



## The Picture from Cost-Benefit Analysis

**Abstract** This chapter focuses on one of the oldest techniques of economic evaluation, cost-benefit analysis (CBA). It takes the readers through the steps involved in conducting a CBA. In addition to conventional steps to be followed, it underscores the use of the technique in examining inclusion and environmental sustainability. It also includes case studies highlighting the application of CBA in influencing policies aimed at achieving sustainable development.

**Keywords** Externalities • Equity • Distributional weights • Net present value • Discount rate • Net social benefit

Decision-makers faced with competing alternatives often need to answer the question whether it is worth investing taxpayer or aid dollars in the pursuit of projects aimed at sustainable development. This is particularly so when longer-term goals seem to come at the expense of short-term economic or political objectives. Choosing to provide rural households with 24-hour electricity may seem like an obvious policy choice keeping in mind broader Sustainable Development Goals. However, when providing household electricity may come at the expense of meeting other priorities, is it still the right decision?

Making decisions, especially involving trade-offs, requires an exposition of the benefits and costs of a project, including the identification of the

main cost and benefit components and their valuation in monetary terms. Cost-benefit analysis (CBA) enables decision-makers to weigh the benefits and costs that accrue to the society, beyond individual entities, in comparable monetary units. In doing so, it helps them to allocate resources in the most efficient manner.

### WHY USE CBA?

CBA is one of the most prominent and widely used evaluation and decision-making tools in public policy. Impact evaluation (IE), as discussed in the previous chapter, focuses on the contribution that can be attributed to a program, and it can be used to identify causality by comparing the outcomes of those benefiting from the project with the counterfactual. CBA has distinctive features that make it complementary to IE.

First, CBA is prospective, in addition to being useful for looking at results retrospectively. It can be used to make projections and calculate the net benefit in terms of present value. This information can allow policy-makers to not only assess whether a project provides enough net benefits to warrant investing limited resources in it, it also provides a measuring stick to help them choose among alternative uses of resources. It therefore provides a firmer basis for the choices made.

Second, CBA assigns values to the benefits and costs of projects. While IE is intended to measure how much the treated individuals are better off (or worse off) compared to the case where there is no intervention, it does not directly consider how much costs were incurred to implement a project or how much have the beneficiaries benefited in monetary terms.

Third, the analysis, in principle, covers the range of benefits and costs, whether they have market prices or not. Many projects generate intangible benefits, which may be difficult to monetize. CBA includes techniques to value such unpriced benefits, both current and future, in present-dollar terms. On many of the SDGs, placing a value on intangible, indirect, and unintended attributes could be crucial. For instance, related to SDG 3 (good health) is an assessment of indirect health benefits of rural electrification such as improved health systems (Chen et al. 2018). However, an intangible outcome of improved rural water supply that is related to SDG 6 (clean water and sanitation) might be increased subjective well-being (Mahasuweerachai and Pangjai 2018). Some recent CBA studies rigorously deal with indirect costs and benefits of projects with regard to environmental protection, another important pillar of SDGs (IED 2016; Rojas-Bacho et al. 2013).

These features have been widely appreciated in economics, particularly in sectors which require ex-ante assessments of large-scale investments, such as energy, transportation, and urban/rural development projects. The use of CBA in some institutions, however, has witnessed a decline over the past few decades. A study by the Independent Evaluation Group (2010b) finds that the percentage of projects for which a CBA was performed (using an economic rate-of-return estimate) declined from 70 percent in the early 1970s to about 30 percent in early 2000s. This was partly explained by a relative shift from the sectors like energy and transport that usually apply CBA to those like education and health that conventionally are hesitant to do so.

Conducting CBA requires data to estimate the likely benefits and costs. A constraint may be the lack of readily usable data on the benefits of certain interventions, for example, health gains from reducing water pollution or improving sanitation. It would help to invest in data collection throughout the planning and implementation stages of projects. Important would be efforts to strengthen the capacity of governments and organizations in this respect as many also lack proper record-keeping processes, making it difficult to use data from previous projects.

It may be more difficult to quantify benefits and costs in some sectors. In recent decades, both governments and aid agencies have been increasingly investing in social sectors such as education and health that may face relatively more data challenges. In some instances, the argument for not utilizing CBA also points to the difficulties in quantifying intangible or non-monetary benefits such as empowerment or improved life satisfaction.

However, it would pay to expand the use of CBA across sectors, particularly in light of advances in data and estimation. Increased sophistication in conducting IEs has meant that it is now possible to get estimates of effects of projects that have already been implemented. These estimates can feed into CBA of future projects and help overcome the oft-cited data limitations, including intangible benefits. This also opens up the field for applying CBA across themes from social inclusion to environmental protection to governance.

## STEPS IN CONDUCTING CBA

Among the steps involved in conducting a CBA, we need to think most carefully about the costs and benefits of the intervention. By eventually aggregating the associated costs and benefits, CBA can guide investing in a project that has the prospect for enhancing sustainable development. In

discussing the costs and benefits, let us consider a rural electrification intervention using the case of an actual project implemented in the district of Ribáuè, Mozambique (Mulder and Tembe 2008).

In designing any intervention, it is essential to identify the policy problem first. Access to modern energy services in Mozambique was still very low, with the vast majority of the population relying entirely on traditional biomass to meet their energy needs at the time of the writing about the project (see also World Bank 2018 for comparative figures). The large gap between urban and rural areas was a pressing concern. Mozambique at that time also exported about as much electricity as it imported. Figure 3.1 shows the geographical setting.

In these circumstances, the payoffs to investing in increasing the coverage of electricity are likely to be high. At the same time, in view of differing costs affected by various factors, it is important to consider alternatives carefully.

The government of Mozambique adopted a National Master Plan for electrification in 2004 in which one of the targets was raising the electricity access rate to 20 percent by 2020. The total investment amounted to US\$850 million, of which some US\$260 million was allocated toward transmission projects and some US\$475 million was allocated toward distribution projects including rural electrification projects, like the one being considered here.

Policy alternatives need to be defined in the context of the problem for which the investment is being sought. The set of alternatives would include the baseline case and other alternatives that are expected to help solve the problem. The baseline case would be the counterfactual assuming there are no changes in policies. Each alternative may vary in inputs used, target area or population covered, or implementation timing. The alternative description includes actions, resources required, and expected results. The alternatives in the case of increasing electricity access in rural areas might be to invest in microgrids or solar energy rather than expanding national-grid coverage.

