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Cost-Benefit Analysis and the Environment
Recent Developments

Chapter 18

Cost-benefit Analysis and Other Decision-making Procedures

CBA is often contrasted with other decision-making aids such as cost-effectiveness analysis (CEA) and multi-criteria analysis (MCA). But the assumption that these aids are substitutable is not valid and great care is needed in defining the question to be asked and in determining which technique is most relevant to helping with the decision. This chapter provides an overview of various techniques. In addition to CEA and MCA it looks at risk assessment, environmental impact assessment, strategic environmental assessment, risk-benefit, risk-risk, and health-health analysis. Each of these approaches reveals insights into features of good decision-making, but CBA tends to have a more comprehensive approach.

18.1. A gallery of procedures

This volume is concerned with recent developments in cost-benefit analysis (CBA). In Chapter 19 we look at some of the reasons that some decision-makers are distrustful of CBA. This distrust is one reason (and it is important to understand it may not be the dominant reason) that some people look for alternatives to CBA. Other reasons for looking for alternatives include:

- A desire to have decision-aiding procedures that are not so demanding in informational terms.
- A desire to have procedures that can be widely understood and which are not reliant on expert.
- A desire to have "rapid" procedures given that political decisions cannot always wait for the results of a CBA.

Over the years, various techniques of appraisal have emerged in the environmental field. We list these as:

- Environmental Impact Assessment (EIA) or Environmental Assessment (EA).
- Strategic Environmental Assessment (SEA).
- Life Cycle Analysis (LCA).
- Risk Assessment (RA).
- Comparative Risk assessment (CRA).
- Risk-Benefit Analysis (RBA).
- Risk-Risk Analysis (RRA).
- Health-Health Analysis (HHA)
- Cost-Effectiveness Analysis (CEA).
- Multi-Criteria Analysis (MCA).

In the remainder of this chapter we look very briefly at each of these procedures. Space forbids a detailed assessment which can be found, for example, in EFTEC (1998). The idea is simply to "locate" CBA in this range of procedures. It is important to understand that the procedures vary significantly in their comprehensiveness and that it cannot be assumed that each is a substitute for the other.

18.2. Environmental Impact Assessment (EIA)

EIA is a systematic procedure for collecting information about the environmental impacts of a project or policy, and for measuring those impacts. It will immediately be obvious that EIA is not a comprehensive evaluation procedure. It ignores non-environmental impacts and it ignores costs. Less obviously, it may not account in a detailed way for the ways in which impacts vary with time. Nonetheless, EIA is an essential part of any evaluative procedure. If we use the benchmark of CBA, then EIA is an essential input to

CBA. CBA covers the other impacts of projects and policies, and it goes one stage further than EIA by attempting to put money values on the environmental impacts. Most EIAs do make an effort, however, to assess the significance of environmental impacts. Some may go further and give the impacts a score (the extent of the impact) and a weight (its importance). Weights might be derived from public surveys but more usually are determined by the analyst in question. Unlike CBA, EIA has no formal decision rule attached to it (*e.g.* benefits must exceed costs), but analysts would typically argue that its purpose is to look at alternative means of minimising the environmental impacts without altering the benefits of the project or policy.

In general, then:

- EIA is an essential input to any decision-making procedure.
- Impacts may be scored and weighted, or they become inputs into a CBA.
- EIA would generally look for ways to minimise environmental impacts without changing (significantly anyway) the benefits or costs of the project or policy.

18.3. Strategic Environmental Assessment (SEA)

SEA is similar to EIA but tends to operate at a "higher" level of decision-making. Instead or single projects or policies, SEA would consider entire programmes of investments or policies. The goal is to look for the synergies between individual policies and projects and to evaluate alternatives in a more comprehensive manner. An SEA is more likely than an EIA to consider issues like: is the policy or project needed at all; and, if it is, what are the alternative options available? In this sense, SEA is seen to be more pro-active than EIA which tends to be reactive. Proactive here means that more opportunity exists for programmes to be better designed (from an environmental perspective) rather than accepting that a specific option is chosen and the task is to minimise environmental impacts from that option. Again, while it encompasses more issues of concern, SEA remains non-comprehensive as a decision-guiding procedure. Issues of time, cost and non-environmental costs and benefits do not figure prominently. Relative to the benchmark of CBA, SEA goes some way to considering the kinds of issues that would be relevant in a CBA – *e.g.* the "with/without" principle and consideration of alternatives.

