Chapter 2
Principles and Practice of Cost–Benefit Analysis

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Abstract Cost–benefit analysis (CBA), or benefit–cost analysis (BCA) as it is often called, has a long history as a methodology for assessing the economic efficiency with which resources are used to support human wellbeing. Its theoretical origins lie in the foundations of welfare economics established by economists such as Hicks, Kaldor, Scitovsky and Little. This review of principles and practice focuses on the advantages and limitations of CBA and related methods in a developing country context. General guidelines are presented.

Keywords Cost–benefit analysis • Willingness to pay • Economic value • Externalities • Cost-effectiveness analysis

Background to CBA

Evolution of CBA

Cost–benefit analysis (CBA), or benefit–cost analysis (BCA) as it is often called, has a long history as a methodology for assessing the economic efficiency with which resources are used to support human wellbeing. Its theoretical origins lie in the foundations of welfare economics established by economists such as Hicks (1939), Kaldor (1939), Scitovsky (1941) and Little (1957).

CBA originated in the US Flood Control Act of 1936 as a means of assessing projects involving public sector investments in the public interest. The Act stipulated that flood control projects would be desirable if 'the benefits to whomsoever they may accrue are in excess of the estimated costs'. The first practical guidelines on how to conduct CBA appeared in 1950 when the US Federal Inter-Agency River

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Basin Committee released the *Proposed Practices for Economic Analysis of River Basin Projects*, popularly referred to as the *Green Book* for project appraisal. Pioneering texts and guidebooks on CBA were subsequently published by economists such as Gittinger (1982), Little and Mirrlees (1974), Pearce (1971), Dasgupta and Pearce (1972), Marglin et al. (1972), Sugden and Williams (1979), Pearce and Nash (1981) and Ray (1984). Early texts on project appraisal in developing countries paid particular attention to shadow pricing, adjusting for scarcity of foreign exchange, inflation, taxes and subsidies, unemployment, unpaid labour and inequalities in income and wealth.

The incorporation of environmental values in CBA occurred somewhat later, with the emergence of environmental economics as a recognised branch of the economics discipline. Freeman (1979) described approaches to valuing environmental benefits, while other authors emphasised the place of CBA and valuation techniques in environmental and natural resource management (Hufschmidt et al. 1983). Case studies for Southeast Asian countries appeared soon after in Dixon and Hufschmidt (1986).

Most contemporary texts and guidelines for CBA highlight the importance of environmental costs and benefits, with an explanation of how to estimate and incorporate them in an economic analysis (Zerbe and Diverly 1994; Hanley and Spash 1995; Bateman et al. 2005; Hanley and Barbier 2009). CBAs are now commonly performed in evaluations of policies, programmes and projects, environmental impact assessments and the management of natural resources and environment more generally (ADB 1997; James 1994; Pearce et al. 1994, 2002; UK Treasury 1997; US EPA 2000). The case studies presented in this volume are just some examples of applications in Southeast Asian countries. Nevertheless, they highlight conceptual and practical difficulties that beset practitioners, especially in a developing country context.

Conceptual Basis of CBA

Wellbeing and Economic Efficiency

CBA is applied principally to evaluate the economic efficiency of different options that are capable of achieving some predetermined policy or management objective. Where the public interest is involved, CBA takes the form of a *social* benefit–cost analysis, concentrating on the wellbeing of the community as a whole. Wellbeing is defined in terms of the utility experienced in the consumption of goods and services produced by the economic system or that are otherwise made available, such as those provided by natural systems and the environment.

CBA focuses on only certain aspects of wellbeing, disregarding other indicators of wellbeing such as social relations, equity and personal security. Fundamental assumptions of CBA are that individual preferences count regarding the use of resources and that the wellbeing of the community comprises an aggregation of the wellbeing of its members. It is assumed that utility itself cannot be measured directly, and interpersonal comparisons of utility are debarred in the analysis.

According to the Pareto *potential economic welfare criterion*, an efficient use of resources is achieved when it is not possible to make some individuals better off without making others worse off. Application of the criterion implies that an economically efficient outcome is achieved when net benefits (total benefits minus total costs) are maximised. Following some change in economic circumstances, the gainers should in principle (but not necessarily in practice) be able to compensate the losers without being made worse off.

The key indicator of utility in CBA is the willingness to pay (WTP) by individuals or the community for positive increases in wellbeing or for the avoidance of losses. In CBA a benefit can be a cost avoided and a cost can be a benefit forgone. Although in theory it is possible to use the willingness to accept (WTA) compensation to indicate a decrease in wellbeing, it is not generally favoured as a basis for evaluation. Such measures may be subject to various kinds of bias, such as exaggerated claims for compensation, leading to inappropriate estimates of the welfare changes involved.

Willingness to Pay and Market Values

The willingness to pay for any good or service by an individual is assumed to be a reflection of his/her underlying utility function. In general, as larger quantities of a good or service are consumed, total utility will increase but at a diminishing rate. The individual's marginal utility accordingly declines. Where the good or service is provided through a market mechanism, the price that the individual is prepared to pay decreases as the quantity consumed increases. This leads to the concept of an *individual demand function* or, when represented graphically, an individual demand curve for the good or service in question.

For the community as a whole, the market demand function for the good or service comprises an aggregation of the demand functions of all individuals in the community. The market demand curve typically slopes downward to the right, expressing the prices that the community is prepared to pay as increasing quantities of the good or service are consumed. The area under the demand curve for a given quantity consumed defines *total benefits* measured in monetary units. Where the WTP exceeds the actual market price, the expenditure that could have been extracted is defined as *consumers' surplus*.

Market demand functions (described as *Marshallian* demand functions) are based on the premise of constant income. Hicks (1943) postulated four kinds of consumers' surplus, in which utility is assumed constant. In reality, only market demand functions can be observed and estimated empirically. However, as argued by Willig (1976), the difference between the Hicksian and Marshallian versions is considered to be so small that Marshallian demand functions suffice for most applications in CBA. Even so, the difficulties of obtaining sound econometric representations of market demand functions should not be underestimated.

Costs in CBA are defined as *opportunity costs*. They measure the benefits forgone by using available resources to provide a good or service rather than using them elsewhere or in some other way to support wellbeing. In general, the total cost of producing the good or service rises at an increasing rate as the quantity produced increases. The marginal cost of production (the extra cost of producing an additional unit of output) typically increases as the volume of output expands.

In a market situation, producers need to charge a price equal to the marginal cost of production to cover their costs of production and reach an acceptable level of profit. The supply curve for the good or service thus increases to the right as larger quantities are offered for sale. The area under the supply curve, for the particular quantity produced and offered for sale, indicates the *total cost* of producing a given quantity of the good or service. Where the market price prevailing in the market exceeds the price that producers are prepared to accept, the additional returns received by producers in excess of their costs of production are defined and measured as *producers' surplus*. Mutual acceptance of a price and quantity by both buyers and sellers in the market leads to a market equilibrium. Summing consumers' surplus and producers' surplus yields an estimate of the *net benefits* received.

Expressed in diagrammatic form, this occurs where the market demand and supply curves intersect. Figure 2.1 illustrates this condition.

In Fig. 2.1 the horizontal axis measures the quantity of a good X traded in the market, while the vertical axis measures its price. The market demand curve is shown as AEB and the supply curve as SET. Intersection of the curves (point E) reveals the equilibrium price (OP_1) and quantity (OQ_1) that clear the market. The total WTP for good X (the total benefit experienced by consumers) is measured as the area $OAEQ_1$, and the total cost of supplying it is $OSEQ_1$. Consumers' surplus is measured as the area AEP_1 and producers' surplus as the area SEP_1. The sum of these two areas represents the net benefits of producing and consuming OQ_1 of good X in the market.

It is instructive to note that most of the studies presented in this volume focus on producers' surplus under the assumption of fixed market prices (i.e. horizontal demand curves). None of the studies explicitly estimates a downward-sloping market demand curve, and the assessments of changes in producers' surplus are all based on the assumption of fixed prices. The study by Bhadranie Thoradeniya (Chap. 7), however, relies on an imputed downward-sloping demand curve and the concept of consumers' surplus when applying an individual travel cost model to estimate the recreation benefits of a river basin in Sri Lanka.

