SOK-2014 . Fall 2024

Cost-benefits analysis: Lecture note

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Section 3

Valuation of non-marketed goods

Estimating the change in social surplus relies on knowledge regarding the impact of a policy, such as the number of affected individuals, and the marginal social benefit or cost associated with an additional unit of the affected good or service. In an ideal market scenario, the market price aligns with both the marginal social cost and the marginal social benefit of an extra unit of the good or service. When market conditions are distorted, we search for a shadow price that can better represent the true marginal social cost.

However, in many CBA, markets for specific goods, such as human life or leisure, do not exist. When no market exists for the particular item in question, two primary methods for estimating shadow prices come into play. It's plausible that the shadow price can be indirectly inferred from the market for a related commodity. By examining this related market, we can extrapolate the value of the non-marketed good. This estimation method relies on observing actual behavior, albeit of a different yet related good traded within a market, and typically falls within the realm of *revealed preference* methods.

The second approach to estimating a shadow price involves using contingent valuation through surveys and belongs to methods grounded in *stated preference*. Note that the key distinction between these two methodologies depends on the use of observations of real behaviors. For instance, the survey method can also be employed to gather information about actual behavior, aligning it more closely with revealed preference rather than stated preference.

Revealed preference methods

We will begin with discussing the revealed preference methods.

Market analogy method–Estimation based on information of an analogous good

Governments often provide private goods such as housing, campsites, university education, among others. However, they may provide these services at substantially lower prices than those prevailing in the market. The price paid for these publicly provided private goods may not align with the market supply curve and only represents a single point on the demand curve. It may, however, be possible to estimate the true demand curve using data from a similar good provided by the private sector.

Using the market price of or expenditures on an analogous good

The market price of a comparable good in the private sector provides a good estimate of the value of a publicly provided good if it equals the average amount that users of the publicly provided good would be willing to pay (WTP).

Where the government provides a good or service at a lower than market price, the price paid by occupants would generally underestimates the benefit of this service because users would be WTP at least this amount; some might pay more.

Let's consider a local government project that offers apartments to 100 households at a monthly rent of 5.000 kr. The government revenue amounts to 500.000 kr. How can we gauge the full extent of the benefits derived from this project? One straightforward estimate might be to solely look at the revenue figure. However, this approach tends to underestimate the actual benefit, as many residents might be willing to pay more for these apartments.

Now, if we take comparable apartments in the private market, which charge a rent of 10.000 kr per month, and consider 10.000 kr as a shadow price, the estimated benefits amount to 1 million NOK.

It's crucial to consider the target demographic of consumers in the public project. For instance, if these apartments are primarily occupied by well-off individuals, then the revenue figure falls significantly short of representing the true measure of their Willingness to Pay (WTP).

Using information about an analogous private-sector good to estimate the demand curve for a publicly provided good

Rather than focus on the average amount that users of a publicly provided good are willing to pay, it is conceptually better and easier to think about the demand curve for the good. We can use private-sector data to help map out the demand curve for a publicly-provide good if the goods and their markets are similar. Of course, using expenditures alone underestimates total benefits because it ignores consumer surplus.

Consider a scenario where the government provides a service, such as access to a public wifi, at no cost, and it attracts 300.000 users daily. This observation represents just one specific point on the demand curve. However, if we can identify a comparable location where the same service is offered at a positive price, we can have better estimate of the potential demand curve. For instance, in another area, a similar service is available at a price of 5 kr, and it attracts 100.000 users per day. See Figure 1. Assuming linearity in demand, we can estimate it using the line *abc*, and the consumer surplus would correspond to the area *oac*.

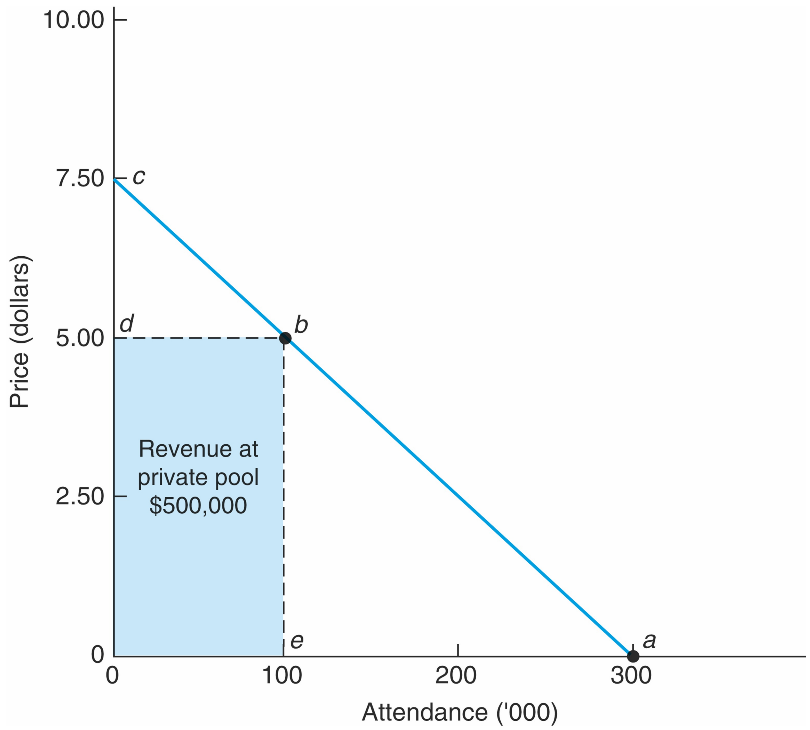

Figure 1: probable demand curve

Trade-off method–Estimation of shadow prices based on trade-offs

We can use the opportunity cost, the value we give up to get a certain good, as a measure of its value. For example, time saved could be valued using the after-tax wage rate. Similarly, the trade-off that people make between changes in fatality risk and wages can be used to value a statistical life.

