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Lecture note

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[*This lecture note covers materials from various sources. Supplementary reading materials include GdR chapter 2 and some parts of GdR chapter 11.*]

Cost-benefit analysis: An assessment tool

Cost-benefit analysis (CBA) is a policy assessment method that quantifies the value of a policy to all members of society in monetary terms.

Suppose we examine if a specific project should be implemented. This project can benefit certain groups in society but it also involves allocating valuable resources, such as land, labor, capital, etc., which could otherwise be used for alternative productive purposes. Our objective is to determine whether it is sensible to implement the project.

To arrive at an informed decision, we need to address several essential questions:

1. First and foremost, who is conducting the evaluation? Is it the society, an organization, or an interest group, for instance?
2. What are the potential alternatives? If resources aren't allocated to the project under consideration, how will they be utilized? How will the affected parties respond in the presence or absence (while taking the alternatives into account) of the project?
3. Who will be impacted by the project? Who stands to benefit, and who might incur costs? In the scenario of winners and losers, how should we assess the distributional effects?
4. How will we measure the benefits and costs? What if the effects of the project extend to non-marketed goods?
5. If the project is likely to have long-lasting effects, how should we incorporate these dynamic impacts into the analysis? In a scenario where the future is uncertain, how can we effectively quantify the overall impact?

The objective of a CBA is to establish a framework for assessing the relative efficiency of policy alternatives. This framework is constructed to address the above questions in a manner consistent with our understanding of economic principles, particularly those of welfare economics.

> Consider the following examples.
>
> a. Building a transportation project, for example, construction of a highway, or extension of railways, aimed at improving and shortening travel between two regions.
>
> b. Developing a mine for extracting minerals for industrial production and export.
>
> Discuss questions 1-5 within the contexts of these two projects.

A framework of CBA

We will develop a framework for CBA from the perspective of a social planner. This approach implies, among other considerations, that our focus is on assessing the changes in social welfare resulting from the project implementation. It is not just about revenue and financial cost of a project but also about how the benefits and costs are distributed to different groups of society. Furthermore, we aim to convert these factors into a welfare-based metric for policy evaluation.

Evaluating the benefits and costs requires a comparison with alternative uses of resources. For instance, construction of a highway would necessitate the allocation of land, labor, concrete, construction machinery, etc. These resources could otherwise be employed in producing other valuable goods and services for the population. While evaluating costs, we will emphasize the concept of opportunity costs, rather than merely focusing on the price of an input. The opportunity cost of employing an input is its value in its most valuable alternative use. It quantifies the value of what society foregoes in order to utilize the input for implementing the project.

To start with, a project can be regarded as a perturbation in the economy that influences the well-being of individuals. This perturbation will be realized in different markets by different groups.

Impacted markets

A project employs inputs and transform them into output. Consider a market that will be impacted due to the project. Examine the diverse sectors (such as consumers, producers, taxpayers etc.) within the affected market and quantify the combined effects across sectors.

Subsequently, aggregate the outcomes across all potentially affected markets. Pay attention if you are double counting the effects if a group appears in different markets with different roles.

Which are the affected markets? Here is a broad classification.

1. Output market
2. Input market
3. Secondary market
4. (Market) of non-traded goods

   Consider the following example and identify various impacted markets.

   Suppose a city builds a new railway line.

   Then the output market is the market for railway trips.

   Building the subway requires inputs, such as the land the stations occupy and the rail passes through, the materials used to build the stations and, of course, labor. These goods or services are called factor inputs. Markets for these inputs are "upstream" of the output markets, and are referred to as input markets.

   The project may also have indirect effects that occur "downstream." For example, a new rail station may affect the market for housing near to the station or may affect the market for gasoline if some commuters switch from driving to commuting via train. Such markets are called "secondary markets." In addition, the output of the project can be an input in another market. For example, suppliers of other goods can use the railway which may reduce their costs of transport considerably. This is also an example of an affected secondary market.

   In addition, we must also consider the externalities, for example, effects on landscape, clean air, climate, or even safety levels, associated with the project even though there are no markets for these "goods."

