1 INTRODUCTION

1.1 ABOUT THIS BOOK

This book is intended as an introduction to Cost-Benefit Analysis (CBA) for people interested in its application to environmental management. The emphasis is very much on application, in that Part II of the book is devoted to cases where CBA has actually been applied to environmental problems. However, the application of a few rules and methods with no understanding of the underlying theoretical background would be dangerous and give a false impression of the robustness of the results. The theory behind CBA must be understood along with the assumptions it makes before presenting the case studies. As with every part of economic theory, there are disagreements concerning the correct approach. We have tried to represent most sides of the arguments over contentious issues, including, over the use of discounting and the choice of discount rate. Yet, to merely present all aspects of an argument without coming down in favour of a particular approach might leave the reader confused and our consciences unclear. We have therefore also felt the need to express our views as to the most useful way in which to proceed.

Although there are many techniques for appraising policies and projects which impact on the environment, this book concentrates rather single-mindedly on CBA and the closely related technique of Cost-Effectiveness Analysis (CEA). The reader should be fully aware that there are many methods of expressing such impacts that an environmental manager can and should consider singly or jointly. Other methods include environmental impact assessment, scenario analysis, and risk-effectiveness analysis; see Walthem (1988); MacAllister (1980). Indeed, in all the case studies considered, physical information about environmental impacts is shown to be an essential prerequisite to CBA/CEA. In addition, the concluding chapter of the book asks how useful CBA/CEA is for environmental management given: (a) the problems encountered in applying either
technique; and (b) the availability of other methods of analysis. We conclude that both CBA and CEA are useful contributions to the decision-making process; but that neither is sufficient as a "stand alone" criterion.

In the rest of this chapter, we first of all take a brief look at the history of CBA. Next, the basic structure of a CBA is outlined. Finally, we summarize the major difficulties facing CBA analysts in considering environmental problems.

1.2 A SHORT HISTORY OF COST-BENEFIT ANALYSIS

The United States (U.S.) federal water agencies, principally the Bureau of Land Reclamation and the U.S. Army Corps of Engineers, were among the first to make use of cost-benefit analysis. As early as 1808 Albert Gallatin, U.S. Secretary of the Treasury, was recommending the comparison of costs and benefits in water-related projects. This precedes the, often cited, cost-benefit writings of the Frenchman, Jules Dupuit, by some 35 years. A chronology of important CBA-related events in the U.S. is shown in Table 1.1.

In the Federal Government, water resource development alone received formal attention with regard to the return on public spending. The Flood Control Act (1936) required the U.S. Army Corps of Engineers to evaluate the benefits and costs of all water resource projects, "to whomsoever they accrue". Early analytic efforts in the water resources area, while unsophisticated, served to stimulate research into the use of economics to aid budget allocation decisions in other areas.

Under the auspices of the Federal Interagency River Basin Committee a guide to CBA was produced, nicknamed the Green Book. This provided a practical guide for conducting CBA. Shortly after the Green Book a similar document was produced with the aim of replacing it, Budget Circular A-47. Besides providing practical guidance, these publications encouraged academic interest.

Eckstein (1958) related the CBA techniques being employed to welfare economic foundations. His book *Water Resource Development* critically investigates the techniques for benefit estimation using market information. Systems analysis was soon being applied to water resource management with the aim of exposing the interdependencies of river systems. A prime example of such research is Krutilla and Eckstein’s (1958) *Multiple Purpose River Development*. Computer-aided systems analysis was also carried out at Harvard resulting in the publication of Arthur Maass and associates (1962) *Design of Water-Resource Systems*. During this era water quantity was the primary concern, but as the rate of dam construction slowed, attention began to turn to other issues. The 1960s saw growing concern over the
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<tr>
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<td>A Gallatin Report on Transportation.</td>
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<td>1936</td>
<td>Flood Control Act: Benefits must exceed costs for flood control projects.</td>
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<td>1946</td>
<td>Federal Interagency River Basin Committee, Subcommittee on Benefits and Costs set up.</td>
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<td>1952</td>
<td>Bureau of the Budget, Budget Circular A-47.</td>
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<td>1955</td>
<td>Harvard University Water Programme set up.</td>
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<td>1964</td>
<td>Allen V Kneese. The Economics of Regional Water Quality Management.</td>
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<td>1967</td>
<td>John Krutilla. &quot;Conservation Reconsidered&quot;. Stressed the importance of use and non-use values for preservation and of option value.</td>
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<td>1981</td>
<td>Presidential Executive Order 12291.</td>
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quality of the environment; this is evident in the work of the Water Quality Program at the independent research body, Resources for the Future, in Washington, D.C. Alternative policy instruments and institutions for controlling water quality were investigated, and methods for economic modelling of water quality developed. Still the main focus was upon supply-side efficiency and the supply of private goods from public projects; for example, efficiently meeting externally fixed ambient water quality standards, and maintaining the efficiency of a river system while introducing a new dam. However, some researchers began to focus upon the benefits of both water quantity and quality. The evaluation of the recreation-based benefits of new reservoirs raised interesting problems for CBA. Notable among this early benefits research is Clawson and Knetsch (1966), which includes the early development of the travel cost method. The emphasis here was on the methods and data required for measuring the benefits of environmental improvement in relation to outdoor recreation.