Value of time saved

When a public project impacts individuals' time, such as alterations in travel duration or waiting in queues for government services, we frequently seek to determine the shadow price associated with the time saved or expended.

The labor market serves as a clear parallel to valuing time saved. In cases where market imperfections are absent (meaning individuals can freely choose their work hours, and there is no unemployment), the wage rate is equivalent to the marginal value of time. Nonetheless, several challenges arise when attempting to utilize the wage rate as a measure for valuing time saved:

- Wages ignore benefits, which are also a form of compensation for work.
- It should take account of taxes as one's decision to work typically depends on the after-tax wage rate (plus benefits).
- People value different types of time differently.
- The wage rate may not be appropriate due to rigidities in the market or market failures. For example, people may not be able to easily adjust the number of hours they work.

Value of a statistical life

The valuation of human life remains a subject of debate. We allocate substantial resources to rescue trapped miners or provide heart transplants to certain individuals, but may not invest in initiatives aimed at improving mine safety or reducing the prevalence of heart disease. In practice, to efficiently allocate resources and assess the advantages of life-saving projects, we must establish a monetary value for a saved life.

Forgone earnings method

This method suggests the value of a life saved equals the person's discounted future earnings. It generates higher values for young, high-income males than old, low-income females. For retired people, the resultant value of life may be negative. Conceptually, most problematically, this method does not reflect what people are WTP for a small reduction in risk of their death.

Willingness to purchase safety

This method estimates the value of life by observing how much people pay for life-saving devices, such as safety belts. If people are indifferent between paying an extra 1000 kr to reduce the probability that they will die by 1/10000, then they value their life at 10 million; Consider the indifference condition: $(\rho + \omega)V - 1000 = \rho V$.

Willingness to avoid danger

Similarly, if a person is willing to forgo an extra 50000 kr per year to increase the probability that he will not have a fatal on-the-job accident by 1/1000, then he values his life at 50 million; considering the indifference condition: $(1/1000) * V = 50000$.

There are several problems with these simple approaches:

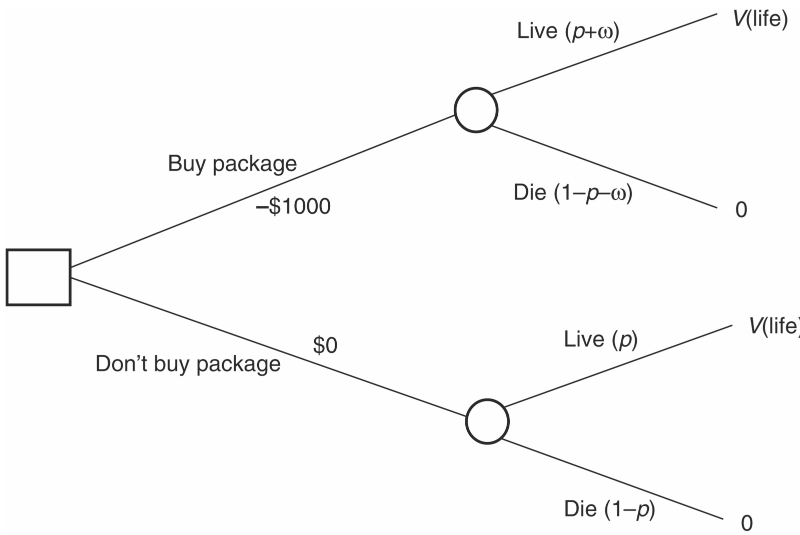

Figure 2: Decision tree for safety package purchase

- These methods assume workers and consumers fully understand the risks, which they may not.
- Are the participants true representative of the population? For example, people who take risky jobs may be more likely to take risks which would lead to a relatively small gap in the salary between risky and less-risky jobs.
- Can we accurately measure the risks?
- The WTP to reduce fatality risk (and therefore the estimated VSL) depends on both the level of risk and the change in the risk level due to the policy. People probably have diminishing marginal utility for safety.

Valuation methods–Valuation of related goods

Estimation based on prices of capital goods

The impacts of a project or policy can be inferred from changes in the price for certain capital goods. For example, the value of noise can be inferred from comparing the price of a house in a noisy neighborhood to the price of a similar house in a quiet neighborhood. Changes in the market values of firms following a regulatory change can be used to estimate the change in producer surplus of the new regulations.

An advantage of using market prices is that information is quickly and efficiently capitalized into prices so that the price differential provides a good estimate of the value of the policy change.

Non-traded intermediate good

If a project produces an intermediate good that is not sold in a well functioning market, then its value can be imputed by determining the value added to the *downstream activity*.

For instance, consider an irrigation project that supplies water to farmers. If water is traded within a well-functioning market, it becomes feasible to estimate the market demand curve. However, if such a market does not exist, we have to infer the shadow price. We can consider to what extent the level of income changes in the downstream industry.

Annual Benefit = NI(with project) – NI(without project)

where, NI = net income of downstream business. The total benefit of a project can be computed by discounting these annual benefits over the project's life. This method can be used to value improvements in human capital, such as training programs, by comparing the average incomes of those in the program to those who are not.

The method assumes the difference in income captures all of the benefits. The assumption is questionable when there may be additional consumption benefits.

Critique of the simple valuation methods

All of the methods discussed above suffer potentially from the *omitted variable problem* (we assume that only the price of the comparable good has changed but in practice the project could affect numerous goods and we may not control for all potential affected markets) and *self-selection bias*.

Hedonic price method

The hedonic price method is a tool for appraising an attribute when its value is reflected in the pricing of assets such as houses or salaries. This method addresses potential challenges arising from omitted variables and self-selection bias and comprises two distinct steps.