A simple policy approval rule

We will introduce some notations here. Let us denote the social surplus that can be accrued from various affected markets by SS. We will elaborate on this concept in the next section.

$SS = SS_O + SS_I + SS_S + SS_E$ (indices O, I, S, and E representing the various markets, output, input, secondary, and external non-marketed goods, respectively).

The change in social surplus, which will be denoted by a notation Δ, is

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

If we can quantify these changes, then we can think of a simple intuitive policy approval rule: A policy can be approved if it is associated with a positive ΔSS, and if there many such alternatives with positive ΔSS, then choose the one with the largest margin.

Two important observations to note here.

Firstly, there will be actors who might participate in multiple types of markets. For instance, a producer in the output market also functions as a consumer in the input market. It's worth noting that occasionally (though exceptions should be kept in mind), the output and input markets of the focal primary product are often collectively referred to as primary markets. This is because these markets realize the direct effects of the production activities associated with the project.

Secondly, there can be situations in which government may play a more active role in the market, for example as one of the suppliers or purchasers. It will then be useful to treat the government as a distinct actor and include the net budget impacts on the government. For a comparative perspective, refer to equations (2.1) and (2.2) in Gines de Rus's textbook (hereafter referred to as GDR) and compare those formulations with the above-mentioned approach of aggregation over markets.

We will, however, have to deal with various critical issues before we come out with a simple quantified measure of ΔSS. For example, how do we measure the social surplus in different types of markets. For a long-lasting project, how do we aggregate effects over time? How do we quantify future effects when there is uncertainty?

A tentative plan: We will now focus on these questions. Here is a tentative plan of how we will proceed in this course. My first lecture (1) will mostly focus on measuring changes in social surplus within the output market. The following lectures will discuss measuring changes in social surplus in the secondary markets (2), input markets (3), analyses of time-related effects (4), externality (5), and risk and uncertainty (6).

Social surplus and allocative efficiency

Why do we focus on the social surplus?

As mentioned at the outset, CBA serves as a framework for evaluating the relative efficiency of policy alternatives. However, at this juncture, it remains unclear how we can quantify the efficiency of a policy.

Social surplus, if it can be measured, serves two objectives. First, it quantifies benefits and costs. Second, if represented in monetary terms, it can be aggregated across groups and markets and comparing policies becomes easier.

However, how does a measure of surplus reflect market efficiency? Since our focus is primarily on the well-being of individuals, groups, and organizations, the concept of collective efficiency must be tied to the preferences of those involved.

Characterizing preference of a producer (of an entrepreneur or of a factor owner) is somewhat easy - a policy is preferred to another if the former results in higher net benefits. A measure of surplus typically quantifies benefits minus costs. We can measure benefits in terms of revenue from sales and costs in terms of the value of the next best alternative uses of inputs.

Establishing a connection between surplus and preference of consumers becomes more intricate. How can we determine whether a diverse group of consumers would be better off under a specific policy compared to an alternative?

Adding to the complexity, economists generally hold that consumers derive utility from consumption. Utility isn't quantified in monetary units, and to make the matter worse, it is not even observable. Moreover, when various consumers undergo distinct degrees of change, how can we express the collective preference of the entire group?

Pareto efficiency

A simple and intuitively appealing definition of efficiency, referred to as Pareto efficiency, underlies modern welfare economics and CBA. An allocation of goods is Pareto-efficient if no alternative allocation can make at least one person better off without making anyone else worse off.

An allocation of goods is inefficient, therefore, if an alternative allocation can be found that would make at least one person better off without making anyone else worse off.

However, the requirement of Pareto efficiency does not narrow down choices over alternatives significantly - several policies can be Pareto efficient with different individual having conflicting preferences.

Welfare function

To capture the collective preference, we can define a general social welfare function. To keep things simple, consider a society comprises of two consumers.

$W = W(U_1, U_2)$ where U_1, U_2 are individual utilities.