Should resource constraints limit the coverage of policies or projects, specific populations or regions may be given priority over others. An observation in the case of expanding rural electricity access has been that poor households are less likely to benefit from the intervention, as they may not be able to pay even the minimum user charges. This essentially excludes them as beneficiaries. Alternatively, the design of the program might be such that poor households are provided financing and increasing

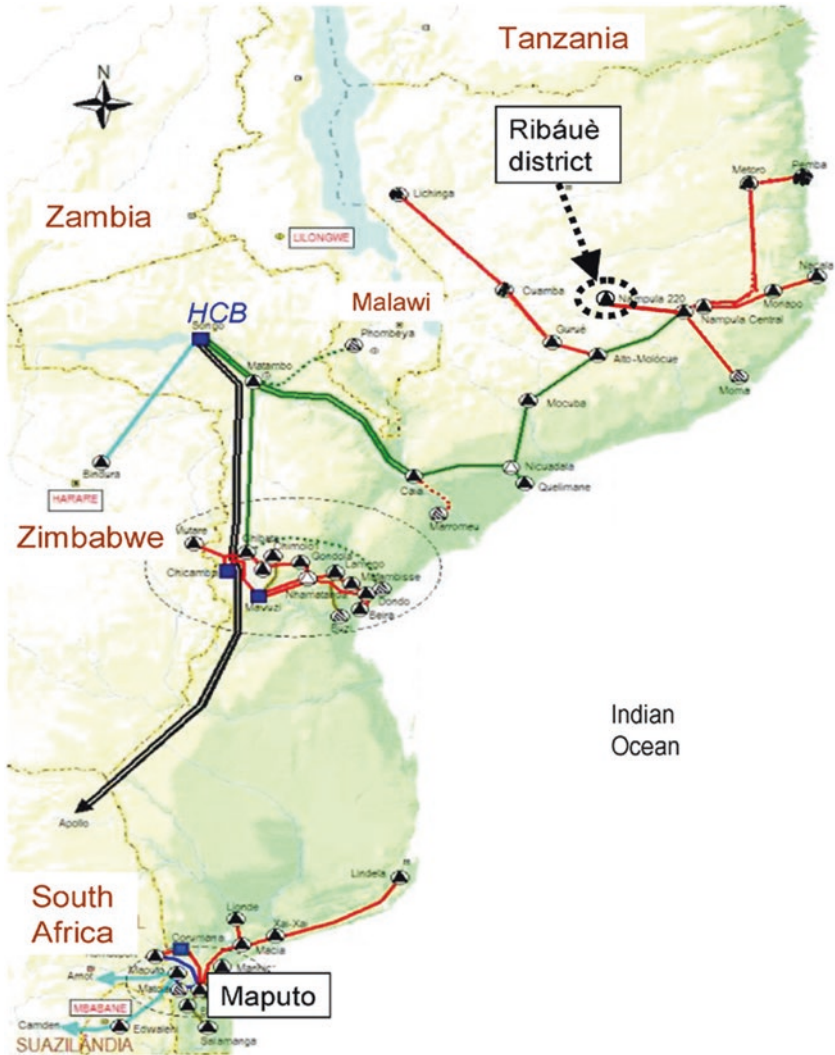


Fig. 3.1 Mozambique electricity system and Ribáuè district. (Source: Mulder and Tembe 2008)

block tariffs are applied for non-poor households based on usage. In this case, benefits accruing to both the poor and non-poor households will have to be accounted for.

Estimating costs and benefits is not always simple. Costs that will be incurred in implementing the rural electrification program may be valued relative to costs that would have been incurred even if the program had not been implemented. Expected benefits to program households would include tangible and intangible benefits. Spillover benefits to households outside the program areas could be important. All these must be considered to ensure that the identified impacts are the incremental benefits and costs relative to the counterfactual.

An overriding consideration involves whose viewpoint or “standing” the analysis tries to represent (Whittington and MacRae 1986). Persons or entities may be given standing by having their preferences or viewpoints counted as the basis for decision-making that aims to maximize welfare. An environmental example would be the case of a pollution control project that abates carbon emissions where it matters if net benefits are sought to be maximized from the point of view of the people living in a locality or a region or the world. Problems of standing also arise in the valuation of life, the consideration of future generations and nonhuman entities, and distributional concerns and weighting of benefits.

### *Identifying Benefits*

CBA needs to incorporate direct and indirect social benefits that accrue to society whether they are tangible or intangible in nature. In addition, externalities, which are positive or negative spillovers, can be an important part of CBA as will be discussed in more detail in a subsequent section.

Here, we identify potential social benefits generated by the rural electrification project in Mozambique. Investing in electrification is directly related to SDG 7 on affordable and clean energy, as well as indirectly to SDG 8 on decent work and economic growth and to SDG 9 on industry, innovation, and infrastructure. The most direct benefit of domestic electricity would be lighting. Benefits from switching to electricity can be calculated by comparing costs of using alternative sources of lighting such as kerosene.

Use of electricity might save time spent on household chores. The time saved can be used either on productive activities, such as wage work, or leisure. This can be valued at the opportunity cost of wage work using the prevailing average market wage rate.

Improved domestic electricity can potentially lead to an increase in household enterprises such as running a small shop or a sewing business. The value of such benefits is the incremental revenue from the enterprise. Households might save on energy costs by substituting electricity for kerosene to meet their cooking and lighting needs. These savings would need to be incorporated in computing net household revenue.

Indirect benefits of rural electrification might include improved health. This might be due to operational efficiency of health-care facilities and longer hours of operation of the clinics. Health benefits might also accrue from reduced indoor air pollution as households shift away from using kerosene and fuelwood for lighting and cooking and switch to electric cook stoves and lightbulbs. Environmental and climate benefits are increasingly noted in the case of energy reforms and energy projects that aim for energy efficiency or a switch to cleaner fuels (see, e.g., IEG 2010a for an application of CBA to energy efficiency projects in China).

Electrification may also reduce fertility as households have alternate sources of recreation or receive family-planning information through television. Additional indirect benefits may include education as children can study and do homework after dark or schools are able to invest in better learning technologies. These benefits can be valued using out-of-pocket health-cost savings, statistical value of a life-year, costs of implementing family-planning programs, and increase in potential wages after school completion.

Much of the additional electricity production in Mozambique is aimed at increasing exports. At the time of the study, in Ribáuè district, a large volume of electricity was consumed by mills producing and exporting cotton fabric and maize. Efficiency of cotton processing and maize milling might improve with electricity, which in turn might increase production levels as well as incomes. Local cotton fabric and maize mills might also make additional savings in energy costs by substituting electricity for diesel.