Suppose we are trying to assess the worth of a scenic view. First, we estimate the impact of an improved scenic view on the value of houses, represented by a slope parameter within a regression model. Consider, for instance, the following regression equation.

$$lnP = b_0 + b_1 ln(area) + b_2 * ln(view) + b_3 * (closetocity) + b_4 * (otherchac.) + error$$

This equation is commonly referred to as a *hedonic price function* or an *implicit price function*.

Note that the coefficient b_2 measures the price elasticity with respect to the variable measuring the quality of *view*.

The change in a house's price resulting from a unit change in a specific attribute, often referred to as the slope, is known as the hedonic price, implicit price, or rent differential associated with that attribute.

In a well-functioning market, the hedonic price can naturally be understood as the extra cost incurred when purchasing a house that offers a slight improvement in a particular attribute.

In the context of the above model, the hedonic price of view can be described as

$$h_v = \frac{\partial P}{\partial view} = b_2 * \frac{P}{view}$$

Next, we can estimate the WTP for scenic views, after controlling for individual taste, which can be proxied by income and other socioeconomic factors. For example, we can estimate the following WTP function (inverse demand function) for scenic views:

$$h_v = W(view, Y, Z)$$

where, h_v is estimated from the hedonic price function, Y is household income, and Z is a vector of household characteristics that reflects tastes. The estimated $W-$function reflects an inverse demand function for scenic views, and can be used to measure the changes in consumer surplus for a certain change in quality of scenic views.

There are several potential problems with hedonic models. First, we implicitly assume that people understand the implications of the attribute that is being valued. For example, people should know the level of pollution at the property they buy and know the expected effect of this level of pollution on their health. In addition, the econometric approach is vulnerable to measurement error and specification error. Further, markets may not necessarily adjust to changes in the attributes of interest and to all other factors in the short run.

Travel cost method

Most applications of the travel cost method (TCM) have predominantly focused on assessing the value of recreational sites.

When we seek to estimate the value of a specific recreational site, we anticipate that the number of visits to a recreational site depends on various factors, including the *true* cost to visit, the price of substitutes, income level of the targeted population, and other potential preference-related characteristics.

The TCM acknowledges that the true cost incurred by individuals for a visit to a recreational site encompasses more than just the admission fee. It encompasses expenses associated with traveling to and from the site. Within these travel costs lie elements like the opportunity cost of time spent traveling, the operational costs of vehicles used for travel, expenses for

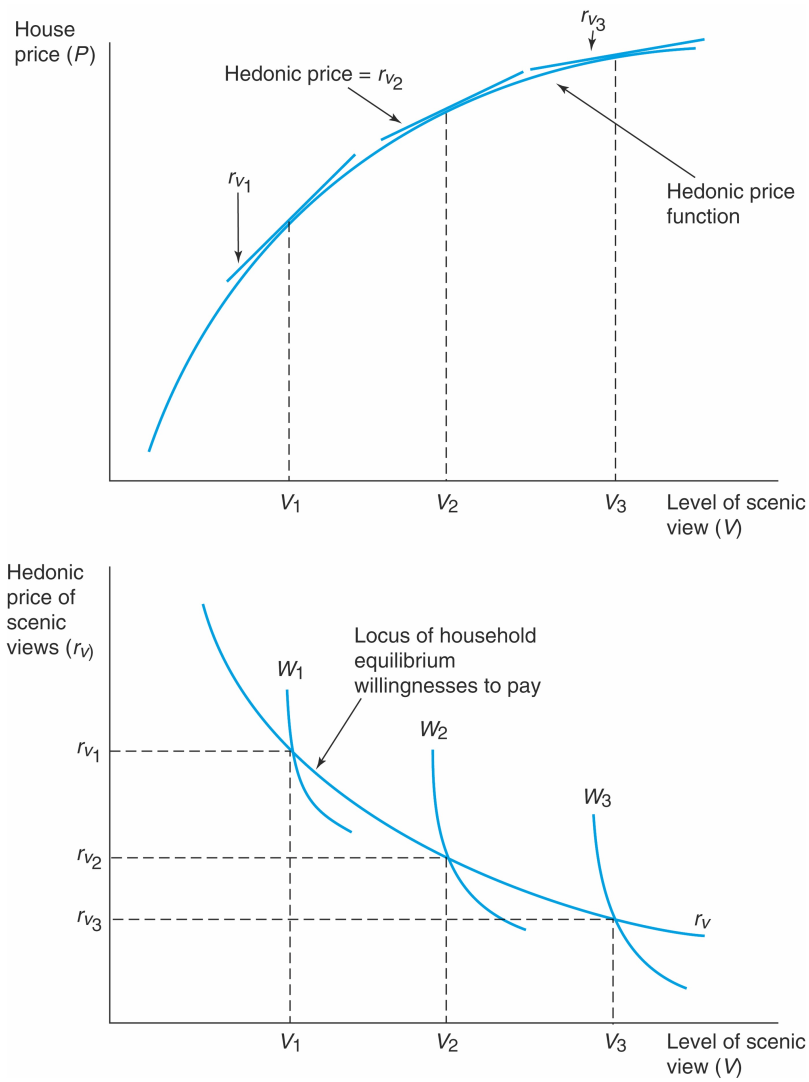

Figure 3: Hedonic pricing

accommodations during overnight stays while traveling or visiting, and parking fees at the site, among others. The sum of these costs constitutes the total cost of visiting the site.

The ingenious aspect of the TCM lies in recognizing that, although admission fees are generally uniform for all individuals and, in some cases, even nonexistent, the total cost encountered by each person varies due to disparities in the travel cost component. Consequently, usage patterns also differ, allowing us to estimate a demand schedule for the site.

