INTRODUCTION

Should Chicago build a new airport, or India a new steel mill? Should higher education expand, or water supplies be improved? How fast should we consume non-renewable resources and what are the costs and benefits of protecting the environment? These are typical of the questions on which cost–benefit analysis has something to say. However, there is no problem, public or personal, to which its broad ideas could not be applied.

The chapters in this book concentrate on those issues that are common to all cost–benefit appraisals. We have cast this introduction in a form that is theoretical and also shows how one might tackle a particular problem. We take an imaginary project and show how the chapters throw light on the analysis of this project. But first a few remarks are needed on the general ideas involved.

The basic notion is very simple. If we have to decide whether to do A or not, the rule is: Do A if the benefits exceed those of the next best alternative course of action, and not otherwise. If we apply this rule to all possible choices, we shall generate the largest possible benefits, given the constraints within which we live. And no one could complain at that.

Going on a step, it seems quite natural to refer to the ‘benefits of the next best alternative to A’ as the ‘costs of A’. For if A is done those alternative benefits are lost. So the rule becomes: do A if its benefits exceed its costs, and not otherwise.

So far so good. The problems arise over the measurement of benefits and costs. This is where many recoil in horror at the idea of measuring everything on one scale. If the objection is on practical grounds that is fair enough; and many economists have swollen up hard before making a particular quantification, or have refused to make one. But if the objection is theoretical it is fair to ask the objector what he means by saying that A is better than B, unless he has some means of comparing the various dimensions along which A and B differ. There are some people who believe that one particular attribute of life, such as the silence of the countryside, is of absolute importance. For them cost–benefit analysis is easy: the value of all other benefits and costs is negligible. More problematical are those people who believe in the absolute importance of two or more items, for they are doomed to intellectual and spiritual frustration. Whenever A is superior to its alternative on one count and inferior on another, they will feel obliged to do both. Choices between such alternatives have to be
made only too often. However, rational choice may be possible even if not every item has a unique price. Often it will be sufficient to know that the prices lie within some finite range; the answer will be unaffected by exact values. The only basic principle is that we should be willing to assign numerical values to costs and benefits, and arrive at decisions by adding them up and accepting those projects whose benefits exceed their costs.

But how are such values to be arrived at? If we assume that only people matter, the analysis naturally involves two steps. First, we must find out how the decision would affect the welfare of each individual concerned. To judge this effect we must ultimately rely on the individual’s own evaluation of his mental state. So the broad principle is that ‘we measure a person’s change in welfare as he or she would value it’. That is, we ask what he or she would be willing to pay to acquire the benefits or to avoid the costs. There is absolutely no need for money to be the numéraire (i.e., the unit of account) in such valuations. It could equally well be bushels of corn but money is convenient.

The problems of inferring people’s values from their responses to hypothetical questions or from their behaviour are clearly acute and present a central problem in cost–benefit analysis.

The second step is to deduce the change in social welfare implied by all the changes in individual welfare. Unless there are no losers, this means somehow valuing each person’s £1. If income were optimally distributed, £1 would be equally valuable regardless of whose it was; that is what ‘optimally distributed’ means. Each person’s £1 has equal weight. And if income is not optimally distributed most economists would argue that it should be redistributed by cash transfers rather than through the choice of projects. But what if we think that cash will not be distributed, even if it should be? Then we may need to value the poor person’s extra £1 more highly than the rich person’s.

However, this raises the kind of question that underlies almost all disputes about cost–benefit analysis, or indeed about moral questions generally: the question of which constraints are to be taken as given. If a government agency knows for certain that cash will not be redistributed to produce a desirable pattern of income, even if it should be, then the agency should allow for distributional factors when evaluating the project. Equally, it should not allow for these factors if it can ensure that redistribution is achieved by some more appropriate method. In practice it may not know whether this can be ensured, or it may decide that the issue is outside its competence. Until this is settled a rational project appraisal is impossible.