18.4. Life Cycle Analysis (LCA)

LCA is similar to EIA in that it identifies the environmental impacts of a policy or project and tries to measure them. It may or may not measure the impacts in the same units, any more than EIA tries to do this. Typically, when attempts are made to adopt the same units they do not include money, although some LCAs have done this. The chief difference between EIA and LCA is that LCA looks not just at the impacts directly arising from a project or policy, but at the whole "life cycle" of impacts. For example, suppose the policy problem is one of choosing between the "best" forms of packaging for a product, say fruit juice. The alternatives might be cartons, bottles and cans. LCA would look at the environmental impacts of each option but going right back to the materials needed for manufacturing of the container (*e.g.* timber and plastics, glass, metals) and the ways in which they will be disposed of once consumers have consumed the juice. Included in the analysis would be the environmental impacts of primary resource extraction and the impacts from landfill, incineration etc. LCAs proceed by establishing an inventory of impacts and then the impacts are subjected to an assessment to establish the extent of

impact and the weight to be attached to it. Relative to the benchmark of CBA, LCA is essentially the physical counterpart to the kind of environmental impact analysis that is required by a CBA. In itself LCA offers no obvious decision rule for policies or projects. Though widely advocated as a comprehensive decision-guidance, LCA does not (usually) consider non-environmental costs and benefits. Hence it is not a comprehensive decision-guide. However, if the choice context is one where one of several options has to be chosen (we must have cans or bottles or cartons, but not none of these), then, provided other things are equal, LCA operates like a cost-effectiveness criterion (see below).

18.5. Risk Assessment (RA)

Risk assessment involves assessing either the health or environmental risks (or both) attached to a product, process, policy or project. Risk assessments may be expressed in various ways:

- As the probability of some defined health or ecosystem effect occurring, *e.g.* a 1 in 100 000 chance of mortality from continued exposure to some chemical.
- As a number of incidences across a defined population, *e.g.* 10 000 premature deaths per annum out of some population.
- As a defined incidence per unit of exposure, *e.g.* X% increase in premature mortality per unit air pollution.
- As a "no effect" level of exposure, *e.g.* below one microgram per cubic metre there may be no health effect.

Risk assessments may not translate into decision rules very easily. One way they may do this is if the actual or estimated risk level is compared to an "acceptable" level which in turn may be the result of some expert judgement or the result of a public survey. A common threshold is to look at unavoidable "everyday" risks and to judge whether people "live with" such a risk. This may make it acceptable. Other procedures tend to be more common and may define the acceptable level as a no-risk level, or even a non-risk level with a sizeable margin or error. Procedures establishing "no effect" levels, *e.g.* of chemicals, define the origin of what the economist would call a "damage function" but cannot inform decision-making unless the goal is in fact to secure that level of risk. Put another way, "no effect" points contain no information about the "damage function".

18.6. Comparative Risk Assessment (CRA)

CRA involves analysing risks but for several alternative projects or policies. The issue is then which option should be chosen and the answer offered by CRA is that the option with the lowest risk should be chosen. Efforts are made to "normalise" the analysis so that like is compared to like. For example, one might want to choose between nuclear energy and coal-fired electricity. One approach would be to normalise the risks of one kilowatt hour of electricity and compute, say, deaths per kWh. The option with the lowest "death rate" would then be chosen. However, in this case, the normalisation process does not extend to cost, so that CRA may want to add a further dimension, the money cost of generating one kWh. Once this is done, the focus tends to shift to cost-effectiveness analysis – see below. A further problem concerns the nature of risk. "One fatality" appears to be a homogenous unit, but if people are not indifferent to the manner of death or whether it is voluntarily or involuntarily borne, then, in effect, the normalisation has

failed. Once again, one can see that CRA is not a comprehensive decision-guide since the way it treats costs (if at all) may not be all-embracing. Nor would CRA deal with benefits.