An example of a welfare function can be

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

A change in welfare can then be expressed as

$dW = \sum_{i=1}^{2} \frac{\partial W}{\partial U_i} dU_i$

Using some results from consumer theory, we can show that for a consumer consuming over two

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

where consumer i choice set consists of m goods, and x_{ij} is i-th consumer's utility-maximizing demand for j-th good. (The derivation is given in Ch 11 in GdR; it is not necessary to derive it for following the current discussion).

Together, we can then express the change in welfare as

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

This observation is important for two reasons. First, it establishes a link between the change in welfare and the change in demand.

Second, it shows that the change in welfare is a weighted sum of the monetary value of the change in demand. These weights affect the marginal impact of a change in income on welfare. Since society comprises individuals with varying levels of wealth, it is expected that these weights should not be the same for everyone.

We will however follow a simplified path: assigning the same weights. We will come back to this issue later in the course while discussing distributional concerns.

Now, we will establish a connection between observed demand behavior and another useful concept: willingness to pay.

Willingness to pay (WTP)

Individual demand curves slope negatively due to diminishing marginal utility. The market demand curve is the horizontal sum of individual demand curves and also slopes downward.

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 an additional unit of a good – the marginal unit.

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. 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. Only if the aggregate net benefits of the policy (as measured by WTP of affected individuals) are positive, then there exists a set of contributions and payments that create a Pareto improvement over the status quo.

We can therefore approximate the change in welfare by the net benefits, the sum of the WTP values. This approach is not without controversy; however, it is a pragmatic one. Additionally, there are strong arguments in favor of evaluating policies based on net benefits.

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.

Limitations of WTP

- It can lead to intransitive social orderings of policies (Arrow 1951).
- Dependence on the distribution of wealth: If the distribution of wealth of society changes, then individual WTP changes, and perhaps, the ranking of alternatives could change.

Consumer surplus

Now that we have to decided to measure benefits in terms of WTP, which can be represented by the inverse demand curve, we can measure the consumer surplus as follows.

The area under the market demand curve from the origin to X^* (see the Figure below) measures the gross benefits to society of consuming X^* units of the good.

If one has to pay P^* for X^* units of the good, then the rectangle bounded by P^* and X^* is the aggregate cost to consumers. The net benefits to consumers are the gross benefits minus the consumers' costs.

The net benefits are called the consumer surplus (CS): it is the area between the demand curve and the P^* line—the light shaded area in Figure 1.

Consumer surplus is important in CBA because changes in CS can be viewed as close approximations of the WTP for (the benefits of) a policy change.

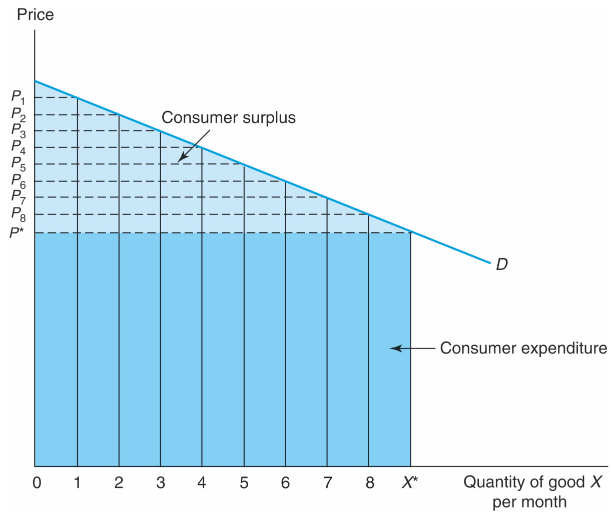

Figure 1: Consumer surplus and consumer expenditure

Equivalence of consumer surplus and compensating variation

(Recall from microeconomic theory) We deal with two types of utility-maximizing demand:

1. Uncompensated or Marshallian demand - Utility-maximizing demand for a given fixed level of income.
2. 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.

Why?

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. If consumers had to spend any more than the value of their compensating variation, then they would be worse off paying to avoid the increase, rather than allowing it to occur.