Likewise, in the personal sphere it is reasonable to take unalterable features of one’s character into account in deciding what is right. But which features are unalterable? In each case the issue is which constraints are exogenous to the decision maker.

This brings us to the relation between cost–benefit analysis and the rest of public policy. The government’s overall aim is presumptively to ensure that social
welfare is maximized subject to those constraints over which it has no control such as tastes, technology and resource endowments. In any economy this objective requires some government activity owing to the failure of free markets to deal with the problems of externality, economies of scale, imperfect information and inadequate markets for risky outcomes, and also because of the problem of the maldistribution of wealth.

Three main methods of intervention are open: regulation, taxes and subsidies, and public direction of what is to be produced, be it via public enterprise or purchase from private firms. Each of these types of government activity can be subjected to cost–benefit analysis, as the case studies in this volume illustrate. In the case of public production the great strength of cost–benefit analysis is that it permits decentralized decision making. This is needed because, even if the public sector is small, no one office can hope to handle the vast mass of technical information needed to decide on specific projects. Decentralization deals with that problem, just as the price mechanism does, but it raises the obverse problem that the right decisions will only result if the prices used by the decision makers correctly reflect the social values of inputs and outputs at the social optimum: what are usually called their ‘shadow prices’.

In a mixed economy market prices often do not do this. So the main problem in cost–benefit analysis is to arrive at adequate and consistent valuations where market prices fail in some way. If production is to take the form of public enterprise, government will generally lay down some of the prices (like the discount rate) to be used by public-sector enterprises, as well as their decision rules. A similar adjustment is to be made in the price quoted when purchase is from private firms. In a more planned economy the government will lay down more of the prices and might, in principle, by iterative search find a complete set of prices, which, if presented to producers, would lead to their production decisions being consistent with each other and with consumers’ preferences. However, in practice no government has tried this and most rely in part on quantitative targets or quotas, as well as taxes and subsidies, to secure consistency in at any rate some areas of production.

If any of the activities of government agencies are non-optimal, the cost–benefit analysis is faced with a second source of difficulty in finding relevant prices: whether and how to allow for those divergences between market prices and social values that arise from the action or inaction of government itself.

Broadly the valuations to be made in any cost–benefit analysis fall under four main headings:

1. The relative valuation of costs and benefits at the time when they occur.
2. The relative valuation of costs and benefits occurring at various points in time: the problem of time preferences and the opportunity cost of capital.
3. The valuation of risky outcomes.
4. The valuation of costs and benefits accruing to people with different incomes.
**Introduction**

Part I of this book deals with the various issues of principle involved in cost–benefit analysis. Part II shows how to evaluate time savings, safety, the environment and exhaustible resources. Part III contains case studies which illustrate some of the problems to which the techniques of cost–benefit analysis have been applied.

### 1 THE OVERALL APPROACH

Suppose there is a river which at present can only be crossed by ferry. The government considers building a bridge, which, being rather upstream, would take the traveller the same time to complete a crossing. The ferry is a privately owned monopoly and charges £0.20 per crossing, while its total costs per crossing are £0.15. It is used for 5,000 crossings per year. The bridge would cost £30,000 to build but would be open free of charge. It is expected that there will be 25,000 crossings a year with the bridge and that the ferry would go out of business. The government send for the cost–benefit analyst to advise them on whether to go ahead with the bridge.

In any cost–benefit exercise it is usually convenient to proceed in two stages:

(a) Value the costs and benefits in each year of the project;
(b) Obtain an aggregate ‘present value’ of the project by ‘discounting’ costs and benefits in future years to make them commensurate with present costs and benefits, and then adding them up.

At each stage the appraisal differs from commercial project appraisal because (i) costs and benefits to all members of society are included and not only the monetary expenditures and receipts of the responsible agency, and (ii) the social discount rate may differ from the private discount rate. The main work goes into step (a) and we shall concentrate on this for the present.