A side effect might be increased tax revenue from increased household enterprises and commercial activity, which is a transfer from households and businesses to the government. Spillover effects might include environmental benefits or costs that must be counted. Electrification increases energy consumption, which in turn may increase emissions. However, emissions can be partially offset by a shift toward cleaner fuels such as using electricity for lighting instead of kerosene. Other effects might include a reduction in rural-urban migration due to increased economic activity and more job opportunities in rural areas. This in turn might ease the congestion in urban areas.

### *Identifying Costs*

As with benefits, identifying the costs associated with a project is not always straightforward. The total cost for each alternative is the increase in the cost relative to the counterfactual, which includes investment and recurrent costs. Investment costs include the necessary costs to implement the project, while recurrent costs include costs in areas such as operation and maintenance.

For expanding rural electrification, the investment costs include those for land, physical infrastructure, technology, and manpower required to expand the national grid. Recurrent costs include those for manpower and public works necessary to maintain the technology and infrastructure. Not included would be sunk costs, which were already incurred or would have been incurred regardless of project implementation and could not be reversed. There is no opportunity cost associated with sunk cost. These costs do not affect the decision of whether to implement the project, or which alternative to select, and are therefore not included in the CBA.

If the government was investing in developing new technology to reduce transmission and distribution losses from the grid at a national level, and if the same technology were to be used to expand rural electricity access, then the R&D cost is essentially a sunk cost and is not included. However, if further R&D were required specifically for the rural electrification project, then it would be included as an investment cost.

Identification and valuation of physical inputs might be straightforward. What is difficult is determining how much of the inputs will be needed and when or for how long they are used. Once these quantities are known, they are valued at their opportunity cost, which is the difference in return between the current use of inputs and the return if the inputs were put to their next best use. In cases where market prices do not reflect opportunity costs due to market failures, shadow prices may be used. A shadow price is a proxy value of the good, usually inferred from stated preferences such as willingness-to-pay (WTP) or willingness-to-accept.

Identification of labor inputs is relatively easy. Valuation generally uses prevailing market wages. Shadow wages may be used in the case of market inefficiency. These are valued using the forgone output if labor (assumed to be fixed in supply) is taken away from other sectors or projects and used in the construction of electricity infrastructure.

Cost estimation is generally based on the assumption that there will be no modifications to the project design. A contingency allowance allows for any distortions in design or implementation schedule, which may add to



the base cost estimate. Contingencies are generally of two types: physical contingencies and price contingencies. Physical contingencies are to cover for physical uncertainties such as increase in the use of real goods and services. They are often calculated as percentages of base costs.

Price contingencies are to cover for inflation and price uncertainties. If, say, owing to topography, the material requirements for constructing high-voltage transmission towers increase, the cost difference would be covered by physical contingencies. On the other hand, if the price of steel required for construction of transmission towers increases globally, then these changes would be covered by price contingencies.

A project may generate indirect costs. For instance, electrification of households may negatively affect agricultural production if it comes at the cost of rationing electricity supply to farms. The loss in crop production can be valued at market prices, assuming a competitive market exists. Other indirect costs may include the effect of television viewing on children's propensity to read or study (World Bank 2000). This can be valued using lost future wages.

### *Valuation Techniques*

Placing values on the principal benefits and costs is a challenge. The valuation technique needs to be selected carefully for each identified cost and benefit so that true social value is derived. Valuation is less complicated when competitive markets exist for the goods and services being included. There are ways and means to value benefit and costs, for instance, improvements in transportation that save time, which people are willing to pay for through the transportation choices they make.

People increase their consumption of something till the additional benefit equals the market price. In principle, the demand schedule for the product in question provides information on the additional benefit reflecting the monetary value of an increase in consumption. This approach can work for goods and services traded in the market. A good part of CBA can rely on the application of market demand for which historic data might be available.

Other indirect valuation techniques are required under conditions of imperfect or missing markets, as discussed in the examples of benefits and costs in the preceding section (see, e.g., Tolley and Fabian 1998). Valuation techniques commonly used in determining shadow prices include: contingent valuation, hedonic pricing, and travel-cost technique.

We now know that rural electrification brings many unpriced benefits: improved health from better indoor air quality and better education outcomes owing to lighting. Such unpriced benefits can be valued by asking individuals the maximum amount they are willing to pay for the benefits. Jeuland et al. (2015) provide an interesting example of preferences for biomass burning compared to improved cook stoves among rural households in north India, one that also captures the accounting of negative externalities (discussed later). This technique is called contingent valuation. It is a flexible tool in that it can be used to value almost anything, although it works best to value benefits from goods and services that individuals can identify and understand.

A major challenge of this technique is bias, which may occur because it depends on the responses given to survey questions. One source of bias is the level of the respondents' knowledge about the goods or services in question. Bias may also occur if the individuals are not familiar with placing monetary values on such things as environmental goods and services, in which case the stated WTP may not reflect the true value.

Taking an example from concerns over indoor air quality, the simplest application of contingent valuation would be to ask respondents what is the maximum price they are willing to pay to mitigate indoor air pollution. More sophisticated ways include presenting respondents with a range of values or double-bounded dichotomous choices and testing their sensitivity to different price levels. Once data are collected, the average WTP and the conditional demand curve at each price level can be traced out.

Hedonic pricing uses the market prices of goods and services under the assumption that these prices reflect the value that people place on their characteristics. It is often used to value environmental goods such as air, water, and land quality. For instance, if two houses, house A and house B, are identical except for the air quality in their respective neighborhoods, the price difference between the two houses can be considered as the price the consumer is willing to pay for good air quality (see Tan Soo 2017 for an example). Hedonic pricing can also be used to infer health benefits or mortality risks by taking the difference in market wages of jobs in green sectors versus those in polluting sectors.

The strength of this method is that it uses the actual market prices and characteristics of the goods and services. The limitation is that it assumes that people are aware of the less tangible attributes of a good, such as the environment and its health attributes or consequences. Hedonic pricing

requires that changes in attributes be linked to WTP; and its use requires data availability and a high degree of technical expertise.

In the valuation of housing or land in electrified villages, the per-square-foot price in villages with 24-hour supply may be compared to the price in villages with no or intermittent power supply. The difference in prices reflects WTP for improved access to electricity.

Mostly used to value the benefits of recreational facilities, the travel-cost technique can also be applied to value environmental and health goods. This technique focuses on the access cost and assumes that an individual will access the facility if the benefits gained outweigh the total travel costs (including opportunity cost of time). Consumers' WTP to visit a recreational facility is thus estimated using the number of trips that they make at different travel costs.