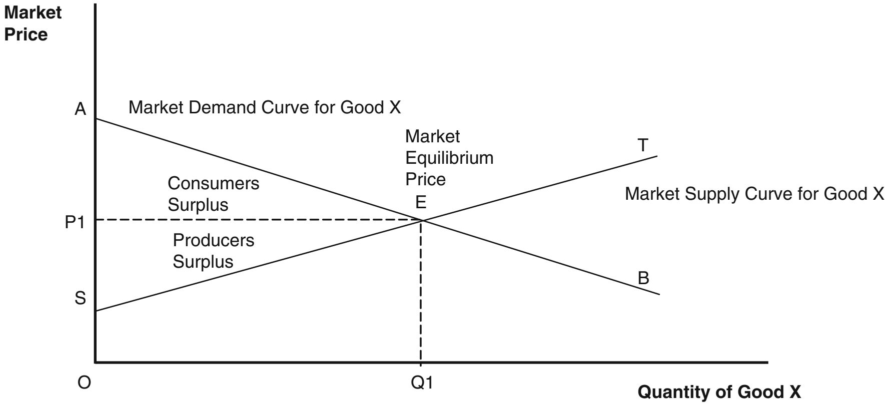

Fig. 2.1 Market supply and demand

Values of the Environment and Natural Resources

Total Economic Value

Ecosystems and natural environments provide goods and services that are essential for human existence, as well as supporting other aspects of wellbeing. Pearce and Turner (1989) introduced the concept of the total economic value (TEV) of the environment, decomposing it into various categories of use and non-use values. Such values have commonly been defined and estimated for natural forests. Valuation methodologies for timber, non-timber forest products (NTFPs) and non-use values are discussed by Bann (1998) among others. A schema for forest-related economic values is presented in the study of rubber plantation development in Cambodia by Yem Dararath et al. (Chap. 7), while Kalyan Hou et al. (Chap. 12) provide estimates of forest-based benefits potentially achievable from community forestry schemes. In the study by Saowalak Roontawanreongsri et al. (Chap. 13), the benefits of forests are categorised and valued in terms of ecosystem services. Similar studies have been performed for other natural resource systems.

It is important, in determining the value of any natural resource system, to avoid double-counting the benefits. For example, when valuing the ecosystem services provided by native forests, while the forest may contain a potential stock of timber as well as non-timber forest products and other attributes of cultural value, it would be erroneous to add all these values together, because timber-felling would be in conflict with other forest uses and values. The lesson to be drawn here is that natural resource and environmental values should be estimated only with respect to a particular policy or resource management scenario.

Environmental Externalities

Many goods and services provided by the environment are used or experienced without passing through markets. In many cases they are provided free or at prices that do not reflect their full opportunity cost or value to the community. An important task in conducting a CBA is to incorporate implicit values of the benefits that are generated by goods and services provided by the environment.

Environmental effects occurring off-site or indirectly as a consequence of human activity are defined as *environmental externalities*. In a CBA, where changes in the environment are favourable, they are specified and valued as *external environmental benefits*, while adverse environmental impacts are valued as *environmental damage costs*. External environmental costs are typically not taken into account in the evaluations, plans and activities of private producers, resulting in a divergence between the private and social costs of production, establishing a strong case for appropriate policy interventions by government. The general aim is to internalise the externalities and induce producers to modify their behaviour to improve community wellbeing.

The studies by Zanxin Wang et al. (Chap. 3), Loan Le Thanh (Chap. 4) and Cheryl Launio et al. (Chap. 5) deal explicitly with emissions of CO_2e as an economic externality, while the forest modelling carried out in the study by Nghiem Thi Hong Nhung (Chap. 6) treats reductions in CO_2e as an important co-benefit of timber production. Damage costs associated with sand mining in river basins are assessed by Bhadranie Thoradeniya (Chap. 9). Vo Thi Lang et al. (Chap. 8) estimate the damage costs resulting from water pollution and its effects on aquaculture. Jaimie Kim B. Arias et al. (Chap. 15) provide estimates of damage costs resulting from storms in San Fernando City, Philippines, while Vo Thanh Danh (Chap. 16) includes damage costs in his study of flooding and salinisation predicted to result from sea level rise in the Mekong Delta, Vietnam.

Conduct of a CBA

Steps in a CBA

Steps in conducting a CBA for a proposed project are defined in the studies by Malabou Baylatry et al. (Chap. 11) and Jaimie Kim B. Arias et al. (Chap. 17) following Boardman et al. (2010). They can be summarised as follows:

- Define the boundaries and time horizon of the project.
- Define the referent groups.
- Select the portfolio of project options.
- Catalogue the potential physical impacts of the project.
- Define what would happen without the project.

- Quantify and predict the outputs and impacts of the project over its expected life.
- Monetise the outputs and impacts.
- Calculate NPV, BCR and IRR for each option, assuming a given discount rate.
- Describe the distribution of costs and benefits.
- Perform sensitivity analysis.
- Make recommendations to decision-makers.

Construction of BAU Scenario

When evaluating options, NPV, BCR and IRR (defined below) should be assessed relative to a base case or business as usual (BAU) scenario. What counts are the incremental changes associated with any option compared with the base case. To construct a BAU scenario, it is necessary to determine the general characteristics of the scenario, currently and in the future, including its geographic boundaries, attributes and functions of the surrounding environment and natural resource systems, the population or community involved, market trends, relevant economic activities, possible impacts of human activity on the environment, the time horizon for analysis and institutional factors including industry structure and government policies and regulations.

A BAU scenario does not imply ‘do-nothing’ as it may include policies and activities that would be in place independently from the options under consideration. Rather, it should incorporate the best assessments of what can be expected over the planning period in the absence of the foreshadowed options. Nevertheless, the general aim of constructing the BAU scenario is to conduct the analysis ‘with and without’ proposed possible actions, noting that the ‘with and without’ situations should not be interpreted as ‘before and after’ chronologically.

Incremental benefits and costs of each option relative to the BAU scenario should be estimated for each future year up to the planning horizon. This involves constructing a scenario for each option, modelling all the changes that can be expected to take place and valuing them in monetary terms. Incremental benefits are calculated as the expected change in benefits relative to the BAU. A similar approach is taken to calculate incremental costs.

The studies by Yem Dararath et al. (Chap. 7), Kalyan Hou et al. (Chap. 12) and Jamie Kim B. Arias et al. Ch (15) all contain clearly defined baseline or BAU scenarios, against which feasible options are compared.

Criteria for Evaluating Options

Several criteria, defined below, are used in CBA to determine on economic efficiency grounds whether or not to undertake a particular investment policy, programme or project. It is convenient to discuss these, in what follows, at the project scale.

Net Present Value (NPV)

This criterion measures the present value of the net benefits of the development project. The formula for calculating NPV is:

$$\mathrm{NPV} = \Sigma(B_t - C_t)/(1 + r)^t \ldots\ldots t = 1..n$$

where B_t is the benefit at time period t and C_t is the cost at period t. The planning horizon or terminal year is n.

For the project to be acceptable on economic grounds, the NPV should be positive. A positive NPV means that the option produces greater net economic benefits, assessed in terms of present values, in comparison with the BAU scenario. Where there are mutually exclusive options, the option with the highest NPV is preferred. Any proposed options that have negative NPVs must be rejected as economically undesirable. In some appraisals, the best option is the BAU scenario itself. In that case, the BAU scenario will have a zero value for its NPV, while all other options will have negative NPVs.

Benefit–Cost Ratio (BCR)

This is the ratio of the present value of benefits to the present value of costs. The formula for calculating the BCR is:

$$BCR = \Sigma B_t/(1 + r)^t/\Sigma C_t/(1 + r)^t \ldots\ldots t = 1..n$$

If the BCR of a project exceeds 1, the present value of benefits is greater than the present value of costs; thus the project is acceptable in terms of economic efficiency. If the BCR is less than 1, the project should be rejected. The BCR should not be used to rank mutually exclusive options, however, as it can lead to rankings that are inconsistent with those obtained using NPV as the ranking criterion.

Internal Rate of Return (IRR)

The IRR is the rate of discount that equates the present value of benefits with the present value of costs. IRR appears as the ‘unknown’ i in the following equation:

$$\Sigma(B_t - C_t)/(1 + i)^t = 0 \ldots\ldots t = 1..n$$

This equation cannot be solved explicitly for the value of i. The only way to determine i is to postulate an initial value and solve for i on a trial-and-error basis – that is, by simulating different values of i until a solution is reached. For some options it may not be possible to calculate an IRR. This can occur when the time path for net benefits of the option fails to change sign ($-$ve to + ve or vice versa). In some cases, where the time path changes sign more than once, multiple solutions may be obtained for the IRR.

The IRR is typically used by finance departments to compare the internal financial productivity of a project with the official interest rate or cost of funds, to see whether the project is desirable as a financial investment. The IRR should not be used to rank mutually exclusive options, as it also can result in a ranking that is inconsistent with a ranking based on NPV.