If they could spend any less, then they would be better off paying to avoid the increase, rather than allowing it to occur. Hence, for a loss in consumer surplus resulting from a price increase to equal the consumers' WTP to avoid the price increase, it has to correspond exactly to the compensating variation value associated with the price increase.

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 (if price increases, CS is smaller on a Marshallian than on a Hicksian demand curve; and if price decreases, it is larger).

The difference is usually small, however, and can be ignored unless there is a large income effect, i.e., large prices changes in key goods (housing, leisure, etc.) are being considered.

Equivalent variation, which is an alternative to compensating variation, 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.

Quantifying the change in consumer surplus

Suppose that a policy results in a price decrease, as in Figure 3. Let $\Delta P = P1 - P^* < 0$ denote the change in price and let $\Delta X = X1 - X^* > 0$ denote the change in the quantity of good X consumed. If the demand curve is linear, then the change in consumer surplus, ΔCS, can be computed by using the formula:

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

Sometimes we may not know the shape of the demand curve and, therefore, may not know directly how many units will be demanded after a price change, but we may know the (own) price elasticity of demand, E_d.

The price elasticity of demand is defined as the percentage change in quantity demanded that results from a 1 percent increase in price.

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

Then the following can be an approximation for the change in consumer surplus for demand curves which exhibit (close to) constant elasticity:

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

> Exercise 1: A person's demand for gizmos is given by the following equation: $q = 6 - 0.5p + 0.0002I$, where q is the quantity demanded at price p when the person's income is I. Assume initially that the person's income is $60000EUR$.
>
> - At what price will demand fall to zero? (This is sometimes called the choke price because it is the price that chokes off demand.)
> - If the market price for gizmos is $10EUR$, how many will be demanded?
> - At a price of $10EUR$, what is the price elasticity of demand for gizmos?
> - At a price of $10EUR$, what is the consumer surplus?