We identified one of the indirect benefits of rural electrification as improved health owing to better operational efficiency of health facilities. To value the health benefits, we can utilize the travel cost that individuals actually incur to visit a clinic with better facilities and equipment in the absence of such a facility nearby.

### *Avoid Double Counting*

Double counting is a common error in aggregating benefits and costs. As a rule, a particular benefit or cost should not be counted more than once. If a project produces intermediate goods that are used as inputs to some other downstream products, the total benefit should only be counted once.

In our rural electrification example, better access to electricity often leads to an increase in time available in terms of labor supply as households save time on chores. If the households have already valued their time use when stating their WTP for electricity, including time use benefits as additional benefits would amount to double counting. Similarly, counting increases in household enterprises owing to increased time available in labor supply, and counting time inputs for household enterprises, would be double counting. Obtaining total benefits can therefore be difficult, as chances of either double counting or underestimating are high, especially if most of the benefits are indirect or intangible.

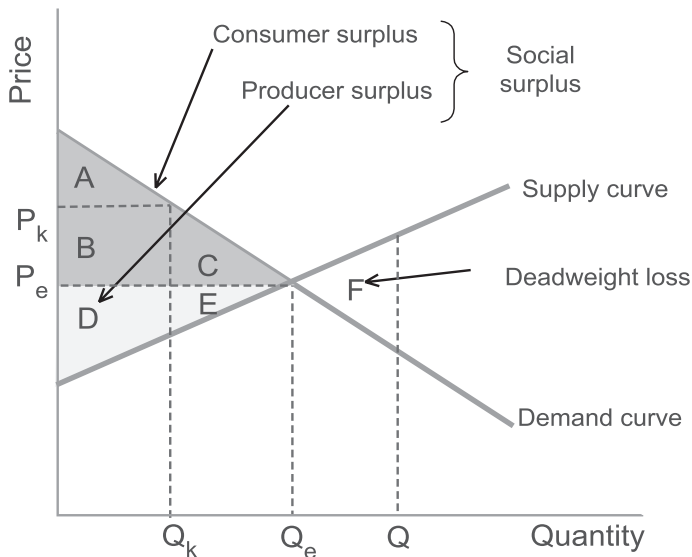
Taxes, subsidies, and government charges could also be a source of double counting if not accounted for properly. Valuation should be based on the concept of WTP and opportunity cost. For example, the private cost of electricity should be valued at what the consumers are willing to

pay inclusive of taxes or transfers to the government. However, cost to the society should be valued using the opportunity cost of production, that is, the price of inputs used to produce forgone outputs, which is exclusive of taxes.

### *Computing Net Social Benefit*

The objective function of CBA is to estimate net social benefit. Once we value benefits and costs, we can compute consumer and producer surplus to arrive at net social benefit (Harberger 1971). Continuing with our rural electrification case study, let us consider two sources of lighting available to households: electricity and the existing source, usually a kerosene lamp.

The valuation of benefits is often done using WTP. Figure 3.2 shows a demand curve derived by the price of lumens (total quantity of visible light emitted by a source); the quantity of kerosene consumed,  $Q_k$  at price  $P_k$ ; and the quantity of electricity consumed,  $Q_e$  and price  $P_e$ . The area under



**Fig. 3.2** Consumer surplus and producer surplus for kerosene and electricity. Note:  $P_e$  is the price of electricity from the grid;  $P_k$  is the price of kerosene;  $Q_e$  is the quantity of electricity used from the grid; and  $Q_k$  is the quantity of kerosene consumed. (Source: Authors' illustration)

the demand curve is the amount the consumer is willing to pay (see also IEG 2008).

The difference between what one is willing to pay and what one actually pays is the consumer surplus. With the assumptions in Fig. 3.2, the consumer surplus for kerosene would be  $(A+B+D)$  minus  $(B+D)$ , which is  $A$ . In the same manner, the consumer surplus for electricity would be  $(A+B+C)$ . Providing electricity, therefore, increases consumer surplus from  $A$  to  $(A+B+C)$ , producing the additional benefit of  $(B+C)$  to consumers.

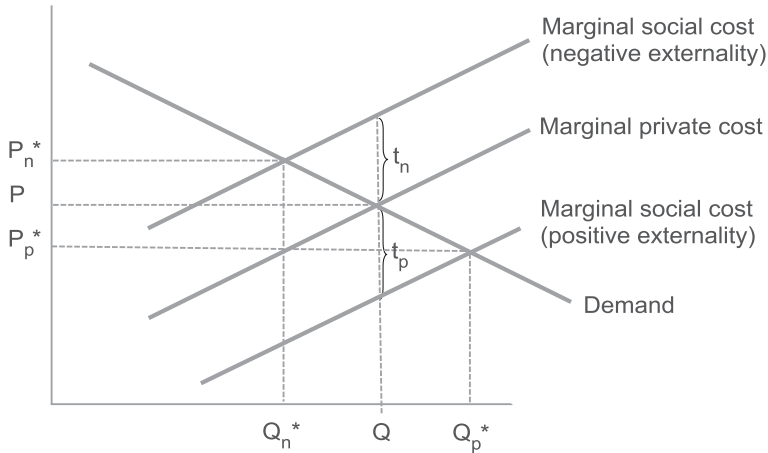
The cost side reflects the opportunity cost, or what is given up, to produce the good in question. The marginal cost curve shows the additional cost incurred to produce an additional unit of a good, and when summed up for the individual producers, it produces a market supply curve. The area under this curve indicates the total variable cost. What the producers actually receive is the price multiplied by the quantity of the good. And the difference between the total revenue and the total variable cost would be the producer surplus for electricity, which is the triangle area  $(D+E)$ .

The equilibrium price and quantity determined in competitive markets yields a consumer surplus and a producer surplus, whose sum is the social surplus. This is the net social benefit as it is calculated by subtracting costs (as opportunity costs) from benefits (as WTP). This equilibrium point reflects allocative efficiency because outputs any less than  $Q_e$  result in a reduction in social surplus, making at least some people worse off relative to the equilibrium point. For example, the output  $Q$ , which deviates from the socially optimum point, will result in less social surplus by the triangle area  $F$ , called deadweight loss.

### *Externalities*

Not elaborated thus far, a vital part of net social benefits is estimating social impacts that may arise in the presence of market failures and market imperfections. Referred to as externalities, these spillover effects can be positive or negative. For instance, subsidized electricity provided to farmers may induce them to extract groundwater excessively, thus reducing the amount available for rural households. Less water for domestic consumption can hurt people's health. This negative health externality imposes a cost on society.