**Consumers’ surplus and willingness to pay**

We need to avoid logical errors in deciding which items are to be included as costs and benefits and to value those that are included correctly. The guiding principle is that we list all parties affected by the project and then value the effect of the project on their welfare as it would be valued in money terms by them. In this case there are four parties: taxpayers, ferry owners, existing travellers and new travellers (who previously did not cross but would do so at the lower price).

1. The taxpayers lose £30,000, assuming the bridge is financed by extra taxes.
2. The ferry owners lose their excess profits of £250 [i.e., 0.05 × 5,000] in each future year for ever (area A on figure 1).
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The existing travellers gain £1,000 [0.20 × 5,000] in each future year for ever, due to the fall in price (areas A + B).

The new travellers: to evaluate their gains is more difficult. We know that the new journey which is most highly valued was nearly made by ferry, and is therefore worth very nearly £0.20; while the journey which is least highly valued is valued only marginally more than its price of £0.00. For the intermediate journeys we have to make some arbitrary assumption and will assume that the value per journey falls at a constant rate from £0.20 to zero. In other words we are assuming that the demand curve is a straight line. So the average gain to new travellers is £0.10 per crossing and the total gain £2,000 [0.10 × 20,000] per year for ever. This figure corresponds to the gain in consumers’ surplus on the part of the new travellers, since it represents the sum of the differences between the maximum they would be willing to pay for their journeys and the amount they actually pay, which in this case is zero. Geometrically it is represented by area C, the area under the demand curve and above a horizontal line at the final price (which here is zero). In this special case where the demand curve is a straight line the value of generated sales will always equal \( \frac{1}{2} (p_0 - p_1)(q_1 - q_0) \), i.e., half the price fall times the quantity increase. This is a formula which is used over and over again in cost–benefit analysis, especially for small changes in prices so the linearity assumption is a reasonable approximation to any actual demand curve.
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Criteria for a welfare gain

We can now tabulate (table 1) the overall picture of net benefits (benefits minus costs), discounting all the future permanent flows of net benefits by an arbitrary 10 per cent per annum to obtain their present values. 4

Can these now be added up? It depends entirely on our approach to the problem of income distribution. If we wish to use the very restrictive Pareto criterion of a welfare improvement, we shall support a project only if some people gain and nobody loses. But if some people gain while others lose, the Pareto criterion provides no guidance. If we follow it we must add up the net receipts of all the parties concerned. Then we only support the project if the sum is positive and compensation is paid to the losers. However, there is in practice almost no case where it is feasible to compensate everybody and if the Pareto rule were applied no projects would ever get done. Therefore many cost–benefit analysts have fallen back on the Hicks–Kaldor criterion, which says that a project can be supported provided the gainers could, in principle, compensate the losers even if they do not. 5

In this case net receipts can always be added. However, there is no ethical justification for the Hicks–Kaldor criterion; where compensation will not be paid there seems no alternative to interpersonal comparisons of the value of each person’s gains and losses.

This brings us to a second case for unweighted adding up—where interpersonal comparisons are made but it is judged that in the prevailing income distribution £1 is equally valuable to all the parties concerned. This may in some cases be quite a reasonable procedure. If not, there are only two alternatives: to use some system of distributional weights or simply to show the net benefits to each party and let the policy maker apply his own evaluation. If distributional weights are used they need not be unique: it may be that the weights can take a wide range of alternative values and yet provide an unambiguous verdict on a project. Viewed from this angle the Pareto criterion is just an extreme case where the distributional weights are allowed to vary infinitely.