Conceptually, estimating the demand schedule involves several steps. First, a random sample of households residing within the market area of the site is selected. Second, these households are surveyed to determine the frequency of their visits to the site over a defined period, encompassing all costs incurred during these visits, expenses related to visiting alternative sites, their incomes, and other characteristics that may influence their demand. Third, a functional form for the demand schedule is specified, and estimation is performed using the survey data.

However, the empirical approach has its limitation in terms of measurement error, selection bias (endogeneity issues), and omitted variable bias.

Stated preference methods

For some public goods, there are no obvious ways to determine preferences through observation of behaviors. In these cases, there may be no alternative to asking a sample of people questions about their valuations. These surveys are typically referred to *contingent valuation* surveys.

The primary use of contingent valuation surveys is to elicit information about WTP for changes in the quantity of a good. Valuation by contingent valuation surveys of goods that are directly consumed by potential consumers is relatively non-controversial. However, valuation of passively-used or non-used good (for example, assessment of preserving an archaeological site) with such a survey is more controversial. The uses of these contingent valuation surveys however, are rapidly growing.

Typical steps in conducting a contingent valuation survey are as follows.

1. Identify a sample of respondents from the population.
2. Ask respondents questions about their valuations of a good.
3. Estimate respondents' WTP for the good using information from the survey.
4. Extrapolate the results to the entire population.

Direct elicitation method

Open-Ended method

Respondents are simply asked to state their maximum WTP for a good or policy being valued.

Close-Ended Iterative Bidding Method

Respondents are asked if they would pay a specified amount for the good or policy. If yes, then the amount is increased incrementally and they are asked again (until there is a response of no). If no, then the amount is lowered and they are asked again (until there is a response of yes). This method is however, found to be too sensitive to the initially presented value.

Contingent Ranking Method

Respondents are asked to rank specific feasible combinations of the good being valued and monetary payments. An example would be low water quality and low taxes vs. high quality and high taxes, including several combinations in between. This method makes it is easier for the respondent to answer (an ordinal procedure). The WTP must be inferred from the rankings, however, rather than being directly elicited. Also, responses tend to be sensitive to the order in which the alternatives are given.

Dichotomous-choice method

Respondents are asked whether they would be willing to pay a particular amount, or bid price, to obtain a good or policy. The range of bid prices are chosen by the analyst. Because many respondents are surveyed, accept/reject probabilities can then be calculated for each bid price. Data can then be plotted in a histogram (number of yes responses versus bid price). The curve fitted to the histogram can be viewed as the demand curve of a randomly drawn member of the sample.

The demand curve shows the probability that an individual would be willing to pay for the good or policy at each price. The area under this curve provides an estimate of the individual's WTP.

The method has several potential challenges.

First, the issue in consideration can be quite complex. Problem arise in defining exactly what the good or policy is (especially for non-used goods). Second, can a question be phrased to elicit a neutral response? Third, the respondents may have non-commitment bias - they do not have to pay their stated willingness to pay. In addition, in iterative bidding methods seem to quite sensitive to initial bidding value and order to bidding.

Judgmental biases may arise in response to certain questions—i.e. is the question framed as WTP or willingness to accept (WTA)? If consumers act rationally and markets operate efficiently, the distinction between WTP and WTA for most goods should have minimal impact.

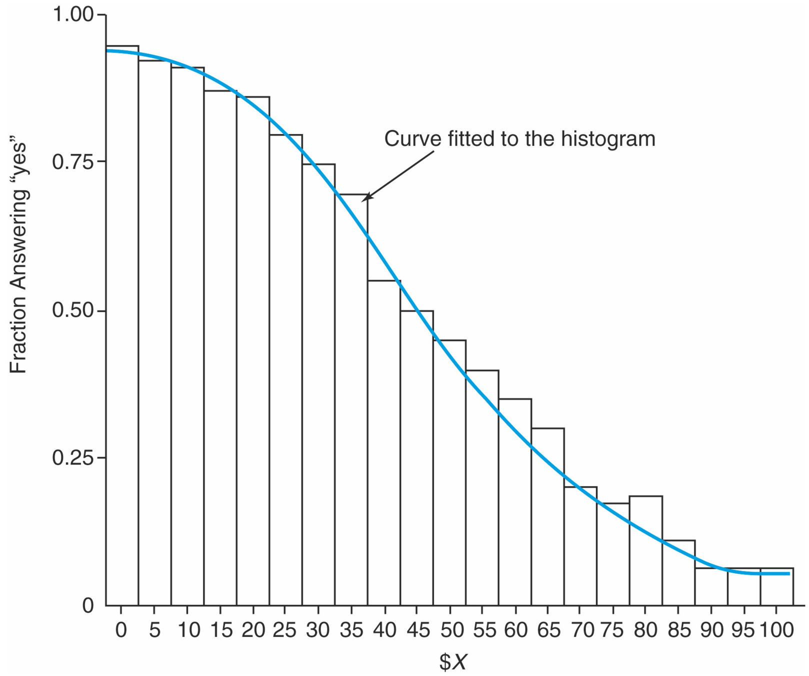

Figure 4: Histogram of dichotomous choice responses

However, empirical evidence indicates that WTA amounts are often higher than WTP amounts, possibly attributed to loss aversion.

Reading materials

1. Boardman et al. Chapters 15
2. "Veileder i samfunnsøkonomiske analyser" section 3.4.

Section 4

Discounting future impacts

We will now address several practical considerations that are essential for calculating the Net Present Value (NPV) of a project. First, we assume that a discount rate has been provided to us. Subsequently, we will delve into the theoretical aspects related to choosing an appropriate discount rate.

Basics of discounting

Discounting takes place over periods not years. However, for expositional simplicity, we assume that each period is a year. Consider an investment that lasts for one year and yields return at an annual interest rate of i.