Figure 3.3 illustrates how the additional cost of a negative externality shifts the marginal cost to society or the supply curve upward by  $t_n$ , caus-



**Fig. 3.3** Marginal social cost in the presence of a positive or a negative externality

ing the equilibrium quantity to decline from  $Q$  to  $Q_n^*$  and the price to rise from  $P$  to  $P_n^*$ . As a result, net benefits decline. In the same way, a positive externality reduces the costs to society, resulting in downward shift of the marginal social cost curve by  $t_p$ , increasing the net social benefits.

### *Project Benefits and Costs*

Identified benefits and costs need to be projected over time. A project-implementation schedule plays a critical role here. Delay in implementation often results in unexpected costs or loss of anticipated benefits. The project may initially bear large benefits that diminish gradually, or it may take some time to fully manifest its effects, resulting in little or no benefit in the first year. For some projects, costs may be large initially but diminish over time, while other projects may require high maintenance costs over the life of the project.

Mulder and Tembe (2008) use data for the rural electrification project over 2000–2005 and project costs and benefits for the period 2005–2020. We can add simulations of the CBA to account for issues such as distributional considerations and uncertainties about the stream of benefits and costs. The study lists the costs and benefits for the project, which are illustrative of estimates that correspond to rural electrification projects more

generally. Costs mostly comprise investment costs and operating and maintenance costs for line construction. Direct benefits include saving in energy costs for businesses and households and increase in energy efficiency for cotton, maize, and other enterprises. There are also important indirect benefits in the areas of education and health. For education, benefit estimates were based on measures of the increased number of students finishing school enabled inter alia from offering night classes and better facilities. Estimation of health improvements would have required a valuation of the health gains from increased hours running hospitals and equipment.

Based on the costs and benefits in 2000–2005, the authors provide three scenarios of benefits and costs: “high” in terms of being optimistic, “medium” in terms of being average, and “low” in terms of being pessimistic. On the cost side, these scenarios yielded three sets of projections of the operating costs. On the benefit side, there were three sets of projections of the direct gains in the form of energy savings and processing improvements in cotton, maize, and other mills. The indirect gains in education from the project too had a range of optimistic, average, and pessimistic increases in the number of new students.

The study’s estimates show how costs, benefits, and net benefits might evolve up to 2020. Interesting is how the estimates are influenced by the expectation of how direct and indirect benefits evolve, including the gains expected in education. The range of low, medium, and high for costs and benefits provides variations that can inform the projections of cumulative net benefits of the three scenarios. Using the medium estimate, the study finds that the benefits strongly outweigh the costs over the period 2005–2020.

### NET PRESENT VALUE (NPV) OF ALTERNATIVE SCENARIOS

It is necessary to discount benefits and costs to their present value to account for the time value of resources. Future benefits and costs must be converted into present value terms by applying an appropriate discount rate. Commonly, people tend to discount the value of things whose consumption is in the future. Discounting the future assumes that individuals prefer current consumption to future consumption. The magnitude of discount can also be assumed to increase with time.

Net present value (NPV) is calculated using the discount rate as follows:

$$\text{Net present value} = \sum_{t=0}^n \frac{NB_t}{(1+s)^t}$$

where  $NB$  is annual net benefit in year  $t$  and  $s$  is discount rate. As is clear from the equation, NPV is defined as the sum of a flow of annual net benefits, which is converted to a present value.

In appraising public policies whose purpose is to improve benefits to society, CBA uses a social discount rate. This is the social rate of time preference, which is the rate at which society would trade a unit of benefit between the present and the future. Choice of a social discount rate greatly influences the decision-making in selecting one project over another. A high social discount rate means that future benefits and costs count for less; therefore, projects with early benefits are preferred. On the other hand, a low discount rate suggests higher valuation of future benefits and costs. Environmental projects typically adopt low discount rates, as the benefits may manifest in later years.

Some projects, especially those pertaining to environmental protection, have impacts across generations. For their CBA, it may not be enough to apply a constant discount rate over the long time period. Instead, a time-declining discount rate may be considered. The use of a time-invariant discount rate in an evaluation of environmental conservation policy is likely to underestimate the benefits for future generations.

The NPV of a project vitally depends on the discount rate selected. Table 3.1 illustrates how NPV is calculated using different discount rates. For simplicity, annual net benefit is assumed to be a constant US\$100 million over ten years. With a constant discount rate of 5 percent, the NPV is US\$772.16 million. At 7 percent, the NPV is less than that under the 5 percent discount rate scenario because the future benefits are valued lower.

Next, we apply the time-declining discount rate, which starts at 7 percent and declines over the years to 3 percent. Even for a period as short as ten years, the selected discount rate makes a significant difference in the computation of NPVs. Using the constant discount rates of 3 percent, 5 percent, and 7 percent for an annual benefit of US\$100 million, NPVs in 100 years are US\$3.16 billion, US\$1.99 billion, and US\$1.43 billion, respectively. The difference in NPVs is significantly higher when the time period is long. Applying a constant discount rate in analyzing the benefits and costs of projects that are likely to have intergenerational effects might not fully measure the true value of benefits and costs far into the future.



**Table 3.1** Calculation of NPVs for alternative scenarios (in million US\$)

Year	Annual net benefit \$	Present value \$		
		Discount rate		
		5%	7%	7%→5%→3%
1	100	95.24	93.46	93.46
2	100	90.70	87.34	87.34
3	100	86.38	81.63	81.63
4	100	82.27	76.29	76.29
5	100	78.35	71.30	78.35
6	100	74.62	66.63	74.62
7	100	71.07	62.27	71.07
8	100	67.68	58.20	78.94
9	100	64.46	54.39	76.64
10	100	61.39	50.83	74.41
<b>Net present values</b>		<b>772.16</b>	<b>702.34</b>	<b>792.75</b>

Source: Authors' illustration

Note: In the last column, it is 7% for years 1–4, 5% for years 5–7, and 3% for years 8–10

The rural electrification project is one such policy intervention that is likely to yield benefits across generations. How individuals value improved health, higher human capital, or cleaner air in a hundred years is unlikely to be reflected in how they currently value the benefits. Selecting a constant discount rate based on the time preference today could lead to rejection of making an investment in rural electrification that potentially has large future benefits.

As the calculation of NPV concerns long-term influences, there are different views on how to incorporate those into the present value. Petri and Thomas (2013) discuss the discount rate and differing views about it in the context of climate change, taking the *Stern Review* (Stern 2006) as a case study. The *Stern Review* uses a normative interest rate of 1.4 percent to calculate the present value of future environmental damages, using the principle that the welfare of all generations should count equally. In contrast, others use a positive rather than a normative rate, say around 6 percent, as observed in market decisions (Nordhaus 2007). This choice has far-reaching consequences.