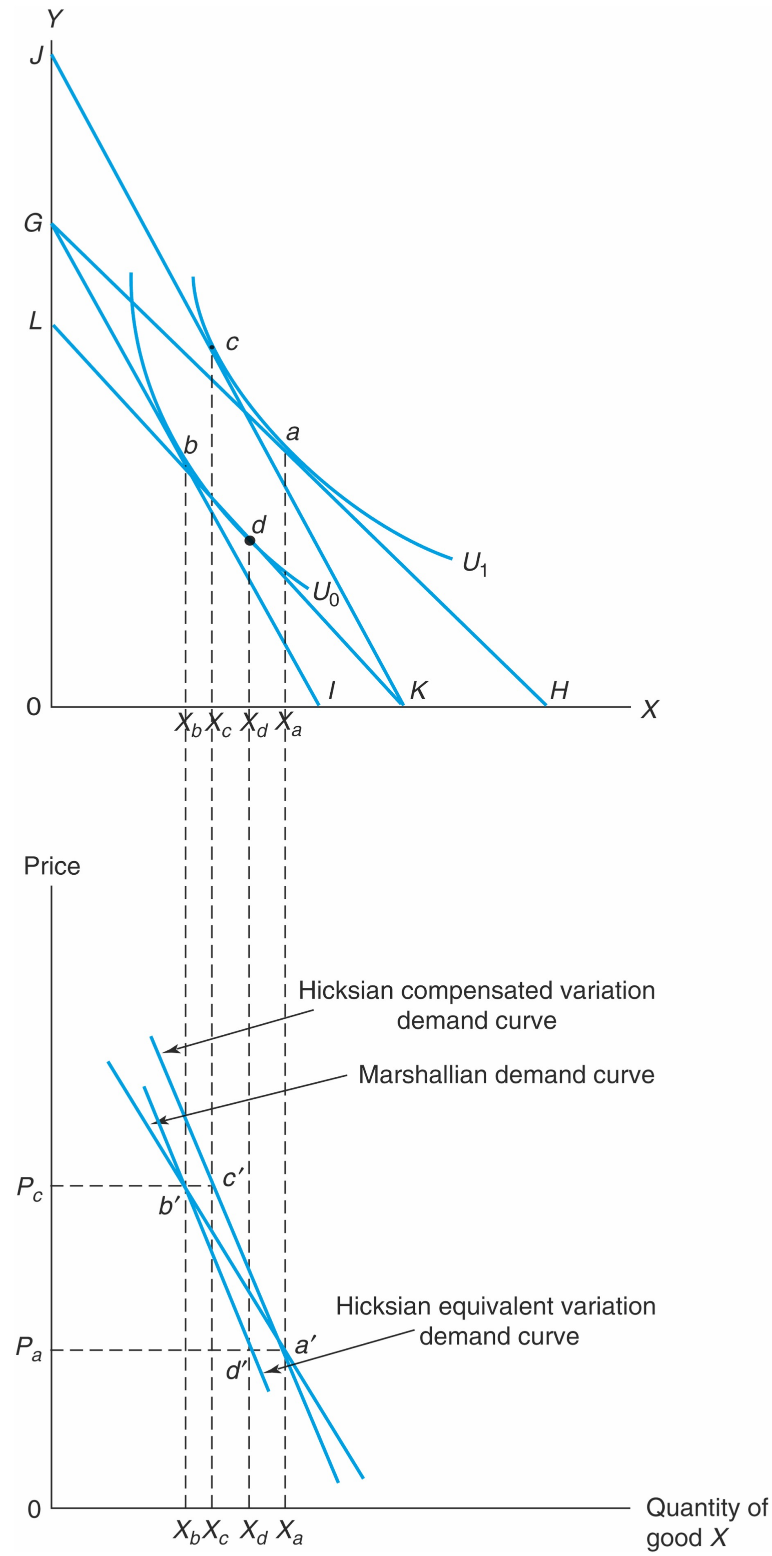

Figure 2: Compensated and uncompensated demand

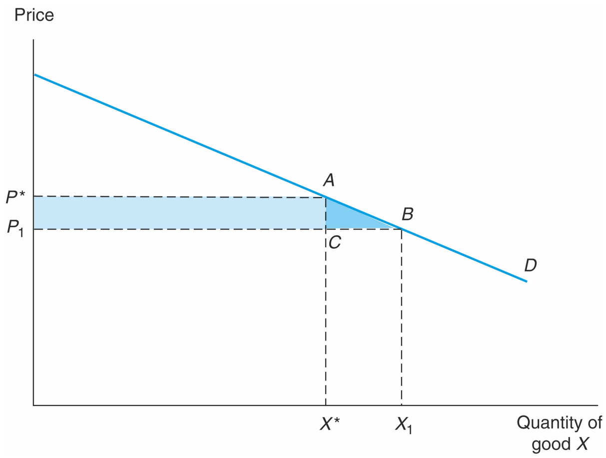

Figure 3: Change in consumer surplus

- If price rises to $12EUR$, how much consumer surplus is lost?
- If income were $80000EUR$, what would be the consumer surplus loss from a price rise from $10EUR$ to $12EUR$?

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. Diagrammatically, it is the area between the price and the supply curve; see Figure 4.

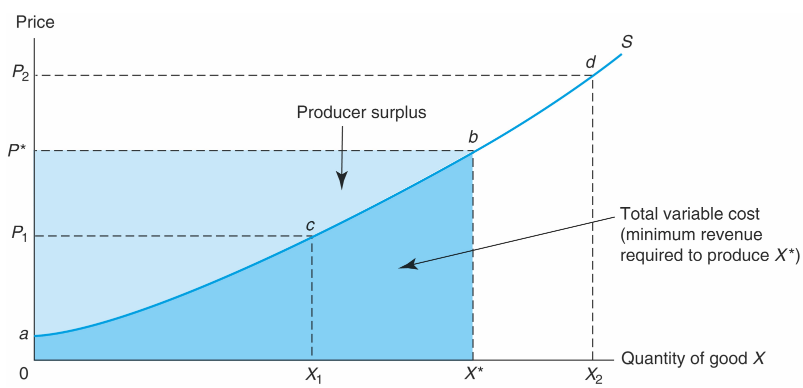

Figure 4: Producer surplus

Social surplus

Ignoring government surplus, consumer surplus plus the producer surplus equals social surplus. Graphically (see Figure 5), social surplus is the area between the demand and supply curves to the left of the equilibrium point.