Interest expanded from water-based recreation into public goods such as wildlife, air quality, human health, and aesthetics. Techniques for the measurement of intangible benefits from environmental improvement have increased to include hedonics, the travel cost method and contingent valuation. Another new aspect of the research of the 1970s and 1980s was the recognition of the importance of nonuse values.

During this same period CBA has received increasing attention in relation to environmental aspects of U.S. government policy-making (for a comprehensive survey see Froehlich et al., 1991). Formal CBA techniques have been required to support environmental regulations since the early 1970s. The early requirements for the inclusion of environmental damages concerned physical measures and environmental impact assessment (EIA), similar to current legislation in the EC. A process of development occurred with the move from the National Environmental Policy Act (NEPA) of 1969 requiring EIAs, to Presidential Executive Order 12291 of 1981 explicitly requiring the application of CBA to new regulations. In the case of environmental legislation, the Executive Order enforces the need for the assessment of the environmental benefits of proposed legislation. CBA can also be required for particular environmental problems, for example the disposal of mine wastes and discharge of hazardous substances into public water systems. In addition, legislation such as the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) 1980 has brought the issue of environmental damage assessment before U.S. courts.

CBA in relation to the environment faces many challenges not least in relation to the treatment of long-term effects, irreversibilities, risk and uncertainty. A strong research community has been built up in the U.S., particularly around the Rocky Mountain region including the Universities of Colorado, New Mexico, and Wyoming. Meanwhile in Europe, development
of both research and practice has been relatively slow. In the United Kingdom (UK), CBA applications have been largely transportation based, starting in 1960 with the M1 motorway project and including since then the closure of rail routes, the 1970s Channel Tunnel proposals, the Third London Airport, and road bridges over the river Tay and Severn. The Department of Transport provides a Manual of Environmental Appraisal (UK Department of Transport, 1983) which gives guidance on the inclusion of environmental impacts. COBA is the Department of Transport procedure for CBA for trunk road schemes. CBA was first applied to trunk road investment in the 1960s and COBA was introduced in the early 1970s. The existing procedure computes a net present value which includes a monetary valuation of time and accident savings but excludes all environmental effects. The Standing Advisory Committee on Trunk Road Assessment (SACTRA) has reviewed environmental assessment procedures and has yet to recommend the use of CBA. There is a persistent belief that environmental considerations cannot be included in a monetary assessment like COBA. Such a position has been criticized as, at best, misleading (see Nash, 1990). The application of CBA to road schemes is discussed at length in Chapter 12.

In the 1970s other types of development projects besides transportation were subject to CBA, such as the New Covent Garden Market, while in the 1980s the Sizewell B Inquiry, pushing the methodology to limits, attempted to apply CBA techniques to the choice of sources for electrical energy generation. In general, the Treasury influences the extent to which a government needs to make monetary evaluations of environmental impacts. The Green Booklet (UK Treasury, 1984) is the guide provided by the Treasury for the appraisal of investments by government departments. Expenditure plans are subject to an appraisal procedure which includes a CBA component. However, the monetary evaluation of environmental impacts has been limited. Currently, under the European Community Directive on Environmental Assessment, certain types of projects must undergo non-monetary assessment of environmental impacts (see Department of the Environment, 1989). As far as environmental-related CBA in the UK is concerned the lack of an Environmental Protection Agency may be an important factor hindering both practice and research.

The UK government began revising its cost-benefit analysis procedures with regard to the environment in 1990. This process can be traced to the publication of the Pearce Report, commissioned by the Secretary of State for the Environment (Pearce et al, 1989). Government and public reaction combined to produce a new White Paper in response, This Common Inheritance (HMSO, 1990). This recommended that environmental impacts be brought into formal appraisal procedures wherever possible. The means to do this are currently being realized on two separate fronts, namely policy appraisal and project appraisal. Guidelines on incorporating environmental impacts in policy appraisal were issued in September 1991 and

A governments' policies can affect the environment from street corner to stratosphere. Yet environmental costs and benefits have not always been well integrated into government policy assessments, and sometimes they have been forgotten entirely. Proper consideration of these effects will improve the quality of policy making.