Table 3.2 presents a comparison of how we can arrive at NPV through market decisions versus normative decisions concerning sustainability. It is

**Table 3.2** How prices shape decisions

<i>Price discounting</i>	<i>Market prices</i>	<i>Externality-corrected prices</i>
Market interest rates	Market decisions	Decisions that internalize the external effects of transactions
Normative (low) interest rates	Decisions that internalize the interests of future generations	Decisions that internalize external effects and the interests of future generations

Source: Petri and Thomas (2013)

a matrix of price and discount rate options, with the varying combinations of these two showing how externalities and future effects are valued. The upper-middle cell of the table shows market decisions, that is, transactions based on market prices and interest rates. These do not account for externalities nor for future effects. The upper-right cell shows the effects of price signals that correct for externalities; for example, prices inclusive of carbon taxes. These decisions account for externalities, but from the viewpoint of profitability for today's investors.

The lower cells introduce corrections to interest rates and externalities. In this row, the welfare of future generations is treated similarly to that of the current one. This row would likely require adjustments to lower discount rates from positive to normative levels. Some have argued that committing to such a welfare perspective would require that subsidies be offered to such investments.

The lower-middle cell of the table shows decisions that account for the interests of future generations. The lower-right cell introduces price signals that reflect externalities and accounts for the interests of future generations. That is, it makes decisions sensitive to the interests of others affected by externalities and those living in the future.

### *Uncertainties and Risks*

Clearly, several assumptions go into the identification and valuation of benefits and costs and the computation of NPV. A key question is how net social benefits change if the assumptions, for example on the scope of rural electrification or on market wages, change. We can examine how sensitive predicted net benefits are to changes in assumptions by conducting a sensitivity analysis.

There are different ways to conduct sensitivity analysis that touch on the various parameters involved in CBA. One method is to recalculate the NPV under different sets of assumptions. Based on the best forecast made through the calculations, the range can be set within which some variables could vary. Conducting sensitivity analysis enables policy-makers to make choices under varying levels of risk and uncertainty.

In the case of rural electrification, the NPV can vary according to different estimates of how much time is saved. The benefit from the estimated time saved by using an electrical appliance can be calculated using the prevailing market wage, but there can be variation in the estimate of the market wages used as well. Table 3.3 illustrates how three alternatives of low, best, and high estimates of the time saved and of the market wage rate can produce nine possible alternative NPVs. Both market wages and time saved are crucial factors in that reasonable changes in these variables could significantly alter the NPV computation.

### *Factoring Social Equity*

Even though rising inequality is viewed as a major global challenge, policy-making using CBA for the most part has not explicitly incorporated equity aspects in the analysis. One of the criticisms of CBA is that it focuses on efficiency at the expense of social equity (Kind et al. 2017). This concern arises from the premise in CBA of favoring a project based primarily on aggregate net benefits and the underlying criterion for Pareto improvement.

Concerns about equality may be neglected in the so-called Pareto improvement criterion. Public policies could be intended to make the

**Table 3.3** Illustration of NPVs for changes in market wages and time saved

		<i>Time saved by using electrical appliance (hours)</i>			
		<i>Low</i>	<i>Best</i>	<i>High</i>	
		2	3	4	
Market wage rate (dollars/hour)	Low	12	NPV1	NPV2	NPV3
	Best	15	NPV4	NPV5	NPV6
	High	18	NPV7	NPV8	NPV9

Source: Adapted from Sinden and Thampapillai (1995)

worse off better, which may not always be a Pareto improvement. Rural electrification is a public policy effort toward greater social inclusion. But there could be situations where such an investment would pass the CBA test only if a dollar increase in the income of a poor rural household is seen to result in a larger increase in social welfare than would a dollar increase in the income of a non-poor rural household.

Most cost-benefit analyses stress the objective of improving social welfare or the well-being of all individuals. But in practice, the welfare implications arising from income differences are not considered. If diminishing marginal utility of money is recognized, then income differences can be accounted for in calculating social welfare benefits. This is especially so for projects with special implications for low-income groups, for example, those dealing with damages from natural calamities that hurt the poor disproportionately.

Considerations of income differences can be realized by assigning distributional weights to various subgroups. Distributional weights reflect the value placed on each dollar received by each group. One general approach is to make the weights inversely proportional to income that would affect the estimated net benefits and favor policies that tend to improve the income distribution.

Applying distributional weights would change the NPVs we previously computed, where equity was not explicitly incorporated. Table 3.4 calculates the NPVs under two alternatives. In both alternative A and alternative B, the annual net benefit is assumed to be US\$100 million each year, and the discount rate is 5 percent. This yields an unweighted NPV of US\$772.16 million. We now divide the population into poor and non-poor rural households and assume that the benefits received from the electrification project differ for the two groups.

There are several ways to show how results vary according to the weights attached to outcomes affecting particular groups. In one of such ways, consider alternative A, which brings much higher benefits to the non-poor households especially at the beginning of the project, as is often the case with electrification projects. In alternative B, on the other hand, the poor benefit from the project much more than the non-poor. The total benefit is taken to be the same. But from a distributional perspective, the benefits received by the poor might be valued higher than the benefits received by the non-poor, say with a distributional weight of 2 for the poor and 0.5 for the non-poor.

**Table 3.4** Calculation of NPVs with distributional weights (in million US\$)

Year	Total annual net benefit \$	Alternative A				Alternative B			
		Annual net benefit \$		Present value \$ (discount rate: 5%)		Annual net benefit \$		Present value \$ (discount rate: 5%)	
		Poor	Non-poor	Unweighted	Weight Poor = 2 Non-poor = 0.5	Poor	Non-poor	Unweighted	Weight Poor = 2 Non-poor = 0.5
1	100	10	90	95.24	61.91	90	10	95.24	176.19
2	100	10	90	90.70	58.96	90	10	90.70	167.80
3	100	10	90	86.38	56.15	90	10	86.38	159.80
4	100	20	80	82.27	65.82	80	20	82.27	139.86
5	100	20	80	78.35	62.68	80	20	78.35	133.20
6	100	20	80	74.62	59.70	80	20	74.62	126.85
7	100	30	70	71.07	67.52	70	30	71.07	110.16
8	100	30	70	67.68	64.30	70	30	67.68	104.90
9	100	30	70	64.46	61.24	70	30	64.46	99.91
10	100	40	60	61.39	67.53	60	40	61.39	85.95
		<b>Net present values</b>		<b>772.16</b>	<b>625.78</b>	<b>Net present values</b>		<b>772.16</b>	<b>1304.62</b>

Author's calculation for illustration

The revised NPV for alternative A shows that when assigning a higher weight to the poor rural households, the weighted NPV of the project is lower than the unweighted NPV. In contrast, the weighted NPV for alternative B is higher. If more benefits are likely to accrue to the poor and achieving social equity is a key objective, then alternative B would be preferred.