Since demand reflects MB and supply reflects MC, net social benefits (social surplus) is maximized where the supply and demand curves intersect. Because this equilibrium price P^* and output level X^* come about under perfect competition, we see that perfect competition maximizes social surplus. This point is a Pareto optimum point and it is allocative efficient.

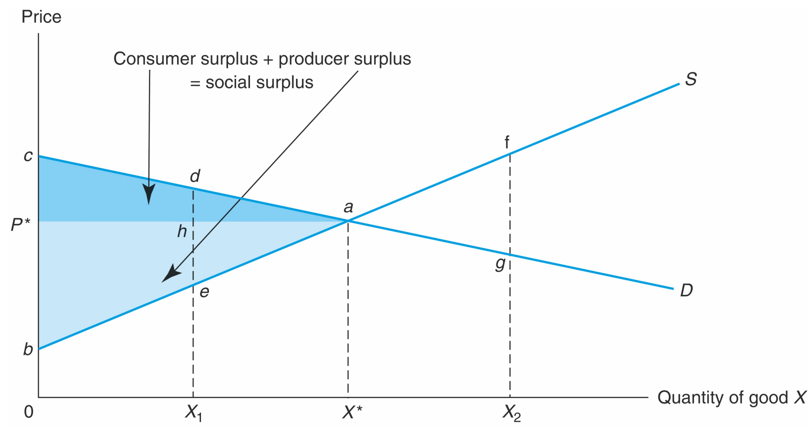

Figure 5: Social surplus

In a perfectly competitive market, anything that interferes with the competitive process will reduce allocative efficiency.

Suppose, for example, government policy restricts output to X_1, due, for example, to output quotas. At least some people will be worse off relative to output level X^*. The loss in social surplus at X_1 would equal the triangular area *dae* – the area between the demand curve (MB) and the supply curve (MC) from X_1 to X^*.

Similarly, the loss in social surplus at X_2 would equal the triangular area *afg* – the area between the demand curve and the supply curve from X^* to X_2. These deadweight losses reflect reductions in social surplus relative to the competitive market equilibrium (at X^*). A government policy that moves the market away from the perfectly competitive equilibrium increases deadweight loss and reduces social surplus.

profits and factor surplus

The formula for producer surplus is not always satisfactory. Sometimes, a change in policy would not only affect the profit of the producer of the final product but can also change prices of the inputs used in production.

We will come back to this issue later in more detail. For the time being, we can simply say that a more useful description of the surplus generated at the production stage could be a sum of the final producer's surplus (sometimes called profits or surplus to those holding entrepreneurial capital) plus the surplus to the factor owners.

$SS = CS + \Pi + FS$

The incremental net social benefit ΔSS of a change in policy is then given by:

$\Delta SS = \Delta CS + \Delta \Pi + \Delta FS$

government surplus

Thus far, we have only considered the effects of policy changes on consumers and producers. From a practical standpoint, it is useful to treat the government as a distinct actor or sector in society. Otherwise, we would have to trace every incremental change in government revenue or expenditure back to individual investors or consumers.

Therefore, we include the net budget impacts on the government, which is typically referred to as the government surplus GS. When there is a change in government surplus, the social surplus consists of the following components:

$SS = CS + PS + GS$

The incremental net social benefit ΔSS of a change in policy is therefore given by:

$\Delta SS = \Delta CS + \Delta PS + \Delta GS$

Often in projects subjected to CBA, a government can bear all the costs of a project, while none of the financial benefits accrue to them. For example, the government may cover all the expenses of constructing rent-free housing for disabled individuals. To simplify matters and align with the assumption of perfect competition, it's reasonable to assume that there's no change in producer surplus in such situations. The project's benefit is the increase in consumer surplus, the cost is the net government expenditure, and the net social benefit equals the benefits minus the costs.