1.3 THE STRUCTURE OF A COST-BENEFIT ANALYSIS

In any CBA, several stages must be conducted. Whilst many will disagree on how these stages are identified, the following structure provides a guide to the essential steps: defining the project, identifying impacts which are economically relevant, physically quantifying impacts, calculating a monetary valuation, discounting, weighting, and sensitivity analysis. We now discuss each of these in turn.¹

Stage One: Definition of Project
This definition will include (i) the reallocation of resources being proposed (for example the construction of a new road bridge connecting an island previously only served by a ferry service to the mainland); and (ii) the population of gainers and losers to be considered. The reason for defining (i) is that a project cannot be appraised unless what is to be appraised is known. This definitional step may also be used to determine the boundaries of the analysis. For example, in the enquiry into the construction of a new nuclear power station at Sizewell in England, the analysis spread over into an appraisal of UK energy policy. In the subsequent enquiry at Hinkley Point, the public inspector was told to restrict admissible evidence to the power station, so excluding UK energy policy.

The motive for (ii) is to determine the population over which costs and benefits are to be aggregated. Sometimes, this population will be determined by law. More frequently, however, some discretion is permitted. In the bridge example mentioned above, do we count only those people in the immediate vicinity of the bridge (say, at the district level), or affected persons at the regional, national or supra-national level? This last category of potential beneficiaries and losers may seem unlikely, but further integration of, for example, environmental policies in the European Community (EC) is an example where supra-national interests may be the relevant ones.
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Stage Two: Identification of Project Impacts

Once the project is defined, the next step is to identify all those impacts resulting from its implementation. For the bridge project, stage two would include a listing of all resources used in constructing the bridge (concrete, steel, labour hours); effects on local unemployment levels; impacts on traffic movements; effects on local property prices; and impacts on the quality of landscape in the area not “picked up” by changes in property values.

Two important concepts here are additionality and displacement. Additionality refers to the net impacts of the project. If a government were appraising the introduction of lower speed limits to reduce road fatalities, this benefit should be measured net of any reduction in fatalities that would have occurred without this policy change (due, for instance, to improvements in car design).

Displacement is often important when CBA is applied by development authorities at the regional level of government, when two possibilities arise. Consider a new car factory in Tayside in Scotland. Will this displace output from some existing plant in any other region of Scotland? If so, the extent of such “crowding out” needs consideration, as does whether the outputs of the two plants are truly homogeneous. This is unlikely, so that perfect (that is one-for-one) displacement is rarely encountered. Secondly, the Tayside plant may displace no Scottish output, but may displace output elsewhere in the UK; if the Scottish development agency is responsible to the UK national treasury, then this could be considered as another case of displacement. However, a weighting system of project costs and benefits can be used to discriminate in favour of increasing economic activity in depressed regions (see the discussion of shadow prices below).

Stage Three: Which Impacts are Economically Relevant?

Here we must run slightly ahead of the discussion in this book, since the question “what to count” is bound up in neo-classical welfare economics, in particular in the social welfare function which society is interested in maximizing. These points are discussed in the next chapter. For present purposes, however, assume that society is interested in maximizing the weighted sum of utilities across its members. These utilities depend upon, amongst other variables, consumption levels of marketed and non-marketed goods. The former include a range of items from bananas to theatre visits, while the latter include fine views and clean air. The aim of CBA is to select projects which add to the total of social utility, by increasing the value of consumables and nice views by more than any associated depletion in the levels of other utility-generating goods. CBA can in fact select the best (most efficient) projects from a list (portfolio) of alternatives.

Thus, what are counted as positive impacts, which from now on will be referred to as benefits, will either be increases in the quantity or quality of goods that generate positive utility or a reduction in the price at which they


are supplied. What we count as costs (that is negative impacts) will include any decreases in the quality or quantity of such goods, or increases in their price. These negative effects also include the using-up of resources (inputs to production) in a project, since if an hour of labour or a bag of cement is used up in constructing a bridge, it cannot be used simultaneously in constructing a dam. This is the concept of opportunity cost.