Internal Economic Rate of Return (IERR)

A distinction is sometimes drawn between an economic IRR and financial IRR. The only difference is that for an IERR, all values for benefits and costs comprise economic rather than financial values. Application of the IERR criterion follows the same rules as for the IRR.

NPV per Unit of Investment (NPVI)

NPVI is calculated as the ratio of the present value of all positive future NPVs of the project to the present value of all negative NPVs. This criterion is applied where there is only a fixed supply of investible funds. The option with the highest NPVI is the preferred option on economic efficiency grounds.

Frameworks for Conducting CBA

Spreadsheet models offer the most effective framework for compiling and analysing all information involved in a CBA. A guidebook demonstrating how to construct and apply a CBA spreadsheet model using Microsoft Excel is available on the EEPSEA website (Predo and James 2006). It is frequently used in EEPSEA training courses and in CBA studies by EEPSEA researchers. Similar guidelines are provided by Campbell and Brown (2003) among others. A major advantage of using a spreadsheet model is that sensitivity analysis (exploring *what if* scenarios by varying the data input or model structure) can be readily carried out as a means of exploring different policy options and identifying critical aspects of the analysis.

Sensitivity Analysis

The economic desirability of a project depends on the values that are estimated for the various categories of benefits and costs, as well as the discount rate that is adopted. The results of an economic analysis should always be subjected to sensitivity analysis to assess their robustness and the factors that could change any initial ranking of options. Sensitivity analysis is especially useful where uncertainty prevails for particular benefits or costs. The problem of uncertainty and how to handle it in CBA is dealt with later in this chapter.

Applications of CBA Evaluation Criteria in Case Studies

For most of the studies in this volume, complete CBAs are conducted, making use of the above evaluation formulae. The CBA of an ecotourism project for Xe Pian National Protected Area in Lao PDR by Malabou Baylatry et al. (Chap. 11) shows how to set up an appropriate spreadsheet model, specify the base case and calculate the incremental NPV, BCR and IRR for the project, using the format of the EEPSEA CBA guide. Incremental analysis is carried out in the studies of land use options for rubber plantations by Yem Dararath et al. (Chap. 7) and for community forestry by Kalyan Hou et al. (Chap. 12). Other studies also apply the relevant formulae for the options involved and compare the results.

Economic vs Financial Analysis

Differences Between Economic and Financial Analysis

The economic analysis conducted in a CBA differs from a financial analysis. As noted, a CBA focuses on the welfare of a community as a whole. Rather than maximising net social benefits as in a CBA, a financial analysis attempts to determine how individuals, households or commercial enterprises can maximise their own net financial returns or minimise the costs of conducting their activities. Indeed, a potential conflict between private and public interests is often what initiates a social CBA.

An important reason for complementing a social CBA with a financial analysis is that financial factors are key determinants of the *decisions and behaviour* of individuals, households and enterprises. The aim of public policy is often to implement an effective system of incentives (financial, informative or regulatory) that aligns private financial interests more closely with the public interest. Monetary incentives have a powerful influence on behaviour.

In a financial analysis, the usual assessment method applied is discounted cash flow (DCF) accounting. The same formulae are used as in a CBA to evaluate the financial viability of an investment or proposed activity by a private entity. Differences are discussed below.

Costs and prices in a CBA are always expressed in 'real' or constant dollar terms (i.e. excluding price and cost inflation), whereas a DCF may or may not incorporate inflationary effects. Instead of a social discount rate, a market interest rate is applied in a financial analysis. The market rate typically includes an inflationary component.

Some of the prices in a CBA can take the form of *shadow prices*, representing the true opportunity costs of resources used by the community or the true value of benefits that are received. Conversion of actual market prices to shadow prices may be required to indicate a scarcity of foreign exchange, the existence of surplus labour (thus affecting the real wage rate), environmental externalities and price distortions for goods and services provided by the environment and natural resource systems. Subsidies and taxes play a role in a DCF, but they are treated as transfer payments in a CBA and are excluded from the analysis.

Depreciation is handled differently in a financial analysis compared with a CBA. In a financial analysis, depreciation is usually represented as a sequence of write-downs of capital asset values, acting as annually recurring costs and a tax offset. In CBA, resources in the form of capital expenditure are identified as they are committed, and allowance is made for a decline in the physical condition of capital assets. Use of the assets is encapsulated in the discount rate, reflecting their opportunity cost. The residual value of assets in a CBA is counted as a benefit at the end of the planning period. It is estimated in real terms, based on what the owners are able to sell them for – hence the price that others are willing to pay to acquire them – or it may refer to the value of the assets if they are retained by their owners for continued use beyond the planning horizon.

Several of the studies in this volume conduct financial analyses alongside the corresponding economic analyses. This occurs in the studies of biofuel production by Zanxin Wang et al. (Chap. 3) and Loan Le Thanh (Chap. 4) as well as the studies on forestry management by Nghiem Thi Hong Nhung (Chap. 6), Tra fish production by Vo Thi Lang et al. (Chap. 8) and river sand mining by Gunaratne (Chap. 10). Financial costs and returns figure prominently in the study of rubber plantations by Yem Dararath et al. (Chap. 7). In several of the studies, it is suggested that the gap between private and social benefits could be bridged by government subsidies, but other interventions such as direct regulations might also be used.

Distributional Effects

Inequalities in Income and WTP

Application of the Pareto potential welfare criterion, focusing on the community as a whole, presumes that the prevailing distribution of income is acceptable. Extreme inequalities in income, commonly occurring in developing countries, inevitably influence the willingness to pay by different groups within the community and their wellbeing. Concerns must then be addressed regarding the equity or fairness of possible outcomes of policies, programmes and projects. Local communities relying on low-income or subsistence activities such as fishing or cropping may be seriously disadvantaged if the results of economic analysis suggest that they should be displaced to make way for more profitable activities such as urban development, agribusiness projects or industrial production. The willingness to pay by such groups to maintain their livelihoods will be constrained by their low incomes and ability to pay.

In such situations, it behoves the analyst to identify the impacts on different groups within the community, so that decision-makers can deal with equity issues alongside economic efficiency considerations when formulating plans of action. Some economists suggest that the relevant trade-offs can be formalised by conducting *weighted* CBA in which differential weights are attached to the benefits and costs associated with different groups within the community (Harberger 1978; Scarborough and Bennett 2012). Either way, policy decisions that forgo economic efficiency to achieve a more equitable distribution of benefits and costs inevitably require subjective judgments about the wellbeing of different groups affected.

Effects on fiscal revenues and expenditures of government agencies similarly may strongly influence policy decisions. One example of an incidence analysis in this volume is the study of an ecotourism project by Malabou Baylatry et al. (Chap. 11) which identifies the costs and benefits for local communities and local government resulting from the project.

Secondary economic impacts of projects, programmes and policies, such as the spillover effects of development on jobs and incomes in a regional or national economy, have distributional implications. Such impacts are sometimes erroneously interpreted as social benefits or costs. Input–output (I-O) models or computable general-equilibrium (CGE) models are capable of predicting such effects. Again, however, while this information may be of importance from a policy perspective, secondary impacts should be excluded from a CBA.

Cost-Effectiveness Analysis

Approaches to Cost-Effectiveness Analysis

Cost-effectiveness analysis (CEA) is often applied where the monetary values of benefits are difficult to obtain due to limitations of time, information or research resources. In a CEA, the expected outcomes of an option are defined in terms of a particular policy objective, an indicator, standard or performance target. The general aim is to achieve the desired outcome at minimum economic cost. Where the benefits of a project or policy are the same for all options, there is little advantage in estimating monetary benefits, as the most desirable outcome depends only on the comparative costs. For example, to select the most economically efficient means of generating a predetermined volume of biodiesel, only the least-cost technology needs to be identified.

An alternative formulation in CEA is to maximise the outcome where a limited budget or bundle of resources is available for implementation. Where a mix of outcomes is possible, there may be difficulties in identifying the main objective and any co-benefits associated with each option. In such cases, subjective weights must be applied to determine the optimal mix of outcomes and the allocation of limited funds.

CEA can be conducted through manual search procedures (setting up tables of options and their costs), simulation modelling (exploration of options and costs through *what if* scenarios) and mathematical programming models (e.g. choosing the least-cost option of meeting fixed targets by means of linear programming or other kinds of optimisation models). Several of the studies in this volume rely on CEA instead of CBA. Typically, the authors derive their results based on spreadsheet simulation modelling. They include the study by Loan Le Thanh (Chap. 4) of biofuel production in Vietnam, the assessment of least-cost options for pollution control in Tra fish production in Vietnam by Vo Thi Lang et al. (Chap. 8) and options for water saving to protect Qixinghe Wetland in China, evaluated by Wu Jian et al. (Chap. 14).