NPV incorporating distributional weights can be expressed as

$$\text{NPV} = \sum_{j=1}^m \left[ W_j \sum_{t=1}^{\infty} \frac{b_{t,j} - c_{t,j}}{(1+r)^t} \right]$$

where  $W_j$  is the distributional weight for group  $j$ ;  $b_{t,j}$  are the benefits received by group  $j$  in period  $t$ ;  $c_{t,j}$  are the costs imposed on group  $j$  in period  $t$ ;  $m$  is the number of groups; and  $r$  is the social discount rate. In this formula, net benefit of each group is weighted and then aggregated to compute the net social benefit. Such weighted CBA can be applied in assessing policies where distributional issues are of particular concern.

### *Make a Recommendation*

The final step in CBA is to select the best alternative based on the net social benefit. This process needs to consider the counterfactual, that is, the benefit to society in the absence of the project. The recommendation must clearly justify the choice of alternative based on the assumptions made, externalities, risks, uncertainties, and distributional consequences. The choice must also reflect the preferences of all stakeholders, ideally through continuous engagement.

### APPLICATIONS OF CBA

CBA, if properly conducted, can be a powerful tool for policy design and decision-making, but its use and effectiveness in project decisions are worth reviewing on an ongoing basis. We find that CBA is in many cases used ex ante to improve decision-making about projects and the choice among alternatives. It is also sometimes used ex post for assessments of the performance of projects.

The World Bank examined how CBA was used in World Bank-supported projects by interviewing 51 project leaders randomly selected from all projects that closed in 2006–2007 and 2008–2009 (IEG 2010b). The interviews revealed that in the experience of more than 80 percent of the project leaders, CBA was usually conducted after the decision had been made to implement a project and that CBA was not the key criterion in deciding whether to fund a project. It was pointed out that the cost-and-benefit data were made available too late to conduct an ex-ante analysis to assist decision-making, which deprived the staff of the needed motivation to conduct a high-quality CBA since the decision of financing the project had already been made.

Annema (2013) reviewed some studies on the use of CBA in mega-project planning. A summary of the findings from the review suggests that political decisions do not necessarily use CBA's main outcomes, such as NPV or benefit-to-cost ratio. One case where CBA was used as a screening device was for developing the Swedish National Transport Investment Plan 2010–2021 (Eliasson and Lundberg 2012). CBA was successfully utilized in investment planning because the Swedish government, recognizing the importance of CBA as a screening tool, conducted CBA at the project preparation stage. The result of the CBA was used in selecting the most viable project from the list of suggestions, leading to an increase in combined benefits. Politicians' initial selection had estimated benefits of 50 billion Swedish kronor. The project selected under CBA criterion has project benefits amounting to 72 billion Swedish kronor.

In some cases, CBA is conducted after the implementation of the project to assess performance. PROGRESA, a large-scale initiative to alleviate poverty in Mexico, was implemented in 1997. The first CBA of PROGRESA was conducted by Coady (2000). All evaluations before that were IEs on outcomes such as reduction in poverty levels or increase in school enrollment.

Coady (2000) mostly conducted cost-effectiveness analysis because of the difficulty in attaching a monetary value to the unpriced benefits thought to arise from educational investments. In 2011, Barham (2011) performed a CBA on the health component of PROGRESA and reported its success based on a benefit-cost ratio, which ranged from 1.3 to 3.6. This benefit-cost ratio was still an underestimation of the total health benefits of PROGRESA, as the benefit estimation only used infant deaths averted.

CBA has also been applied to evaluate institutional policies, such as the implementation of ADB's safeguards policy pertaining to inclusive and environmentally sustainable economic growth. The evaluation estimated the benefits and costs of implementing environmental and involuntary resettlement safeguards on a road rehabilitation project in Sri Lanka (IED 2016). The CBA generated counterfactual scenarios with and without the safeguards. While data were limited, the CBA still generated valuable results. Two out of the three road segments for which the CBA was conducted had positive NPV under the "with safeguards" scenario, and all road segments had negative NPV under the "without safeguards" scenario. The process of conducting this CBA was equally valuable, highlighting methodological challenges (e.g., with respect to assigning values) and data gaps in conducting CBA of safeguards policies.

A CBA of a proposed policy to introduce cleaner fuel in Mexico highlights the application of CBA to environmental protection policies. In Mexico, a country with a severe air pollution problem, a CBA was conducted prior to designing a policy on fuel quality improvement, which allowed policy-makers to incorporate the CBA results into their plan (see Box 3.1). Linked to SDG 11 on sustainable cities and communities and to SDG 13 on climate action, this example, reported in Rojas-Bacho et al. (2013), reiterates the importance of the timing of analysis, as CBA can clearly bring in more benefits if done prior to the beginning of the decision-making process.

**Box 3.1 CBA of Fuel Quality Improvement in Mexico (Rojas-Bacho et al. 2013)**

Despite the Mexican government's efforts to reduce air pollution by shutting down factories and refineries in Mexico City, air pollution continued to cause approximately seven thousand deaths per year. To reduce the emissions from private vehicles and trucks, which were the main source of pollutants, the Ministry of Environment and Natural Resources (SEMARNAT) revised the fuel quality standard in 2006, aiming to reduce sulfur levels in gasoline and diesel.

Prior to making the policy decision, SEMARNAT and PEMEX (a state-owned fuel producer) were required to conduct a CBA of low-sulfur fuel production. This followed the 2001 government mandate that all federally funded investment projects must carry out a CBA. In 2002, SEMARNAT formed a working group with PEMEX and



other public and private institutions, including the National Institute of Ecology (INE), to design the policy. The first proposal, put together in 2003, aimed for sulfur levels in all fuels to be reduced by 2008. This required upgrading refinery infrastructure, which was initially estimated to cost about US\$2 billion, a number later revised to US\$2.7 billion (Image 3.1).