The future value in one year of an amount Xinvested at interest rate i is: $Y = X(1+i)$.

Then the present value (PV) of this future aggregate fund of Y must be the same as X, which gives us a formula for PV as

$PV \ = \ X = Y/(1+i)$

We can extend this line of argument to investments that yield returns over multiple years.

The present value, PV, of an amount Y received in $T-$th years, with interest compounded annually at rate i is:

$PV = \frac{Y}{(1+i)^T}$.

This formulation presents a case of exponential discounting where the T-th period discount factor is given by $\delta^T = 1/(1+i)^T$.

The present value for a stream of benefits $\underline{B} = (B_0, B_1, ..., B_T)$ and costs $\underline{C} = (C_0, C_1, ..., C_T)$ over T years (here 0 denoting the current year) *is*:

$PV(\underline{B}) = \sum_{t=0}^{T} \frac{B_t}{(1+i)^t}$ and $PV(\underline{C}) = \sum_{t=0}^{T} \frac{C_t}{(1+i)^t}$

Net Present Value (NPV)

Net present value (NPV) of a project with a stream of benefits $\underline{B} = (B_1, ..., B_T)$ and costs $\underline{C} = (C_1, ..., C_T)$ over T years is

$NPV(\underline{B}, \underline{C}) = \sum_{t=0}^{T} \frac{B_t}{(1+i)^t} - \sum_{t=0}^{T} \frac{C_t}{(1+i)^t} = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+i)^t}$.

See, for example, Figure 1 and Figure 2, which illustrates the timeline of a project with streams of benefits and costs accrued over 5 years, and consider an interest rate of 0.04.

Year	Event	Annual benefits	Annual costs	Annual net social benefits
0	Purchase and install	0	500,000	–500,000
1	Annual benefits and costs	150,000	25,000	125,000
2	Annual benefits and costs	150,000	25,000	125,000
3	Annual benefits and costs	150,000	25,000	125,000
4	Annual benefits and costs	150,000	25,000	125,000
5	Annual benefits and costs	150,000	25,000	125,000
	PV	667,773	611,296	56,478

Figure 5: Streams of benefits and costs of a project

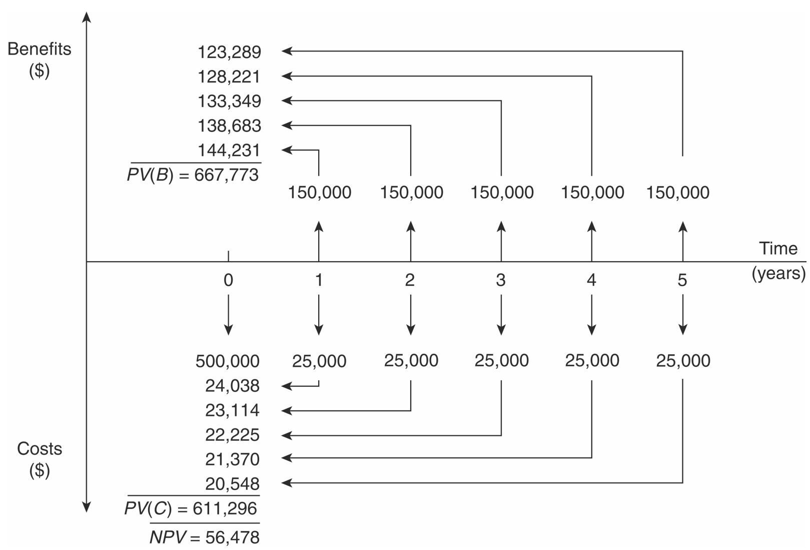

Figure 6: A project with streams of future benefits and costs

Inspecting the formula for NPV, we can see that for a project that typically yields benefits in later years and incurs higher costs in the current year, NPV can decrease with the interest rate i. If we set $i = 0$, the formula simply adds the net benefits (benefits minus costs) over the years.

For example, the project described in Figure 1 will have an aggregate (non-discounted) benefit of $750,000$ and an aggregate (non-discounted) cost of $625,000$, thus generating a net figure of $125,000$. For large values of i, the future benefits are less valuable in today's terms and will reduce the NPV.

Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) of a project equals the interest rate at which the project's NPV equals zero. Sometimes, IRR provides a good indication of the desirability of a project. IRR is the highest interest rate that leaves the project profitable.

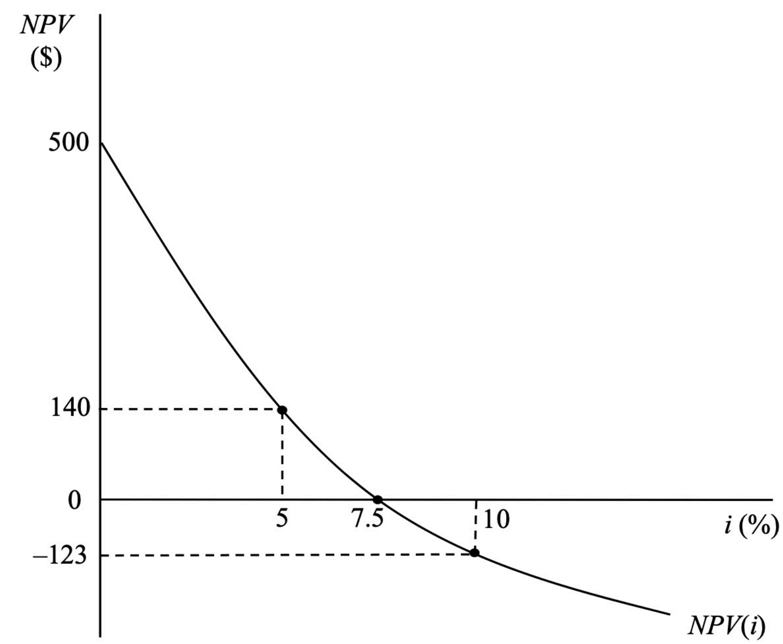

Figure 7: Internal rate of return

Compounding over multiple subperiods

All the previous formulas considered the length of the periods to be one year and the rate of interest/discount to be an annual one. However, it might be possible that benefits or costs are realized at different intervals, such as semi-annually or quarterly, etc. In such cases, the interest rate needs to be adjusted accordingly.