Cost Trade-Off Analysis

When environmental quality targets cannot easily be established, subjective judgments about the required level of environmental protection can be assisted by cost trade-off analysis. Cost trade-off analysis helps to determine an acceptable level of environmental mitigation or protection, depending on the cost at each level. Usually the total costs and marginal costs of environment protection increase sharply as higher levels of control are approached. The shape of the cost curve often suggests a logical cut-off point for environmental mitigation or protection. Environmental targets may be established as part of the cost trade-off analysis.

Threshold Value Analysis

In cases where economic development and environmental preservation alternatives are mutually exclusive, especially where irreversible environmental impacts are predicted as a consequence of development, and/or where there are difficulties in estimating the nonmarket values of development proposals, the *threshold value approach* can serve as a useful way of considering resource use options. A relevant example is deciding on the use of a wild river either for construction of a reservoir for hydropower production or its preservation for recreational use and wilderness values.

Threshold value analysis is based on the concept of opportunity cost. The opportunity cost of the preservation option consists of the value of net benefits forgone for the development alternative. The environmental benefits are thus not valued directly, but a reference value is provided against which the relative value of the environment may be assessed subjectively. The threshold value indicates the price that the community must be prepared to pay to justify the preservation option. This value can be measured as a capitalised value or as an annually recurring value. A more sophisticated approach, pioneered by Krutilla and Fisher (1985), allows for differential growth rates in development benefits and calculates an initial year's cost that would have be borne to justify the preservation option.

Threshold values may also be applied in benefit–cost analyses where the NPV and rank order of options are sensitive to environmental values. Calculations can be made to determine the threshold values of environmental benefits that would be required to change the NPVs and the rank order of options under consideration. With information on threshold values, decision-makers are obliged to judge subjectively the relevant trade-offs and identify the option that might be considered most acceptable by the community. In the present volume, however, none of the studies adopts the threshold value approach.

Discounting in CBA

The Discount Rate

Discount rates are used in economic analysis as a means of comparing present and future values of benefits and costs. The general formula translating the future value of a benefit or cost to its present value is

$$\mathrm{PV} = \mathrm{FV}_t/(1 + r)^t$$

where PV is present value, FV_t is the value at some point of time in the future, r is the rate of discount and t is the specified future year. The expression $1/(1+r)^t$ is called a *discount factor*. It reduces the future value to a smaller present value. The

Table 2.1 Discount factors and present values of $100

Discount factors						
	Planning horizon (years)					
r	**0**	**10**	**20**	**30**	**50**	**100**
3 %	1.000	0.744	0.554	0.412	0.228	0.052
7 %	1.000	0.508	0.258	0.131	0.034	0.001
12 %	1.000	0.322	0.104	0.033	0.003	0.000
Present values of $100						
	Planning horizon (years)					
r	**0**	**10**	**20**	**30**	**50**	**100**
3 %	100.00	74.41	55.37	41.20	22.81	5.20
7 %	100.00	50.83	25.84	13.14	3.39	0.12
12 %	100.00	32.20	10.37	3.34	0.35	0.00

process of applying a discount rate is known as *discounting*. The higher the discount rate, the smaller will be the present value of any future benefit or cost. Some simple calculations demonstrate the effects of different discount rates and time horizons on present values, as shown in Table 2.1.

The table reveals that with a discount rate of 7 %, the discount factor at year 10 is calculated as $1/(1+0.07)^{10}$ or 0.5083. This means that $100 worth of goods and services in year 10 would be valued at only $50.83 at the present time. The $100 at year 30 would have a present value of only $13.14. With a 12 % discount rate, $100 at years 10 and 30 would have present values of $32.20 and $3.34, respectively. Beyond 30 years, unless a very low discount rate was adopted, the present value of $100 would be negligible.

Economic Rationale for Discounting

Economists give two reasons for justifying the use of a discount rate. The first is known as the *social rate of time preference*. Given the choice of consuming a given bundle of goods or services now or the same bundle in the future, people tend to place more importance on consuming now. People do not live forever, so they prefer to enjoy life now rather than later; immediate satiation of wants takes precedence over deferred satiation. Another explanation is that there may be uncertainty about the future availability of the same bundle of goods and services, and because consumption in the present is more certain, it is more highly valued than consumption in the future.

In general, the social rate of time preference adopted by policymakers when prioritising public sector activities and investments is lower than the private rate of time preference. Society is longer-lived than individuals, and risk can be spread over a larger number of people, compared with individual risk-bearing. Yet another consideration is that, as a consequence of rising living standards, higher incomes will be available in the future to support consumption, so the value of consumption relative to income is higher at present than in the future.

The second justification of a discount rate is the concept of the *opportunity cost of capital*. Capital is defined as any resource or bundle of resources (real or financial) that is capable of generating income in the future. Suppose a given bundle of resources is invested now and left to grow at a compound rate r until sometime (year *t*) in the future. The concept is similar to placing a sum of money in a bank and watching it grow at compound interest. The opportunity forgone by consuming a given bundle of resources now is the benefit forgone that could otherwise be obtained by investing the same bundle of resources in some other alternative.

Discount rates of 3 and 6 % are used in the study of sea dikes in Vietnam by Vo Thanh Danh (Chap. 16). In the optimisation model of forest management presented by Nghiem Thi Hong Nhung (Chap. 6), discount rates of 1–8 % are simulated. The discount rate is varied in the study of biodiesel production in China by Zanxin Wang et al. (Chap. 3) indicating that the financial viability and choice of production method depend critically on the discount rate that is applied. In the same study, cost and benefit components are also subjected to sensitivity analysis.

The choice of a time horizon in a CBA is closely associated with selection of a discount rate. Many analysts choose a convenient time horizon that coincides with the expected life of a project. Others simply make an arbitrary choice such as 25 years. The effects of a project may extend well into the future, in which case an appropriate value should be included in the terminal year of the assessment, such as the residual value of the project.

The discount rate is usually predetermined by the finance department or monetary authority that oversees public sector investments by government agencies. Where an official rate is not prescribed, the usual practice is to apply the rate of interest on long-term (10-year) government bonds. This rate should be the real rate of interest, namely, the market rate adjusted for the rate of general price inflation in the national economy. In developing countries, the opportunity cost of capital is considered to be very high, so it is not unusual to encounter high rates of discount that the monetary authorities prescribe in economic and financial appraisals. What often counts in practice is whether variation of the discount rate in sensitivity analysis significantly changes any ranking of policy options.

Some Implications of Discounting

As noted, the effect of discounting is to downplay the importance of future benefits and costs. This creates difficulties in applying CBA where large magnitudes of benefits and costs are predicted for the distant future. Relevant examples are assessments of the damage costs of greenhouse gas emissions under a BAU scenario (Stern 2007; Garnaut 2008), the costs of decommissioning nuclear power plants or the benefits that accrue from hydropower schemes. Unless a low discount rate is applied, such benefits and costs will have only a minor effect on calculations of NPV. The UK Treasury (2003) has recognised the need for

Table 2.2 Schedule of declining discount rates (UK Treasury p98 2003)

Period of years	0–30	31–75	76–125	126–200	201–300	301+
Discount rate	3.5 %	3.0 %	2.5 %	2.0 %	1.5 %	1.0 %

considering lower discount rates for economic assessments with long time horizons (i.e. exceeding 30 years) and has recommended a schedule of declining discount rates, reproduced as Table 2.2.

Serious ethical concerns must be addressed where long-term effects – either in the base case or in policy options – have strong implications for the welfare of future generations. Lowering the discount rate to increase the present value of long-term costs and benefits may not be an effective or politically acceptable means of addressing long-term inequities in the inter-temporal distribution of costs and benefits. In reality, economic efficiency analysis might simply be overruled by ethical judgments and policy decisions.

Discounting can also raise difficulties in the management of natural resources. In forestry, for example, trees may take many years to reach maturity and a state suitable for timber harvesting. The net returns obtainable from a harvest planned 50 or more years into the future rarely match the returns that can be made by investing in other projects with higher productivity and more immediate economic rewards. The study by Nghiem Thi Nhung (Chap. 6) deals with fast-growing species of eucalypts and acacias, determining the optimal rotation age by means of the Faustmann formula. The optimal rotation age for *Eucalyptus urophylla* was found to be only 9 or 10 years, and for *Acacia mangium*, it was 13 years. Higher discount rates shorten the rotation age. Including values for carbon sequestration increases NPVs but also shortens rotation age. The study notes that using short-rotation small-size wood is suitable for manufacturing timber products such as chipboard, medium-density fibreboard or paper, whereas longer-rotation wood can be used for construction, wood processing and exports.