Now, let's contrast this with a scenario where the government builds the same housing but charges a market rent. Is it still reasonable to assume that there's no change in producer surplus? Indeed, it is. We can measure the benefit as the change in consumer surplus and the cost as the change in government expenditure (i.e., construction costs plus operating costs). The rent paid is essentially a transfer – a cost to consumers but a benefit to the government. The net effect of a transfer is zero. Thus, it can be disregarded in the calculation of net social benefits.

Consider the following example.

Assume that initially the perfectly competitive market shown in Figure 6 is in equilibrium at a price of P^* and the quantity X^*. Then suppose that a new policy is enacted that guarantees sellers a price of P_T. Generically, these are known as *target pricing policies*.

At a target price of P_T, sellers desire to sell a quantity of X_T. However, buyers are willing to pay a price of only P_D for this quantity, so this becomes the effective market price. Under target pricing, the gap between P_T and P_D is filled by subsidies paid to sellers by the government.

As the marginal cost of producing X_T exceeds marginal benefit for this quantity of good X, a social surplus loss (deadweight loss), corresponding to area *bde*, results from the policy.

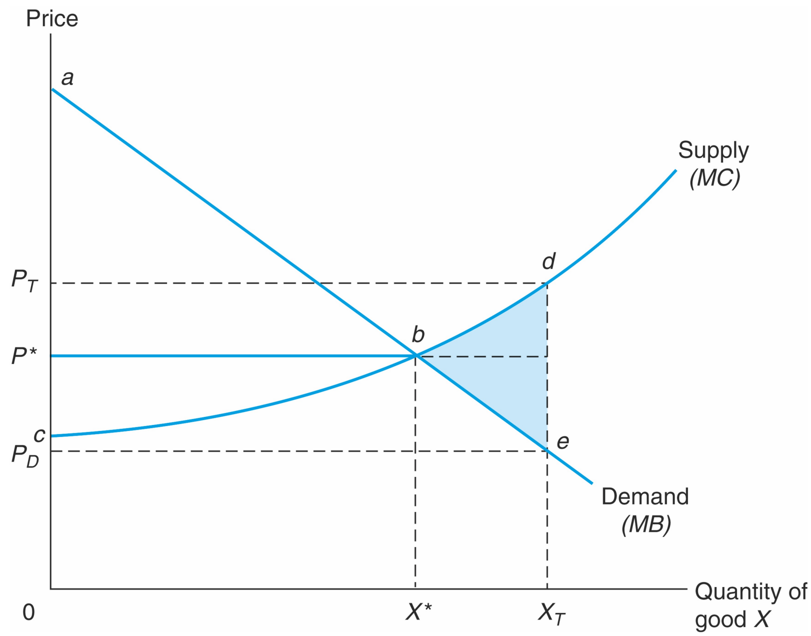

Figure 6: Deadweight loss from target pricing

Marginal cost of public funds

Most public policies and projects are financed using public funds, which are raised through taxation. However, taxes often lead to distortions in production efficiency and are associated with deadweight losses.

We refer to the portion of each tax or subsidy that contributes to a deadweight loss as a potential source of leakage or an excess tax burden. In the case of the target pricing example, for instance, this leakage or excess tax burden can be represented by the area $bde/P_T deP_D$. TThe 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).

Numerous empirical estimates exist regarding the magnitude of METB. Additionally, there are direct estimates available for MCPF. These estimates vary for several reasons, including the type of tax, as mentioned earlier.

For instance, 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. For a detailed discussion on this matter, refer to Holtsmark and Bjertnæs (2015).

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

Considering these efficiency effects, we can express the change in social surplus as follows:

$\Delta SS = \Delta CS + \Delta PS + (MCPF)\Delta GS.$

If we like to distinguishes between producer surplus that accrues to firms, denoted as $\Delta\Pi$, and producer surplus that accrues to factors of production, denoted as ΔFS, then the above can be expressed as

$\Delta SS = \Delta CS + \Delta\Pi + \Delta FS + (MCPF)\Delta GS.$

This formulation evaluates alternatives in terms of allocative efficiency. However, at times, the weights may assume different values due to equity considerations.