The conversion formula is given by

$(1 + i_s)^s = (1 + i)$,

where s is the number of subperiods (for example, 2 in the case of half-yearly, 4 in the case of quarterly), and i_s denotes the corresponding interest/discount rate.

Solving for i_s gives

$i_s = (1 + i)^{\frac{1}{s}} - 1$.

Some useful formulae

If future returns are constant across periods, then we can use the following formula to represent the sum of a finite geometric series.

$a + ad + ad^2 + ... + ad^n = a\frac{1-d^{n+1}}{1-d}$ where $a > 0$, and $d \neq 1$.

Also note that as n approaches infinity, the absolute value of d must be less than one for the series to converge. The sum then becomes

$a + ad + ad^2 + ... = \frac{a}{1-d}$ where $0 < d < 1$.

Using the formula for the sum of a finite number of terms in a geometric series

$\sum_{t=0}^{T} \frac{V}{(1+i)^t} = V[\frac{1+i-(1+i)^{-T}}{i}]$, and

$\sum_{t=1}^{T} \frac{V}{(1+i)^t} = V[\frac{1-(1+i)^{-T}}{i}]$.

Observe that the difference between the two expressions above stems from the different the number of periods considered in the two series, one starts from period 0 and the other starts from period 1.

Annuity and perpetuity

An annuity is an equal, fixed amount received (or paid) each year for a number of years. A perpetuity is an indefinite annuity. Many CBAs contain annuities or perpetuities. Fortunately, there are some simple formulas for calculating their PVs.

The present value of an annuity of V per annum (with payments received at the end of each year) for$T$ years starting from year 1 with interest at $i$percent is given by

$PV = \sum_{t=1}^{T} \frac{V}{(1+i)^t} = V[\frac{1-(1+i)^{-T}}{i}]$

and the present value of the present value of an amount V received at the end of each year (starting from year 1) in perpetuity is

$PV = \sum_{t=1}^{\infty} \frac{V}{(1+i)^t} = \frac{V}{i}$.

Equivalent Annual Net Benefits (EANB)

It is sometimes useful to convert the NPV of a project in terms of an Annutiy; for example, find V such that a project with a stream of benefits $\underline{B} = (B_0, B_1, ..., B_T)$ and costs $\underline{C} = (C_0, C_1, ..., C_T)$ satisfies the following:

$NPV(\underline{B}, \underline{C}) = \sum_{t=1}^{T} \frac{V}{(1+i)^t} = V \sum_{t=1}^{T} \frac{1}{(1+i)^t} = V[\frac{1-(1+i)^{-T}}{i}]$.

The value of V refers to the annuity payment (also called *Equivalent Annual Net Benefits* or EANB) and the term $(1-(1+i)^{-T})/i$ is called the $T-$period annuity factor, which equals the present value of an annuity payment of 1kr over T periods at an annual interest rate of i. Thus,

$EANB = \frac{NPV}{annuityfactor}$

Comparing returns in nominal versus real terms

A relevant question when quantifying future benefits and costs is whether these measurements should be expressed in real or nominal rates.

Fortunately, as long as we maintain consistency in expressing benefits/costs and the discount rate in the same manner, both methods will yield the same comparative assessment. We should either measure benefits and costs in real dollars and discount them using a real interest rate, or measure them in nominal dollars and discount using a nominal interest rate.

Expressing benefits and costs in real terms is sometimes more intuitive because it takes into account the potential effects of inflation on future benefits and costs. However, when doing so, we must convert the nominal interest rate to a real discount rate using the following formula, where i, r, and m represent the annual nominal interest rate, the annual real interest rate, and the annual inflation rate, respectively:

$(1+r)(1+m) = (1+i)$,

which gives

$r = \frac{i-m}{1+m}$.

Expressing figures in real terms would also grant us greater flexibility when selecting variable inflation rates for future periods. Future inflation rate forecasts are typically obtainable from statistical bureaus.

Project selection

After discounting the benefits and costs, we require a decision criterion for accepting or rejecting a project and for selecting one if there are multiple acceptable projects. NPV can serve as a key indicator for this assessment purpose.

When faced with the decision of whether to accept or reject a single project, it is logical to apply the decision rule:
Accept if $NPV > 0$; reject if $NPV < 0$.

This is because we have already expressed the benefits and costs of the public project under consideration in monetary terms. Consequently, we can interpret the project as an investment project. If we could invest funds in a project that would yield returns at the same interest rate, then its NPV would be precisely zero. We can regard such a project as the opportunity cost of the public project.

A project with a positive NPV implies that the funds invested in the project generate benefits exceeding its opportunity cost. This not only enables the recovery of the invested funds along with interest payments but also yields additional benefits.

This NPV-based decision rule can also be applied to choose among multiple projects. If the impacts of multiple, mutually exclusive alternative projects are calculated relative to the status quo, one should choose the project with the *highest* NPV, as long as this project's $NPV > 0$. If the $NPV < 0$ for all projects, one should maintain the status quo.

Another indicator for assessment is the IRR. Recall that IRR is the value of the interest rate that makes NPV equal to zero.

A commonly used decision rule, when there is only one alternative, is to invest in the project if its IRR is greater than the discount rate.

Similarly, when comparing two projects with different IRRs, one might prefer the one with the higher IRR, especially when one project consistently dominates the other in terms of NPV.