For biologically renewable resource systems, such as wild fisheries, it is well documented in the literature that unless the rate of growth of net economic returns exceeds the discount rate, economic efficiency analysis may imply that the relevant populations be driven to extinction (Clark 2010; Fisher 1981). In the mining industry, adoption of a high discount rate may lead to early exhaustion of the resource, with few alternatives to generate ongoing income. Wherever such extreme solutions are implied by the mechanical application of CBA, the possibility should be considered of introducing additional constraints in the analysis, such that economic efficiency is optimised subject to a minimum standard or target that decision-makers consider should be met in the broader interests of the community, now and in the future.

Risk Assessment in CBA

Risk Assessment

Risk assessment involves two main tasks: risk analysis and risk evaluation (Aven 2008). Risk analysis seeks answers to questions such as: (1) How does alternative *I* compare with alternative *II*? (2) Is the risk too high? (3) Is there a need to implement risk-reducing measures? In this chapter, the focus is on risk analysis to account for risk and uncertainty in the benefit–cost analysis framework.

Incorporating Risk and Uncertainty in Benefit–Cost Analysis

The terms 'risk' and 'uncertainty' are commonly used interchangeably, but a distinction is drawn for economic analysis. With risk, the probability distributions for variables are known. With uncertainty, the probability distributions are not known (Dixon et al. 1989; US Department of Transportation 2003).

Typically, benefit–cost analysis is carried out in a deterministic manner. However, the analyst is usually faced with a number of risks and uncertainties when evaluating an investment or project, as the parameter values and assumptions of any economic model are uncertain and subject to change. In many cases the problem of risk and uncertainty is ignored (Dixon et al. 1989). The common approaches to account for risk and uncertainty in CBA are (1) sensitivity analysis, (2) expected values (certainty equivalents) of scenarios and (3) risk analysis through Monte Carlo simulation. Only the third method, simulation, offers a practical methodology for analysing the overall risk of a project (Treasury Board of Canada Secretariat 1998). The following sections discuss each of these methods.

Sensitivity Analysis

The traditional means by which risk can be evaluated is sensitivity analysis. This approach can be used to account for the uncertainty in the model to quantify the impacts of policy changes and uncertain variables such as price and climate on the estimates of the net benefits of a project. Sensitivity analysis helps to test the robustness of the model results, establish critical values and discover thresholds or breakeven values around which the initially preferred option may change, thereby identifying sensitive or important variables (Pannell 1997). As a special case, involving irreversible impacts, Krutilla and Fisher (1985) applied the concept of threshold values when evaluating development versus preservation options for Hells Canyon in the USA.

In a typical sensitivity analysis, the value of an input variable or key outcome variable identified as a significant potential source of uncertainty is altered, either within some percentage of the initial value or over a range of reasonable values, while all other input values are held constant. Changes in the results of analysis are duly noted. This sensitivity process is repeated for other input variables for which risk has been identified. The input variables may then be ranked according to the effect of their variability on CBA results (ADB 1997; US Department of Transportation 2003).

A more systematic way of conducting sensitivity analysis is calculating the sensitivity indicator and associated switching value (ADB 1997). The sensitivity indicator compares the percentage change in a variable with a percentage change in a measure of project worth, usually the NPV. A switching value identifies the percentage change in a variable for the NPV to become zero, the economic internal rate of return to fall to cut-off rate and the project decision to change.

The CBA studies in this volume typically include sensitivity analysis to test the robustness of the results. For example, in the study by Bayani-Arias (Chap. 15) on coastal erosion, when comparing the present value of adaptation options, variations in the scenario of the impacts of coastal erosion are described as low, average and high. Discount rates were applied in the analysis ranging from 1 to 15 %. In the study by Vo Thanh Danh (Chap. 16), the likelihood of an extreme storm event and sea level rise was assessed, and sensitivity analysis showed that the expected NPVs of dike options were very sensitive to changes in the discount rate. If the salinity-protected area comprises 50 % of the total land area, however, the CBA results are not significantly altered.

Expected Values Approach

A straightforward and commonly used approach to valuing projects is to calculate the project's expected value. The expected value is the sum of the product of the probability of each possible state of the world and the value of the project in that state of the world.

The expected value approach is an extension of sensitivity analysis through two commonly used decision analysis techniques called payoff matrices and decision tree analysis (Pearce and Nash 1981; Dixon et al. 1989). The approach can be used to assist the decision-maker in making the best decision, but only after allowing for the decision-maker's own attitude towards risk in defining acceptable planning and management strategies. Payoff matrices are usually applied to rank alternative strategies, actions or options that are mutually exclusive.

If an option has two possible outcomes, low = \$20 and high = \$200, with probabilities of 25 and 75 %, respectively, then the expected value of the option is (\$20 × 0.25) + (\$200 × 0.75) = \$5 + \$150 = \$155. If the decision-maker has a completely rational attitude to risk, then he/she should be indifferent between investing in the option and accepting \$155 as the certainty equivalent.

For multiple but mutually exclusive options, each of which has a different outcome depending on the level of an independent 'driver' and its probability of

Table 2.3 Payoff matrix of net benefits ($′000/year) under different adaptation options and rainfall conditions

	Rainfall		
Option	Poor (0.25)	Average (0.50)	Good (0.25)
No adaptation	28	60	340
Partial adaptation	40	100	160
Full adaptation	20	140	200

occurrence, expected values can be calculated from a representative payoff matrix. For example, where options for adaptation to flooding are defined as no adaptation, partial adaptation and full adaptation and where the outcomes or benefits are affected by poor, average or good rainfall events, a payoff matrix of net benefits can be constructed, as shown in Table 2.3.

The expected payoff for each adaptation option can be calculated as:

No adaptation: $(28*0.25)+(60*0.50)+(340*0.25)=\$122$
Partial adaptation: $(40*0.25)+(100*0.50)+(160*0.25)=\$100$
Full adaptation: $(20*0.25)+(140*0.50)+(200*0.25)=\$125$

In this example, the full adaptation option has the highest expected value and is thus the preferred alternative. The challenge in this approach is assigning the probabilities of events. Where probabilities are not known, arbitrary or subjective judgments must be made about the outcomes in the payoff matrix. Another drawback with the approach is that it assumes that the decision-maker is risk neutral. It does not allow for the effects of specific events, such as extreme events resulting from climate change, on human welfare (Dixon et al. 1989; Treasury Board of Canada Secretariat 1998).

Risk Analysis Using Monte Carlo Simulation

Risk analysis is any method – qualitative and/or quantitative – for assessing the impacts of risk on decision situations. The goal of any of these methods is to help the decision-maker choose a course of action, enabling a better understanding of the possible outcomes that could occur.

Quantitative risk analysis seeks to determine the outcomes of a decision situation as a probability distribution. Ideally, all CBA should be approached as a risk analysis because there is always some uncertainty in the data. In general, quantitative risk analysis involves four steps (Palisade Corporation 2009; Treasury Board of Canada Secretariat 1998):

1. Develop the basic model that will calculate NPV. This model is sometimes called the deterministic model because it uses a single deterministic value for each variable.

2. Identify and link the uncertain variables in the model to information about their maximum and minimum values (range) and about the probabilities of various values within those ranges. More specifically this involves linking the uncertain variables in the model by specifying the appropriate probability distribution function using the information available or derived from expert opinion.
3. Analyse the model with simulation. Run the model many times (a) to obtain a large number of NPVs to determine the range and probabilities of all possible outcomes for the results and (b) to determine the frequency with which various NPVs occur in the results, and, on this basis, predict the likely range of the NPV and the probabilities of various NPVs within that range.
4. Using the decision rules, interpret the results to identify the best alternative investment or, if there is only one, to decide whether it is likely to be a good investment based on the results provided and personal preferences relating to risk.

It is important to note that risk analysis is not a substitute for careful and detailed development of tables of costs, benefits and parameters. Setting up a sound deterministic model before thinking about risk is extremely important.