The crucial point here is that the environmental impacts of projects count so long as they either (i) cause at least one person in the relevant population to become more or less happy; and/or (ii) change the level or quality of output of some positively valued commodity. For example, the environmental impacts of the bridge could consist of a deterioration of landscape quality and of adverse effects on fish spawning grounds (due to hydrological factors). The former is relevant to the CBA if at least one person dislikes the landscape change; the latter is relevant if at least one fisherman finds he catches fewer fish per hour at sea (or alternatively must expend more resources to catch the same number of fish). The absence of a market for landscape quality is irrelevant; similarly, the absence of a market for air quality is irrelevant when we consider the impacts of a new coal-fired power station on acid rain. In fact, many environmental effects will fail to be recorded by market price movements, since the stock of environmental quality frequently displays public good aspects (non-rivalness and non-excludability). All that matters is that an impact on production or utility can be recorded. Unpriced impacts are the most important feature of environmental CBA. These unpriced impacts are referred to as *externailities*, which may be either positive, in conferring benefits (my beautiful wood gives you enjoyment, yet you pay me nothing to enjoy it); or negative in exacting costs such as the acid rain example (where, since none owns clean air, the power station pays nothing to use it up when polluting). A full discussion of externalities and public goods may be found, for example, in Baumol and Oates (1988). The central message of this book is that environmental impacts are very likely to be relevant both in carrying out a CBA and to the resulting decision on project choice.

One class of impacts that should be excluded from a CBA are transfer payments. Good examples are reductions of indirect tax revenue due to a project going ahead, or additional unemployment benefits becoming payable. Neither of these flows constitutes a using-up of real resources (such as labour hours), but are merely redistributions of money through (generally) the government. Less indirect taxes received (a loss) are cancelled out by less taxes paid (a gain). For this reason, most government guidelines on CBA (for example UK Treasury, 1984) recommend the exclusion of such transfer payment effects. There are, however, two exceptions: first, where a tax is designed to correct a market imperfection (for example, a pollution tax attempting to make polluters pay the social cost of their actions). Here, taxes are to be interpreted as shadow prices, as
discussed below. However, this type of tax is rare, and even where set, is usually a bad guide to marginal external costs. The second exception is where the government decides to place unequal weight on gains and losses attached to different groups within society in any year. Here, gains and losses will not cancel out. However, such weighting is unusual in the OECD countries.

Stage Four: Physical Quantification of Relevant Impacts

This stage involves determining the physical amounts of cost and benefit flows for a project, and identifying when in time they will occur. In the bridge example, this would include: the number of vehicles a year crossing the bridge; the time savings accruing to those using the bridge instead of the existing ferry service; the number of years the bridge will last before major repairs are necessary; and the extent to which fish populations will be disrupted. For environmental impacts such as these, the use of Environmental Impact Analysis is clearly important.

All calculations made at this stage will be performed under varying levels of uncertainty. For example, the effect on fish populations may be very difficult to predict; whereas the amounts of concrete and steel needed to construct the bridge are relatively easy to predict. In some cases, it may be possible to attach probabilities to uncertain events and calculate an "expected value". For example, suppose that engineers know that there is a 30% probability that the bridge will last for 10 years, a 50% probability that it will last 15 years, and a 20% probability that it will last 20 years. The expected value for the bridge's lifetime is \( (0.3 \times 10) + (0.5 \times 15) + (0.2 \times 20) \), or \( 3 + 7.5 + 4 \) = 14.5 years (note that all probabilities must sum to one). This calculation of expected value can equally be applied to monetary flows.

Stage Five: Monetary Valuation of Relevant Effects

In order for physical measures of impacts to be co-measurable, they must be valued in common units. The common unit in CBA is money, whether dollars, pounds or yen. This is merely a device of convenience, rather than an implicit statement that money is all that matters. Markets generate the relative values of all traded goods and services as relative prices: prices are therefore very useful in comparing tonnes of steel with working hours saved, since not only are both made co-measurable, but some indication of their current relative scarcity is provided. Prices carry valuable information. The remaining tasks for the CBA analyst are then to:

(i) predict prices for value flows extending into the future;
(ii) correct market prices where necessary; and,
(iii) calculate prices (relative values in common units) where none exist.
When part of the output of a soil conservation project, for example, is an increase in crop outputs over a 30-year time period, knowledge of the prices of these crops over this time span is central to the estimation of project benefits. There is an important point here, since future prices may change in both real and nominal terms. If the former is occurring, then we need to know, for example, how the price of wheat will change relative to the price of corn (that is the rate of exchange between them). However, inflation can push up the prices of both without their relative values changing. The CBA should be carried out in real terms. Relative (real) price changes are of relevance, with discounting (see below) being done at the real discount rate. Nominal historical values can be converted into real values using a price index: in this case, the most general measure of price changes available (such as the Retail Price Index) should be used, rather than a project-specific index, since the analyst is interested in the change in welfare at the broadest (economic) level.