**Image 3.1** Pollution in Mexico City. (Credit: Usfirstgov/CC BY)



INE estimated the benefits and costs over the period 2005–2030. However, it was the first time where a major federal investment project used CBA and included environmental externalities. INE formed a scientific panel to provide advice on conducting CBA. Another challenge was to find reliable estimates of the effects of poor air quality on mortality. As a previous study on Mexico City that was used to compute these estimates only captured short-term effects, INE used the estimates from cohort studies in the United States, which measured long-term effects. The final challenge was related to the monetization of health benefits. There was only one prior study on Mexico on the WTP for mortality risks. It used two methods—hedonic wages, which compared average wages in dangerous jobs with safer jobs to place value on safety, and contingent valuation, which asked how much individuals were willing to pay for a reduction in child mortality risk. INE decided to use values from a meta-analysis of studies in the United States and adjust for Mexican incomes using an estimate of WTP for health with rising income.

The final CBA was submitted to the Ministry of Finance in 2006, and the Congress approved the project. As the supply of ultra-low-sulfur diesel completely depended on imports, compliance proved costly. Domestic technical and engineering plans made no progress either. Consequently, the plan for ultra-low-sulfur diesel had to be delayed by some four years. A revised proposal was made to increase the project's budget to US\$5.9 billion, which called for another CBA. Although some benefits were lost due to the delay in compliance and increased costs, the revised CBA showed positive net benefits. After the revised funding was approved by the Ministry of Finance, cleaner fuels became available nationwide by 2011.

The Mexican government realized the need for improving technical capacity and developing a set of guidelines for CBA, including guidelines on discount rates and monetary valuation of intangible benefits.

Another example of CBA applied to environmental policy pertains to water recycling projects in India. The CBA dealt with the externalities generated by small-scale water projects (Labhasetwar 2013; NEERI 2007). It required identification and valuation of unintended consequences such as water pollution and health outcomes. The findings revealed that CBA can make greater contributions if it is done thoroughly, considering all potential externalities, as was done in this study (see Box 3.2).

### **Box 3.2 CBA of Water Projects in India (Labhasetwar 2013)**

Water scarcity in India is serious and worsening. Freshwater availability in India is only 1851 cubic meters per capita per year, compared to an average of 9974 cubic meters per capita per year in the United States (FAO 2012). Surface water availability continues to fall, and the per capita yearly surface water availability in 2050 is projected to be nearly half the amount in 1991 (Kumar et al. 2005). Adding to water scarcity, water quality deterioration imposes costs on human health, the environment, and agricultural production.

India has invested a large amount of money in water-resource projects, whose costs and benefits are long term and go beyond the

project site, producing significant uncertainty. CBA can assist in answering questions on the types of water projects to be approved based on calculation of costs and benefits including externalities. Conducting CBA of small-scale water projects involves gathering lot of project-specific scientific, engineering, and economic details. However, with growing knowledge of the technique, there is also wider use of CBA in evaluating small-scale water projects.

In Madhya Pradesh, the infrastructure for proper wastewater disposal was inadequate. A third of rural households and a quarter of urban households had no wastewater drainage system, causing groundwater contamination and making drinking and irrigation water unsafe. There was therefore a need for a cost-efficient gray water (defined as wastewater from showers and basins but not from kitchen or toilet waste) recycling system. A CBA of such a project was conducted by several organizations including the National Environmental Engineering Research Institute (Godfrey et al. 2009) (Image 3.2).

**Image 3.2** Gray water reuse facility at secondary school. (Credit: The Sustainable Sanitation Alliance Secretariat/CC BY)



The CBA (see Godfrey et al. 2009) estimated investment costs for gray water treatment and reuse system and for land, civil works and facilities, and piping works as well as any negative externality from gray water reuse. Financial costs (resulting from financing the investment) and operating and maintenance costs of a gray water recycling system were considered on the cost side.

Estimation of benefits from the project included avoided expenses or savings from improved access to water infrastructure as well as health benefits in terms of avoided health expenditures. Benefits also covered environmental impacts such as avoided overexploitation of groundwater, reduced water pollution, and positive spillover on agriculture.

The results (Table 3.5 below) showed that the estimated benefits of a gray water reuse system are far higher than the costs. Based on this finding, the government of Madhya Pradesh allocated funds for the construction of 412 gray water reuse systems in April 2006.

**Table 3.5** Summary of annualized cost and benefits (in Indian Rupees)

<i>S. no.</i>	<i>Parameter</i>	<i>Annualized benefit</i>	<i>Annualized cost</i>
1	Capital cost of gray water reuse system		INR 6036 (interest rate @12% per annum)
2	Operation and maintenance cost		INR 5725
3	Availability of gray water	INR 30,000	
4	Avoidance of water infrastructure	INR 50,000	
5	Environmental benefits	INR 44,000	
6	Health benefits	INR 793,380	
7	External cost		Negligible

Source: Godfrey et al. (2009)

## CONCLUSION

CBA is a valuable tool in the evaluator's kit for quantifying the likely net gains from investing in projects and taking certain policy directions. It provides an intuitive and empirical framework to think about both the cost side and the benefit side of interventions and compare the two to make judgments about net benefits. Where well applied, CBA has helped make crucial policy decisions. Importantly, it can be a valuable tool in assessing individual or collective efforts in furthering the SDGs.

The limits to the use of CBA have to do with its scope, which often is within the confines of individual projects and not encompassing broader

policy or strategy framework adequately. The availability of data to compute monetary values of social outcomes has also been a constraint. There are several questions on valuation, for example, of items not traded in the market or issues of present versus future value. As with IEs, technical, organizational, and political challenges can also impede CBA from being conducted in a way that is timely and useful.

Increasingly, attention has shifted toward measuring the causal impact of policies, which puts the spotlight on the use of IE. IE and CBA are complementary tools of policy decision-making. While CBA supports initial decisions on investment, it also emphasizes the cost-side assessment, which is often lacking in IE. Without information on costs, there is no means to determine whether an investment is worthwhile.

CBA also has the flexibility to be applied to complex sustainable development issues. For instance, long-term cost and benefit estimation can take into account the environmental impact of a project in the future. Distributional impacts can also be evaluated by assigning appropriate distributional weights, thus giving explicit consideration to issues of equity.

Like IEs using panel data or follow-up of beneficiaries for long periods, CBA can also be conducted more dynamically. As the estimation of costs and benefits involves uncertainty, it is important to monitor the process and review the CBA. Costs and benefits can then be recalculated based on a midterm evaluation.

There is a need for better data collection and improvement in methods so that CBA can be increasingly applied to issues of sustainable development. There is great potential in complementing CBA with IE and OBE to produce high-quality and useful evaluations.

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