Adjusting for the Covariance of Related Risk Variables

When multiple uncertain inputs or output variables are considered in the model, some risk variables might be correlated. For example, if the NPV of the CBA model is based on the assumption of a high value for 'total corn production' and a high value for 'average price of corn', then the NPV may be outside the plausible range in the real world. A high production of corn normally results in a low corn price and vice versa. For the outcome of the analysis to be realistic, it must take these correlations into account. The analyst should consider adjusting for the covariance of related risk variables. Failure to take covariances into account can lead to large errors in judging risk. For example, in his pioneering study of risk analysis in project appraisal, Pouliquen (1970) cited a project for which the risk of failure was 15 % when labour productivity and port capacity were treated as independent variables but about 40 % when their positive correlation was taken into account.

Interpreting the Results of Risk Analysis

Risk analysis produces a list of NPVs, one for each run of the CBA model, which can be analysed statistically and graphically to see the probabilities of various outcomes. Two types of graphs that show the probability distribution of the NPV are (1) probability-density graph, which shows the individual probability of each NPV, and (2) cumulative-distribution graph**,** which shows how probable it is that the NPV will be lower than a particular value. Both types of graphs are useful for communicating with the decision-maker.

The decision rules for risk analysis in CBA in situations where there is significant uncertainty are as follows (Palisade Corporation 2009; Treasury Board of Canada Secretariat 1998; Richardson et al. 2006):

1. If the lowest possible NPV is greater than zero, accept the project.
2. If the highest possible NPV is less than zero, reject the project.
3. If the maximum NPV is higher than zero and the minimum is lower, calculate the expected NPV (ENPV). If the ENPV is greater than zero, accept the project but examine the risk of loss.
4. If the cumulative probability distribution curves for two mutually exclusive projects do not intersect, choose the option whose probability distribution is farther to the right.
5. If the cumulative probability distribution curves for two mutually exclusive projects intersect, be guided by the ENPV. If the ENPVs are similar, consider the risk profile of each alternative. Alternatively, conduct a second-degree stochastic dominance analysis using a certain risk-aversion coefficient to assess the more risk-efficient project.

Studies by Vo Thanh Danh (Chap. 16) and Predo and Francisco (2008) (not in this volume) are examples where risk analysis using Monte Carlo simulation in a CBA framework is applied. Vo Thanh Danh examined the uncertainty of cost variables using a uniform distribution and the benefits from avoided flood and storm damage using the expected value approach by obtaining the product of total damage avoided and probability of events. Although a Monte Carlo simulation was applied in the analysis, the study generated only the expected net present value (ENPV) but not the distribution of ENPV. The study by Predo and Francisco (2008) on land use alternatives identified the price of timber as the key uncertain variable and used time-series data to obtain the probability distribution function of prices. Their risk analysis provided not only mean estimates but also the entire distribution of the NPV estimates. The NPV of various land use alternatives can lie within a wide range of values. For example, the ENPV of one of the options ranged from a low value of PhP $-29{,}577$ ha^{-1} to a maximum of PhP 31.4 M ha^{-1}. While timber-based systems obtained the highest NPV, they seemed to be the most risky options, as indicated by the high coefficient variations ranging from 164 to 205 %.

Advantages and Limitations of Risk Analysis

Advantages of risk analysis documented in the literature include the following:

- It can rescue a deterministic benefit–cost analysis that has run into difficulties because of unresolved uncertainties in important variables.
- It can help bridge the communications gap between the analyst and the decision-maker. A range of possible outcomes, with probabilities attached, is inherently more plausible to a decision-maker than a single deterministic NPV. Risk analysis provides more and better information to guide the decision.

- It identifies where action to decrease risk might have the most effect.
- It aids the reformulation of projects to better suit the preferences of the investor, including preferences for risk.
- It induces careful thought about the risk variables and uses information that is available on ranges and probabilities to enrich the benefit–cost data. It facilitates the thorough use of experts.

However, risk analysis in CBA is not a panacea. It has various limitations, such as the following:

- The problem of correlated variables, if not properly contained, can result in misleading conclusions.
- The use of ranges and probabilities in the input variables makes the uncertainty visible, thereby making some managers uncomfortable.
- If the deterministic benefit–cost model is not sound, a risk analysis might obscure this by adding a layer of probabilistic calculations, thereby creating a spurious impression of accuracy.
- There is difficulty identifying the appropriate probability distribution for long-term uncertain events.

Sources of Probability Data

One of the major tasks in conducting a risk analysis is identifying the sources of probability data needed to specify the range of values each variable can take (minimum to maximum) and the probability distribution of the values in that range. There are two possible sources: historical data and expert judgment.

If historical data are available, the analyst can use the maximum and minimum values that occurred in the past as an appropriate range for the values of the variable. With the help of readily available commercial computer software packages for risk analysis, the probability distribution can easily be derived by fitting the data to an appropriate functional form. In the absence of historical data, or if historical data is not enough to underpin an estimate of the range and probabilities of a particular variable, then it may still be possible to rely on expert judgment, even though such judgments are typically subjective. For example, farmers are often able to provide expert judgment on the minimum, most likely, and maximum crop yield during El Niño, La Niña and neutral seasons based on their knowledge and long-term experience in farming. Similarly, the agronomist can provide expert judgment on the mostly likely yield of crops in any particular season.

A problem faced by SE Asia (and other parts of the world) is that, with the onset of climate change, it is anticipated that the probability distributions for a number of key driving variables such as temperature, wind, rainfall, floods and storm surge will shift and change in form. While the performance of global climate change models is continually improving, it will become increasingly necessary to rely on projected modelling results rather than historical data. It also begs the question as to whether a risk-neutral approach in economic appraisals is prudent, given that any shifts in probability distributions will have magnified effects in the tails of the distributions and the associated extreme events.

Techniques for Valuing the Environment

Valuation Methods

Over the last few decades, economists have devised a wide range of economic techniques to value the environment, some focusing specifically on developing countries (Freeman 1993; Abelson 1996; Pearce et al. 2002; Haab and McConnell 2002; Hanley and Barbier 2009; Glover and Jessup 2006; Glover 2010). The techniques belong broadly to three main categories: market-based techniques, surrogate market techniques and stated preference models. Each technique is described briefly below, including where it has been applied in the studies appearing in this volume.

Market-Based Techniques

Productivity Changes Method

This approach can be used when an environmental change leads to changes in production levels, costs or prices. Dose–response functions are usually needed to estimate physical changes in production as a consequence of changes in environmental conditions. Where changes occur only in output levels and/or costs, changes in producers' surplus can be estimated. If the change in productivity also results in a change in market equilibrium price, changes in consumers' surplus also need to be considered. The productivity changes technique is applied in a large number of the case studies in this volume: Zanxin Wang et al. (Chap. 3) for biodiesel production, Nghiem Thi Hong Nhung (Chap. 6) for forestry, Yem Dararath et al. (Chap. 7) for rubber production, Vo Thi Lang et al. (Chap. 8) for fish production, Bhadrani (Chap. 9) for tourism and industry, Gunaratne (Chap. 10) for sand mining, Kalyan et al. (Chap. 12) for forest products, Roongtawanreongsri et al. (Chap. 13) for timber values, Jaimie Kim B. Arias et al. (Chap. 15) for fisheries and Vo Thanh Danh (Chap. 16) for fisheries and agriculture.

Human Capital Approach

This method is frequently used in estimating external damage costs resulting from environmental pollution or other undesirable impacts. Changes in labour productivity can be measured using the human capital approach. Usually, the focus is on adverse health effects, providing estimates of forgone income, costs of medical treatment and costs reflecting psychological discomfort and distress. Reductions in health-related environmental damage costs, resulting from the introduction of environmental protection measures, can be incorporated in a CBA as benefits.

Results obtained using the human capital approach should not be interpreted as the value of human life. Most economists prefer to avoid placing direct values on life, although it is possible to obtain implicit policy values by observing the expenditures undertaken by public authorities to reduce accident rates or serious medical disorders. Another indicator is the willingness to pay by individuals to reduce the *risk* of premature mortality. Rather than the value of life, it is usually the value of statistical life (VSL) that is incorporated in a CBA. The ADB workbook on valuing environmental impacts has a sound discussion of the costs of morbidity and mortality including VSL (ADB 1996).

Defensive Expenditures

Defensive expenditures indicate the minimum amount that people would be willing to pay to prevent an adverse environmental impact. The relevant environmental benefits may exceed the expenditures involved, but if people are observed to be actually undertaking such expenditures (e.g. the construction of levees to prevent flood damage or the introduction of soundproofing in homes), it can be presumed that their valuation of benefits will be at least as great as the costs incurred. Defensive expenditures are assessed for flood control measures in the studies by Jaimie Kim B. Arias et al. (Chap. 15) and Vo Thanh Danh (Chap. 16).