Although IRR conveys useful information, there are some problems associated with using IRR as a decision rule. For instance, IRR may not be unique; that is, there may be more than one interest rate at which the NPV is zero. Second, IRRs are expressed as percentages (ratios), not in monetary values. Therefore, they should not be used to select one project from a group of projects that differ in size.

Comparing projects with different time frames

Choosing one project over another solely based on the NPV of each project is problematic if the two projects have different time frames. Such projects are not directly comparable.

Two appropriate methods to evaluate projects with different life spans are:

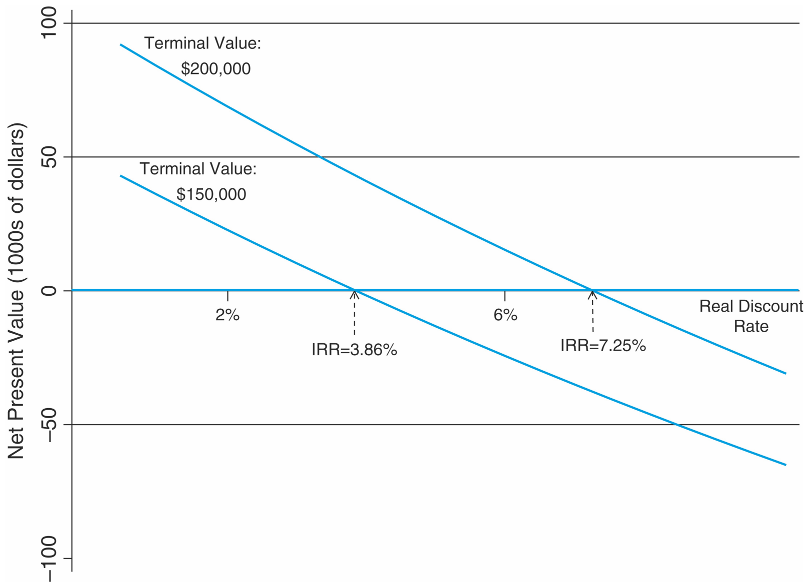

Figure 8: Two projects with different IRR

Roll over method

If project A spans n times the number of years as project B, then assume that project B is repeated n times and compare the NPV of n repeated project Bs to the NPV of (one) project A.

For example, if project A lasts 30 years and project B lasts 15 years, compare the NPV of project A to the NPV of 2 back-to-back project Bs, where the latter is computed:

$NPV = x + \frac{x}{(1+i)^{15}}$,

where x is the NPV of one 15-years lasting project B.

Equivalent Annual Net Benefits Method

Recall that $EANB = NPV/(annuityfactor)$, which is the amount received each year for the life of the project that has the same NPV as the project itself.

Comparisons can be drawn based on EANBs, which provide more comparable per-year figures. However, it does not take into account that the two projects have different lifespans.

Selection of discount rate

So far, we have presented our analysis for a given discount rate. This discount rate effectively assigns varying weights to the benefits and costs accrued in different periods. When assessing government policies or projects, we must determine the suitable weights to apply to policy impacts occurring in different years.

The choice of the appropriate discount rate is equivalent to determining the proper set of weights, also known as social discount rates (SDR).

Various approaches have been employed to determine the Social Discount Rate (SDR). Two prominent methods are the Rate of Time Preference method and the Opportunity Cost of Capital method.

An Individual's Marginal Rate of Time Preference (MTRP)

An individual's marginal rate of substitution (MRS) between periods measures how much additional consumption she would accept in the future to be willing to postpone one unit consumption in the current year. Her marginal rate of time preference (MRTP) is $MRS-1$.

Equality of MRTPs and market interest rate in perfect capital market

In a perfectly competitive capital market, an individual's MRTP equals the market interest rate i, as shown in Figure 5.

The observation of the equality between MRTP and the market interest rate is significant. It implies that even if individuals have varying time preferences, their consumption choices may differ, but their MRTPs will remain identical to the prevailing market interest rate. We can therefore uniquely characterize the common market interest rate as the social rate of time preference.

Equality of the Social Rate of Time Preference and the Return on Investment (ROI) in perfect capital market

Economists have extended the analysis to to incorporate production within a closed economy. The analysis shows that if there are no market failures or taxes, and that there are no transaction costs associated with borrowing and lending, then the MRTP and the market interest rate coincides with the marginal rate of return on investment (ROI). In such a closed economy (with the assumption of perfect capital market), the common interest rate would be the obvious choice for the SDR.

