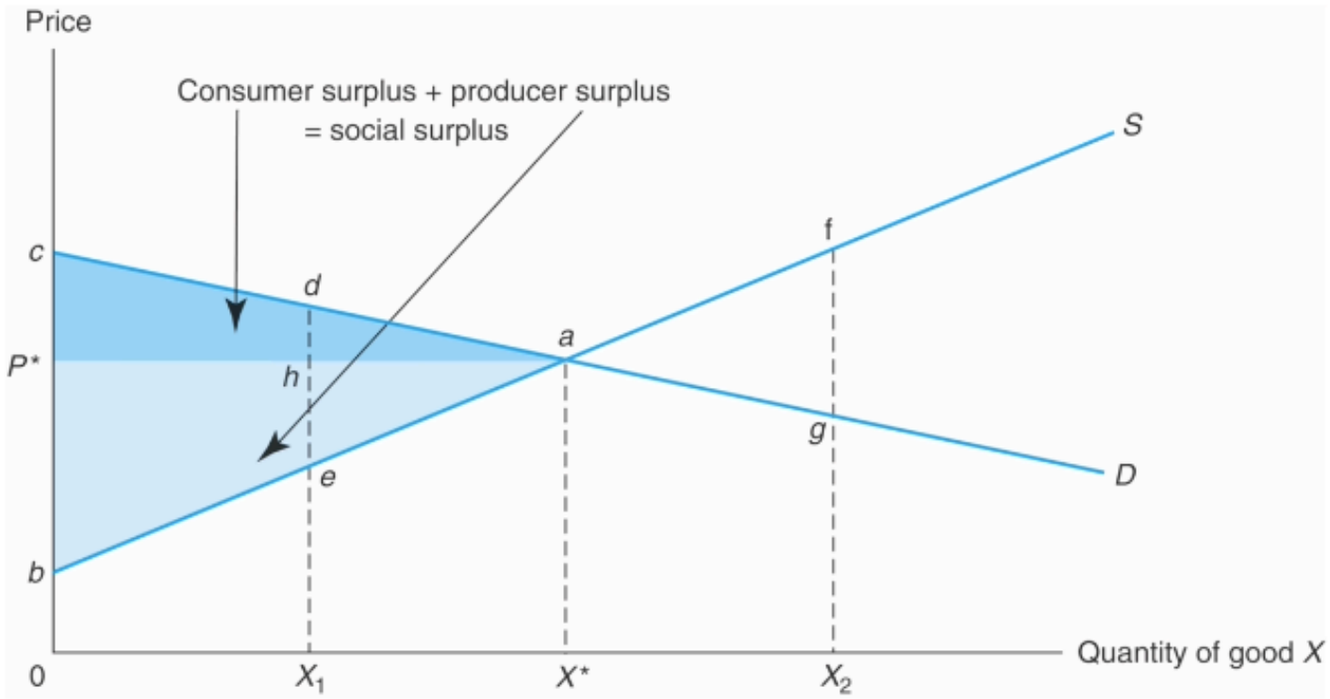


Figure 5: Social surplus

- In absence of perfectly competition, anything that interferes with the competitive process will reduce allocative efficiency.

- For example, if government policy restricts output to X_1, because of quotas, the loss in social surplus equals the triangular area *dae*.

Marginal cost of public funds

- Most public policies and projects are financed using public funds, which are raised through taxation.

- Taxes and subsidies lead to distortions in production efficiency and are associated with deadweight losses.

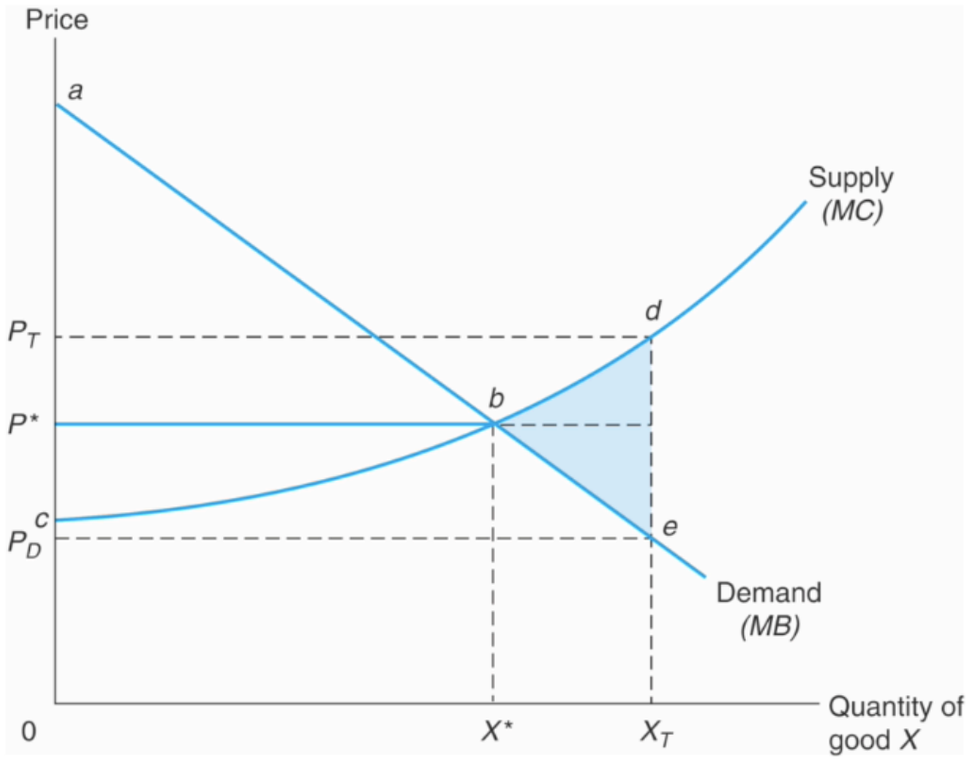


Figure 6: Deadweight loss from target pricing

Marginal cost of public funds

- The increase in deadweight loss resulting from raising an additional dollar of tax revenue is termed the **marginal excess tax burden** (METB).

- The social cost of generating monetary units through taxes is equivalent to 1 + METB, which is called the **marginal cost of public funds** (MCPF).

- MCPF can vary depending on factors such as market structure, type of tax being introduced etc.

- In the case of Norway, NOU 1997:27 (Nyttekostnadsanalyser – Prinsipper for lønnsomhetsvurderinger i offentlig sektor) discussed the appropriate size of the marginal cost of public funds.

- They recommended setting the MCPF in CBA at **1.2**
  [see Holtsmark and Bjertnæs (2015) Link: https://www.ssb.no/offentlig-sektor/artikler-og-publikasjoner/_attachment/221608?_ts=14c26cec7a0]

- A program that requires government expenditure funded by taxation incurs a social cost equal to the amount spent multiplied by the MCPF

Reading materials

- Boardman et al. Chapters 1, 2, and 3.
- “Veileder i samfunnsøkonomiske analyser”, section 3 and 4.