Replacement/Repair Expenditures

These expenditures are typically undertaken after environmental damage has occurred, such as the application of fertilisers to offset a loss of soil nutrients or the clean-up costs incurred by households after flooding. It is spurious to make estimates of such costs and assume ex ante that they can be equated with environmental benefits, as people may not be willing to incur the costs involved. Empirical observations or surveys should be undertaken to demonstrate that the expenditures have been or will be undertaken. It can be assumed that such expenditures represent only a minimum value for the associated benefits. Flood damage estimates are provided in the studies by Jaimie Kim B. Arias et al. (Chap. 15) and Vo Thanh Danh (Chap. 16).

Shadow Projects

Expenditures on shadow projects are a special example of replacement cost. In the environmental context, a shadow project is defined as a man-made substitute for a natural system that may be severely damaged or lost as a result of human activity. The concept is closely related to environmental offset schemes, in which natural ecosystems or ecosystem services displaced by development are replicated elsewhere. When using the costs of shadow projects to value the environment, the same caveats apply as for the defensive expenditure and replacement expenditure approaches.

Surrogate Market Techniques

Property Value Differentials

In a competitive market, property asset prices and rents reflect the value of service from a property, including productive and consumptive environmental services. The property value approach (or so-called *hedonic price* method) can be used to estimate the implicit price of environmental attributes. A common application is the use of house prices to estimate environmental values. The same house with a given set of attributes can be expected to command a much higher price in an attractive or favourable environment, compared with an environment that is degraded.

The extent to which environmental attributes affect property values can be determined using multivariable regression models. Alternatively, and more easily, property value differentials generated by differences in environmental quality may be assessed by property valuation experts. Property owners themselves are often aware of the effects of environmental conditions on the value of their properties and may provide such information by means of interviews or questionnaires. Jaimie Kim B. Arias et al. (Chap. 15) and Saowalak Roongtawanreongsri et al. (Chap. 13) both apply the property value approach when assessing flood damage in their studies.

Travel Cost Method

The travel cost method assumes that the willingness to pay for recreation at a particular site can be inferred from the cost of travel by visitors to the site. The so-called zonal travel cost models are applied by undertaking an on-site survey to ascertain the frequency of visits, distances travelled, the cost of travel (including the implicit value of time), details of each visiting group and other socioeconomic information. Population statistics must be obtained for different zones of trip origin, and visitation rates by zone are calculated. A regression equation is derived showing the relationship between visitation rates and travel costs. This equation is then used to simulate the effect of hypothetical entry charges to derive a demand curve for recreation at the site. Where entry to the site is free, the entire area under the implicit demand curve provides an estimate of the consumers' surplus. Where an entry fee is charged, consumers' surplus comprises the area bounded by the price line and the demand curve.

To estimate changes in benefits for a particular site resulting from a change in environmental quality, such as an improvement in water quality, it is necessary to predict an upward shift in the demand curve, indicating a higher visitation rate and an increase in consumers' surplus for those still visiting the site. The increase in benefits is measured as the difference in total area between the original and new implicit demand curves.

Variations of the travel cost model allow for substitute sites, congestion externalities and individual versus zonal models. The study by Bhadranie Thoradeniya (Chap. 9) features an *individual travel cost model* to estimate recreation values in the Ma Oya River Basin in Sri Lanka.

Wage Differentials

The wage differential method values differences in environmental quality or risk in terms of the wages accepted by workers in different locations. It presumes that workers will accept lower wages in environmentally attractive sites and demand higher wages in degraded sites. Statistical models can be used to estimate the implicit environmental values. However, the method is difficult to apply because wages may be subject to various kinds of labour market rigidities and regulations. In addition, decisions regarding workplace location are typically based on a much wider set of criteria than environmental conditions or wages. None of the studies in the present collection makes use of the wage differential approach.

Stated Preference Models

Contingent Valuation

The contingent valuation method (CVM) establishes a hypothetical market for an environmental good or service and uses a survey questionnaire to elicit people's willingness to pay for some change in the supply or quality of the good or service (Mitchell and Carson 1989; Bateman et al. 2002). CVM is one method of directly measuring existence values and prospective values in an economic evaluation. It can be used to measure use values as well as non-use values.

CVM is subject to a wide range of potential biases; thus careful consideration must be given to the kind of scenario conveyed to respondents, the type of question asked (open-ended questions, payment card method, bidding game techniques, dichotomous choice), the specified payment vehicle and the statistical models used. Application of CVM must be carefully designed and administered to minimise biases. Gunaratne (Chap. 10) uses CVM to determine the WTP by miners for royalties on sand extracted from rivers in Sri Lanka, and Jaimie Kim B. Arias et al. (Chap. 17) apply contingent valuation to determine the WTP for a Technology-Based Flood Early Warning System to be installed along the Sta. Cruz River Watershed in the Philippines.

Choice Modelling

Choice modelling is a stated preference technique in which respondents choose their most preferred resource use option from a number of alternatives. Each alternative exhibits a number of attributes such as land affected, impacts on threatened species or cost to the household. Statistical models are applied to obtain estimates of people's WTP for particular environmental attributes as well as the value of aggregate changes in environmental quality. Choice modelling can thus be used to produce estimates of the value of multiple resource use alternatives.

Choice modelling has traditionally been applied to evaluate choices involving consumer goods, transportation, tourism and the selection of landfill sites. Texts in choice modelling include those by Louviere et al. (2000), Hensher et al. (2005) and Bennett and Blamey (2001). The technique is increasingly being used in developing countries, including applications to value environmental attributes (Bennett and Birol 2010). The study by Cheryl Launio et al. (Chap. 5) applies choice modelling of farmers' preferences regarding the use of rice straw. Gunaratne (Chap. 10) applies a discrete choice experiment (DCE) model to evaluate the preferences of local communities regarding sand mining.

Other Approaches to Valuation

Benefit Transfer Method

The benefit transfer technique borrows values from a so-called *study site* and applies them to a site to be evaluated (the *policy site*). Benefit transfers are used in several of the studies in this volume. In the study of biofuel production by Loan (Chap. 4), pollution damage costs are transferred from other similar studies. Roongtawanreongsri et al. (Chap. 13) use transferred benefits, adjusted for income levels and preferences, to value the ecosystem services provided by a protected forest in Thailand.

Benefit values may be transferred in several ways. The values may be transferred in unadjusted raw form. Examples include the typical value of a recreation visit to a natural area or the value of a rare species. Values may be adjusted as part of the transfer. For example, when the transfer involves two different countries, it is necessary to convert currencies allowing for the exchange rate or purchasing power of the currency. Other adjustments may be required to compensate for the effects of inflation. Differences in living standards may be handled by means of adjustment factors or value weights based on per capita incomes.

A common practice is to transfer data relating to physical factors or relationships at the study site and combine it with data applicable at the policy site. A good example is transferring physical dose–response functions, such as those determining the physical impacts of air pollution on human health or crops, and valuing them in terms of local costs and prices. Such functions may be derived by way of multivariable regression models, in which local data for the explanatory variables can be incorporated. Meta-analyses of comparable study sites (the compilation of large databanks from numerous studies to permit generalised statistical analysis of economic values) are an extension of this approach.

The robustness of the benefit transfer method depends largely on the quality of results for the study sites and the presence of similar conditions at both the study site and the policy site. For reliable use of the benefit transfer technique, the attributes of the study and policy sites should be similar; any environmental change under consideration at the policy site must be similar to that at the study site; and the socioeconomic characteristics and preferences of the population should be similar or at least adjusted as part of the transfer procedure.

Interactive website databases of environmental values have been constructed to facilitate benefit transfers for the purpose of economic analysis (DECCW 2004; Environment Canada 2009). In practical applications, this may be the only easily accessible source of information to fill any gaps in environmental values required to complete a CBA. Various authors have recently explored the use of choice modelling as a basis for transferring environmental values in economic analysis (Morrison et al. 2002; Rolfe and Bennett 2006).

Delphi Technique

This approach uses direct questioning of experts or community representatives to place a value on particular goods or services. It is usually applied in an iterative fashion, in group sessions, to achieve a consensus result.

Valuation Methods Applied in Case Studies

Environmental valuation is a critical step in the procedure for conducting a CBA. The case studies in this volume feature most of the valuation methods previously discussed. In any full CBA, it is customary to begin with market and financial values and modify them in accordance with the principles of welfare economics, including the incorporation of nonmarket values where relevant. The issues, approaches, methodologies and policy recommendations appearing in the studies here have been determined by EEPSEA researchers themselves and accordingly exemplify the kinds of economic assessments that may be carried out in Southeast Asian countries.