Consider the following example. A new public transit system is expected to produce the earnings given in the second column of Table 1.2 over its first four years of operation. Year 0 is the first year of operation. If the inflation rate over this period is expected to remain constant at 5% per year, the real value of these returns is as shown in column three. For any year, the real value of benefits in year 0 currency is $B_t/(1 + \rho)^t$, where $\rho$ is the inflation rate (so that $(1 + \rho) = 1.05$) and $t$ is the number of years since year 0. The CBA analyst would use the second set of values in conjunction with the real rate of discount.

Tasks (ii) and (iii) consist of adjusting market prices. In a perfectly competitive market, under certain assumptions, a the equilibrium price indicates both the marginal social cost (MSC) and marginal social benefit (MSB) of the production of one more (or one less) unit of that good. This is because opportunity costs of production are given by the supply curve (given perfectly competitive input markets), whilst the demand curve is a schedule of marginal willingness to pay. Clearly there will be many cases,

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<th>Year in which Benefit Occurs</th>
<th>Value of Benefit in Nominal Terms (£ millions)</th>
<th>Value of Benefit in Real Terms (£ millions)</th>
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<tr>
<td>0</td>
<td>400</td>
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<th>Benefit in Terms</th>
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However, when the market price is a bad indicator of both MSC and MSB. If this is the case, shadow prices can be used to reflect true resource scarcity. Three cases can be distinguished:

1. imperfect competition;
2. government intervention in the market; and
3. the absence of a market.

1. Imperfect Competition
If there is imperfect competition in a market, microeconomic theory shows that market price will not equal marginal cost in most cases. Consider Figure 1.1, which shows a monopolist facing a demand curve D. The monopolist maximizes profits by producing at \(X_m\) and charging a price \(P_m\). Suppose that a project requires the output of this monopolist as an input: then, so long as consumers can buy all the effectively demand at \(P_m\), the true cost to the economy of one more unit of X is not \(P_m\) but \(C_m\), the monopolist's marginal cost. This will be true if only and only if all costs to society of producing X are also borne by the monopolist (that is, if no external costs of production are involved).

![Figure 1.1: Price and marginal cost for a monopolist](image-url)
2. Government Intervention
Suppose the project in question will lead to an increase in agricultural output (say as a result of land drainage). How should one more unit of such output be valued? If more wheat is to be grown and sold, then surely the market price of wheat indicates the MSB? This will not be so if the government artificially holds up the price of wheat above world market levels. Most Western governments do indeed support their agricultural sectors, and most do it partially by holding up prices. This may be achieved by a mixture of import levies, intervention buying and deficiency payments. In Figure 1.2, the market for wheat in the EC is shown. Consumers could buy at a world price of \( P_w \), but are prevented from doing so by import taxes which raise prices domestically to \( P_r \). Farmers in the EC produce \( Q_r \) wheat in response to this latter price, and EC consumers buy \( Q_d \) given their demand curve \( D_{ec} \). This reduces the volume of imports to \( (Q_d - Q_r) \), whilst the EC collects tariff revenues of \( [(Q_d - Q_r) \times (P_r - P_w)] \). Now \( P_d \) is the willingness to pay (WTP) of the marginal consumer for one more tonne of wheat; however, this consumer could have bought this extra tonne at the (lower) world market price of \( P_w \). The consumer is in fact losing out as a result of the price support since the increase in price has reduced his or her consumers' surplus (see Chapter 2), although farmers in the EC and, in this instance, EC taxpayers have gained. Losses will in fact be bigger than gains, so that the MSB of the extra tonne of wheat is less than \( P_w \). With farm outputs, "producer subsidy equivalents" are calculated annually to adjust farm-gate prices into estimates of MSB.

3. The Absence of a Market
Commonly in CBA, the analyst is faced with the difficulty of placing a value on a good not traded in markets and for which no obvious price exists. In this case, there are a number of techniques available which seek to estimate the MSB of such goods. For example, if a CBA is being conducted on a new nuclear power station, one benefit is that less electricity is needed from alternative, fossil-fuel powered-generating stations. Fossil-fuel stations emit sulphur dioxide (SO₂) and nitrous oxides (NOₓ), both contributors to acid rain. So one benefit of the nuclear station is lower acid-rain-causing emissions, and thus (on this measure) cleaner air. But clean air is not something that people buy and sell in markets, as we have already noted. No obvious market price thus exists to value this project impact. Equivalently, one cost of the nuclear power station is the possibility of a leakage, leading to deaths through cancer. But how should the value of a human life be taken into account? Again, we can try to estimate either the marginal benefit of keeping someone alive or the marginal social cost of someone dying. Whilst such calculations might seem repugnant to many, the valuation of life turns out to be crucial for projects as diverse as the