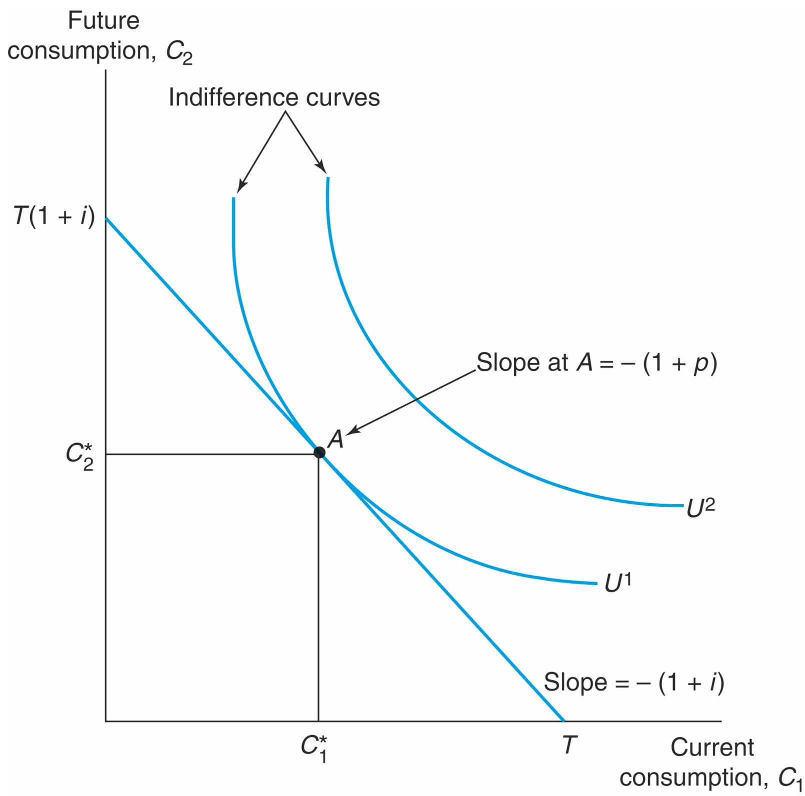

Figure 9: MRTP equals the market interest rate

Social opportunity cost of capital method

The social opportunity cost of capital (SOC) method builds on influential work by Arnold Harberger. Harberger analyzed a closed domestic market for investment and savings. He assumed that any new government project would be funded by domestic government borrowing which would raise the interest rate and result in a fall in private investment and an increase in savings.

Harberger argues that the social discount rate should reflect the social opportunity cost of capital, which can be obtained by weighting the marginal rate of return on private investment and the after-tax marginal return on savings (or foregone consumption) with respective weights given by the size of the relative contributions that investment and consumption would make toward funding the project.

Ramsey model: Social time preference method

Frank Ramsey suggested an approach for determining the SDR that does not rely on market rates of interest. He proposed a model with infinite periods in which society (or a single representative individual) attempts to maximize a social welfare function that reflects the values society places on per capita consumption over time.

Following this model, the society's *marginal rate of time preference* (STP), would equal the sum of two components: one that reflects the reality of impatience and the other that reflects society's preference for smoothing consumption over time:

$STP = \rho + \mu g,$

where g is the percentage change in per capita consumption (i.e. consumption growth) and is the absolute value of the elasticity of the marginal utility of consumption with respect to changes in consumption, and ρ, g, $\mu \geq 0$. This equation is known as the Ramsey formula.

Discounting Intergenerational projects

So far we've discussed only constant (time-invariant) SDRs. Time invariant SDR may be appropriate for projects affecting the same group of people over different years. There are reasons, however, to suggest the use of a time-declining SDR for projects that might affects different generations.

Empirical evidence suggests that people use lower discount rates for events that occur farther into the future. Long-term environmental and health consequences have very small present values when discounted using a constant rate, often implying that spending a relatively small amount today to avert a costly disaster several centuries in the future is not cost-beneficial.

Constant rates do not appropriately take into account the preferences of future, as yet unborn, generations.

Constant rates do not appropriately allow for uncertainty as to market discount rates in the future.

To address these issues, a time-declining rate schedule is often recommended.

Current practice in Norway

Current discounting practices for public projects vary depending on the nature and scope of the projects; see the Norwegian guideline in the review committee's report on cost benefit analysis (NOU 2012: 16, pp. 66-67). Here I am quoting some relevant parts of it (from page 13):

> *Recommendation (pp. 13)*
>
> – In principle, the real risk-adjusted social discount rate should reflect the risk-free interest rate and the risk associated with the project and, consequently, reflect the project's risk adjusted opportunity cost of capital… A real risk-adjusted discount rate of 4 percent will be reasonable for use in the cost-benefit analysis of an ordinary public measure, such as a transportation measure, for effects in the first 40 years from the date of analysis.
>
> – Beyond 40 years, it is reasonable to assume that one will be unable to secure a long-term rate in the market, and the discount rate should accordingly be determined on the basis of a declining certainty equivalent rate as the interest rate risk is supposed to increase with the time horizon. A rate of 3 percent is recommended for the years from 40 to 75 years into the future. A discount rate of 2 percent is recommended for subsequent years.
>
> *Historical guidelines (pp. 66)*
>
> From 1967 to 1999, Norway used an approach where the discount rate was based on the Ramsey model. Based on a report by Leif Johansen in 1967, in which it was assumed that = 1 percent, $\mu = 3$ and g = 3 percent, the discount rate was put at 10 percent in circular R-3/1975. In circular R25/78, the discount rate was changed to 7 percent … The recommendations in the NOU 1997: 27 Green Paper were based on the Capital Asset Pricing Model. Circular R-14/99 stipulates that a riskfree real rate of 3.5 percent should be assumed for cost-benefit analysis purposes. Three different risk classes were defined, with a risk-adjusted rate of 4, 6 and

8 percent, respectively. Specific calculation of the risk-adjusted required rate of return was recommended for large projects or groups of projects.

Current guidelines (pp. 67)

A new circular R-109/2005, replacing R-14/99, was issued following revision of the Ministry of Finance cost-benefit analysis guide in 2005. The risk-free rate for use in the cost-benefit analysis of central government measures was here put at 2 percent, and it was noted that a normal project will have a risk premium of 2 percentage points, and thus a risk-adjusted required rate of return of 4 percent. For measures where considerable systematic risk may reasonably be assumed, it is stated that a risk premium of 4 percentage points, and thus a discount rate of 6 percent, may be appropriate. Specific calculation of the riskadjusted required rate of return continued to be recommended for large projects or groups of projects. This applies, in particular, to projects falling within the scope of the system for quality assurance of major public projects ... The Ministry of Transport and Communications concluded by applying a discount rate of 4.5 percent to all projects within its area of responsibility, whilst for practical reasons not distinguishing between road, railway and aviation.

Reading materials

1. Boardman et al. Chapters 9 and 10.
2. "Veileder i samfunnsøkonomiske analyser" section 3.5.