For the time being we shall assume, as many cost–benefit analysts do, that unweighted adding up is permissible. We now learn an important lesson: that the area A disappears from the calculation. The reason is of course that it was a transfer payment (monopoly rent) rather than a payment for real goods and services; and if everybody’s £1 is equally valuable transfers cannot change social welfare. Consumers used to pay this rent and now they do not, but there is no saving in resource cost as a result of the non-payment after the bridge is built. The economic cost–saving from the demise of the ferry comes from the liberation of resources worth B for production elsewhere in the economy. The only other economic change is the value of the additional consumption (C) – the real value of the first 5,000 journeys is neither more nor less than it was before. Thus, if one had wanted to take a short cut to estimating future net benefits (granted all

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Table 1

<table>
<thead>
<tr>
<th>Future net benefits per year for ever</th>
<th>Present value at 10% discount rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>£</td>
<td>Area in figure 1</td>
</tr>
<tr>
<td>Ferryowners</td>
<td>− 250</td>
</tr>
<tr>
<td>Existing consumers</td>
<td>+ 1000</td>
</tr>
<tr>
<td>New consumers</td>
<td>+ 2000</td>
</tr>
<tr>
<td>Taxpayers</td>
<td>−</td>
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<tr>
<td>Society</td>
<td>+ 20,000</td>
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...pounds equally valuable) one could have straightforwardly identified only the changes of real economic significance, i.e., the cost–saving on the ferry (B) and the consumers’ surplus on the generated traffic (C).

Suppose the shares of the ferry company, which were previously worth £2,500, fall to zero. Should this also be included as a cost? Clearly not, since when we calculated the capitalized value of the ferry’s profits we were in fact approximating the change in welfare of the shareholders, which is measured by changes in the value of their equity. We can use one measure or the other but not both, and it may generally be easier to measure the yield and to ignore changes in asset values.

So let us bravely add up the table. The present value turns out to be negative (− £2,500) and the project should be turned down. At this point someone might suggest that the project could be made ‘viable’ by charging a toll on the bridge. This is nonsense – all that it does is to reduce the number of journeys and hence reduce the gain in the real value of additional consumption, without any corresponding reduction in cost. The reader might like to confirm his understanding of the argument so far by recalculating the table for the case where the government levies a toll of £0.05 per crossing. The moral of this is that the prices charged for the output of a project may profoundly affect its economic desirability. The correct price is the marginal social cost per unit of output, which is zero in the case of journeys across an uncongested bridge.

2 MEASURING COSTS AND BENEFITS WHEN THEY OCCUR

The concept of a shadow price

The concept of the shadow price associated with a constraint is of fundamental importance.

Consider first a simple example: you are to find two numbers, each greater than
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or equal to zero, which maximizes the sum of their squares. The objective is clear enough, but, as stated, this problem is ill defined. There is no solution because one can make the sum of the squares as big as one wishes by simply increasing the numbers themselves without bound. The problem can be made well defined by adding a constraint: for example, the sum of the first number and twice the second number must be less than or equal to ten. The solution is easy to see. One wants to make both numbers as large as possible, but for each unit subtracted from the second number, the first number can be increased by two units whilst remaining within the constraint, with a net gain to the sum of the squares. Therefore the solution is that the first number should be 10, the second number should be zero and the sum of the squares will be 100. So 100 is the value of the objective at the solution of the problem.

Now, suppose the constraint is relaxed by one unit. The first number plus twice the second number must be less than or equal to 11. Clearly, the solution will be to put the first number at 11 and leave the second number at zero. The objective will increase to 121 at the new solution.

In this case the shadow price is 121 − 100 = 21.

The shadow price therefore measures how much better we could do, measured by the stated objective, if the constraint were relaxed by one unit: it is the penalty of having to observe the constraint. Put another way, it is the maximum we should be willing to pay to secure a relaxation of the constraint.

In practical work we have to face a series of constraints. If there were no constraints then there would be few interesting problems! Each constraint will have its own shadow price. It will be apparent how very useful that information is. It tells us which are the most important (or damaging) constraints and therefore where it would be most productive to direct effort towards relaxing constraints.

Consider now a simplified economic example which illustrates the way in which these concepts arise in planning.