It may be noted that in many of the studies, there is an emphasis on productivity changes and market values. Similar observations in a developing country context have been made by other authors (Abelson 1996). This could simply reflect the strong dependence of developing countries on natural resources to support real incomes and livelihoods. Such countries usually have large populations in rural areas, and their production activities typically take the form of cropping, fisheries, forestry, aquaculture and animal production, all of which have close connections with natural resource systems. Other factors may also be responsible, such as low incomes and a limited ability of people to pay for environmental protection in the form of public goods, institutional fragilities that make it difficult to implement schemes that translate nonmarket benefits into actual payment schemes and budgetary constraints that limit the willingness and ability of governments to allocate funding to environmental protection or improvement programmes and projects.

Several of the studies supplement the social economic analysis with financial appraisals to explain the attitudes and behaviour of producers and the effects of policy options on producers' surplus. In other studies, market values are applied in assessing the economic significance of environmental impacts on human health, property and natural assets. The level of economic expertise required to apply market-based valuation methods should not be underestimated, as the application of these methods often requires complex analysis carried out in conjunction with other disciplines.

Where markets do not exist or are subject to significant distortions, it is more appropriate to consider using other valuation methods such as the travel cost method, property value differentials and stated preference modelling. All these methods have been applied in the case studies appearing in this volume. Two of the studies use multinomial logit models to analyse the choice behaviour of individuals, although not aiming specifically to provide environmental values. Some of these techniques, if properly applied, require substantial funding and research input. In developing countries funding support for economic assessments is often limited, thereby necessitating the use of less sophisticated valuation methods. For this reason, techniques such as cost-effectiveness analysis and threshold value analysis are often applied in preference to full cost–benefit analysis.

The benefit transfer technique is applied in some of the studies where nonmarket values are a component of the CBA, such as values for biodiversity and protected areas. In several of the studies, benefit transfers are used to value externalities associated with carbon emissions, although the values have typically been based on abatement costs or the prevailing price of tradable carbon credits in markets for certified emission reductions rather than direct valuation of environmental damage costs.

Significant progress has been made in developing countries, especially in academia, on methods for estimating nonmarket environmental values. There is now a growing awareness of the scope for applying stated preference models such as CVM and choice experiments. As per capita incomes increase over time, it can be expected that nonmarket values for the environment and natural resources will assume even greater importance. However, a high level of skills in experimental design, data collection and econometric methods is required to apply such methods. At present, the level of economic expertise tends to vary between countries. Some countries have reached high standards in their education and training programmes, but others still require further capacity-building.

It must be recognised that where benefit transfers are the only feasible source of nonmarket values, appropriate values may be obtainable only if pre-existing nonmarket valuation studies have been conducted for similar sites or circumstances. This underlines the importance of encouraging nonmarket valuation studies in capacity-building programmes, to help establish databases for economic assessments where full valuation based on primary data cannot easily be carried out.

Stated preference estimates of the WTP for environmental and natural resource attributes or improvements have important potential applications in developing countries. For example, they may guide the design and implementation of actual pricing and charging systems such as payments for environmental services (Pagiola et al. 2002), charges for reticulated water supplies and wastewater treatment schemes and entry fees to national parks. Even where actual pricing is not possible, implicit nonmarket values for natural assets can convey strong messages to policymakers regarding levels of public sector investment that may be warranted to protect such assets and meet community expectations.

The focus of economic analysis should clearly be on facilitating policy decisions, not the derivation of values per se. In practice, valuation methods will tend to be chosen that provide the most effective decision support and can realistically be carried out in the context of available funding, data, technical expertise and the time frame for research.

Strengths and Limitations of BCA

Limitations of Scientific Assessments

In most applications involving natural resources and the environment, the robustness of the economics results depends critically on the integrity and reliability of the scientific modelling and research that has been conducted for the biophysical aspects, especially the interrelationships between the natural environment and human activity. ‘Getting the science right’ is essential; otherwise economics results will be seriously compromised. Scientific uncertainties continue to hamper economic analyses of issues such as climate change, long-term impacts of persistent pollutants on human health and the behaviour of natural ecosystems in response to human activity.

Multi-objective Trade-Off Analysis

As noted, in reality decision-makers may focus on a broader set of indicators of wellbeing than economic efficiency. This is especially the case where *sustainability* is the professed aim of policy or where outcomes are assessed in terms of triple bottom line accounting: economic, social and environmental. Sustainability is best regarded as a multi-attribute or multi-objective concept, involving considerations of economic efficiency, ecological integrity, prevention of irreversible damage and inter- and intragenerational equity.

Frameworks and procedures for assessing trade-offs among multiple objectives may involve the use of decision support systems, participatory systems analysis models and multi-criteria analysis models (Janssen 1993). Information relating to economic efficiency may be incorporated in such models, alongside other indicators of community wellbeing. One advantage of such models is that the information used may be quantitative or qualitative and monetary or nonmonetary. However, it is essential not to double-count effects within the analysis. For example, if various kinds of physical indicators are adopted to represent the environmental outcomes of options, they should not be double-counted as monetary environmental values in the economic information. Similar caveats apply to social indicators.

Multi-criteria analysis (MCA) is applied in the study by Gunaratne (Chap. 10) using the DEFINITE software program (Janssen et al. 2001) to evaluate options for sand mining in terms of various social, economic, environmental and technical criteria. Multi-criteria trade-off analysis is used also in the study by Wu Jian et al. (-Chap. 14) in exploring options for managing the Qixinghe Wetland in China.

A major difficulty encountered in using multi-objective models is establishing relative importance weights for the criteria adopted in the assessments. The weights may be elicited from technical experts, community representatives or decision-makers themselves. Various mathematical methods and elicitation procedures may be used to derive weights (Janssen 1993). Subjective weights perform a similar function to the monetary values in a benefit–cost analysis, but they clearly relate to a broader set of objectives and decision criteria than economic efficiency.

The main challenge in applying methods such as MCA is to identify which options, which criteria and whose value weights are to be taken into account when setting up the evaluation framework and deriving the results. Success depends as much on the processes of defining the decision problem and ensuring that representative values are incorporated in the analysis as on the mathematical specifications of the calculations undertaken

Ownership of Assessment Process

A final limitation of CBA is that – depending on how the process is coordinated – it may be dominated by technical experts, economists and bureaucrats, with little opportunity for the community or different interest groups to gain a sense of ownership of the assessment process or the results of analysis. Stakeholders may, however, be engaged in assessments by means of surveys, direct consultations, focus group discussions, workshops and other participatory activities. The details of analysis including assumptions adopted, techniques applied, data used and issues of importance should be clearly identified, discussed and reported. Often, local knowledge and experience is a valuable source of information. The study of river basin management by Bhadranie Thoradeniya (Chap. 9) uses an educated trade-off framework (ETF) and participatory decision-making process that includes assessments and results of CBA.

Strengths of CBA

Transparency of Analysis

Perhaps the main strength of CBA is that it forces the analyst to undertake a comprehensive assessment of factors that are likely to affect community wellbeing as a consequence of any kind of planned action. The boundaries of analysis – both spatially and temporally – must be clearly defined. If properly conducted, scientific assessments underlying the economic analysis will be objective and soundly based. Valuations undertaken by economists should also be objective, albeit based on a narrow set of criteria relating to only one indicator of human wellbeing. All results obtained in a CBA should be transparent and available for scrutiny and possible amendment. The ability to explore different data inputs, structural relationships and valuation methods, carry out sensitivity analysis and evaluate the results is a particularly powerful feature of the method.

Promotion of Sustainable Economic Development

Possibly the greatest advantage of CBA is that it converts all information into a single, easily understood indicator using monetary values as the common measuring rod. In the early years of environmental management and environmental impact assessment, limitations of environmental valuation methods meant that the economic aspects of proposed developments were seen mainly in terms of direct financial benefits to private interests, with environmental effects addressed only in descriptive or qualitative form. Thus, the decision context was usually conceptualised as 'the environment versus development' implying that a conflict or trade-off between the two was necessarily involved. Invariably, state treasuries, finance departments and economic development agencies gave greater weight to the direct benefits of development initiatives that could be more easily expressed and measured in monetary terms.

The insights offered by the World Commission on Environment and Development dramatically changed this perception, convincingly demonstrating that environment protection and development should be mutually reinforcing (WCED 1987). CBA has emerged as an important vehicle for integrating the values of natural resources and environment within mainstream development planning and policymaking. As a facilitator of this process in South East Asia, through its capacity-building programmes, EEPSEA has hopefully played a constructive role.

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