A planner in a developing country has to set the outputs of two commodities: manufactured goods and food. He values a unit of manufactured goods at US $4 and a unit of food at US $7. To produce a unit of manufactured goods requires two units of trained labour and one unit of capital equipment. To produce a unit of food requires three units of trained labour and one unit of capital equipment. Twelve units of labour and five units of capital are available. What output levels should be set in order to maximize the value of the plan?

This is a simple Linear Programming problem. It is linear because the objective and the technical constraints all have coefficients which are independent of the volumes produced: doubling all outputs doubles the value of the plan and also doubles the input requirements.
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Denote the quantity of manufactures by \( M \) and the quantity of food by \( F \). Then the objective is to

Maximize \( 4M + 7F \)

The constraints say that the consumption of each of the two factors cannot exceed the total amounts available

- Capital constraint: \( M + F \leq 5 \)
- Labour constraint: \( 2M + 3F \leq 12 \)

and \( M \geq 0 \) and \( F \geq 0 \)

This problem can be solved using the diagram in figure 2. The diagram shows the line representing points such that

\[
M + F = 5 \quad \text{or equivalently} \quad F = 5 - M
\]

The capital constraint dictates that the planner must choose a point on that line or below it. The line representing the labour constraint is similarly shown. Since the constraints must be observed simultaneously the feasible region is the area bounded by all the constraints.

The diagram also shows the lines representing

\[
4M + 7F = 42 \quad \text{and} \quad 4M + 7F = 49
\]

These are sometimes referred to as ‘iso-revenue lines’. If they were feasible then all points on these lines would yield a value to the plan of 42 and 49 respectively. The problem is solved by finding a point on a line parallel to these two lines, as far away to the north east of the origin as possible whilst being within the feasible region.

This must occur at one of the three vertices and these are the only points we need to consider. \( M = 5 \) and \( F = 0 \) yields a value of \$20; \( M = 3 \) and \( F = 2 \) yields a value of \$26; \( M = 0 \) and \( F = 4 \) yields a value of \$28. As is obvious from the relative slopes of the lines in the diagrams, this last point is the solution to the problem: produce no units of manufactures, four units of food, giving a value of \$28.

Now, what of the shadow prices of the constraints? Note that the solution point lies inside the capital constraint. The capital constraint turns out to be ‘non-binding’, that is, irrelevant! Therefore the value to the plan of an extra unit of capital is zero – this is its shadow price. This is a general result. *Any resource which is in excess supply at an optimum allocation of resources will have a social value of zero.* In the context of our example note that this shadow price may be quite different from the international market price of capital (denominated in US $). So we see that there may be a distinction between the market price of a resource and its ‘true’ value measured relative to the objective. Note also that the shadow price is a marginal concept – we say that the value of an extra unit of capital is zero, *on the margin.* This is not to deny the value of intra-marginal units.
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Figure 2

The technology dictates that we cannot produce anything unless we have some capital. It is just that too much is available, so it is not worth paying anything to get some more. Indeed, it would be sensible to sell the one unit of surplus capital on the international market for whatever positive price it would fetch, providing that it were feasible to do so at a sufficiently low selling and transport cost.

Finally, note that the shadow price is only meaningful in relation to the particular objective. For instance, if the relative valuations of the two products changed from the present ratio of 4:7 then the slope of the iso-revenue line would change. It might become sufficiently steep for the optimum point to shift to $M = 3$ and $F = 2$, or even to $M = 5$ and $F = 0$. In either case the capital constraint binds and the shadow price is definitely positive. So shadow prices depend upon the nature of the technical constraints, the quantities of resources available and the particular objectives.

What is the shadow price of skilled labour? If the quantity of skilled labour that is available increases from 12 to 13 then the intercept of the labour constraint on the vertical axis of figure 2 will increase from $12/3 = 4$ to $13/3$. Therefore the output of food can increase by $1/3$. The value of this incremental output is $57/3$ and so that is the shadow price of the skilled labour constraint.