18.7. Risk-Benefit Analysis (RBA)

RBA tends to take two forms, each of which is reducible to another form of decision rule. In other words, RBA is not a separate procedure. The first meaning relates to benefits, costs and risks, where risks are treated as costs and valued in money terms. In that case the formula for accepting a project or policy would be:

[Benefits – Costs – Risks] > 0

This is no different to a CBA rule.

In the second case the RBA rule reduces to CRA. Benefits might be standardised, *e.g.* to "passenger kilometres" and the risk element might be fatalities. "Fatalities per passenger kilometre" might then be the thing that should be minimised. As with CRA, cost may or may not enter the picture. If it does, then RBA tends to result in CBA or cost-effectiveness analysis.

18.8. Risk-Risk Analysis (RRA)

RRA tends to focus on health risks and asks what would happen to health risks if some policy was adopted and what would happen if it was not adopted. The "with/without" focus is familiar in CBA. The novelty tends to be the fact that not undertaking a policy may itself impose costs in terms of lives or morbidity. For example, a policy of banning or lowering consumption of saccharin might have a justification in reducing health risks from its consumption. But the with-policy option may result in consumers switching to sugar in place of the banned saccharin, thus increasing morbidity by that route. The advantage of RRA is that it forces decision-makers to look at the behavioural responses to regulations. Once again, however, all other components in a CBA equation are ignored, so the procedure is not comprehensive.

18.9. Health-Health Analysis (HHA)

HHA is similar to RRA but instead of comparing the risks with and without the behavioural reaction to a policy, it compares the change in risks from a policy with the risks associated with the *expenditure* on the policy. As such, it offers a subtle focus on policy that is easily overlooked. Since policies costs money, the money has to come from somewhere and, ultimately, the source is the taxpayer. But if taxpayers pay part of their taxes for life-saving policies, their incomes are reduced. Some of that reduced income would have been spent on life-saving or health-enhancing activities. Hence the taxation actually increases life risks. HHA compares the anticipated saving in lives from a policy with the lives lost because of the cost of the policy. In principle, policies costing more lives than they save are not desirable. HHA proceeds by estimating the costs of a life-saving policy and the number of lives saved. It then allocates the policy costs to households. Life risks are related to household incomes through regression analysis, so that it is possible to estimate lives lost due to income reductions. Once again, the procedure is not comprehensive: policies could fail an HHA test but pass a CBA test, and *vice versa*.

18.10. Cost-Effectiveness Analysis (CEA)

The easiest way to think about CEA is to assume that there is a single indicator of effectiveness, *E*, and this is to be compared to a cost of *C*. Suppose there is now just a single project or policy to be appraised. CEA would require that *E* be compared to *C*. The usual procedure is to produce a cost-effectiveness ratio (CER):

$$CER = \frac{E}{C} \qquad [18.1]$$

Notice that *E* is in some environmental unit and *C* is in money units. The fact that they are in different units has an important implication which is, unfortunately, widely disregarded in the literature. A moment's inspection of [18.1] shows that the ratio is perfectly meaningful – *e.g.* it might be read as US Dollars per hectare of land conserved. But the ratio says nothing at all as to whether the conservation policy in question is worth undertaking. In other words, CEA cannot help with the issue of whether or not to undertake any conservation. It should be immediately obvious that this question cannot be answered unless *E* and *C* are in the same units.

CEA can only offer guidance on which of several alternative policies (or projects) to select, given that one has to select one. By extension, CEA can *rank* any set of policies, all of which could be undertaken, but given that at least some of them must be undertaken. To see the limitation of CEA, equation [18.1] should be sufficient to show that an entire list of policies, ranked by their cost-effectiveness, could be adopted without any assurance that any one of them is actually worth doing. The notion of "worth doing" only has meaning if one can compare costs and benefits in a manner that enables one to say costs are greater (smaller) than benefits. In turn, that requires that costs and benefits have a common *numeraire* which, in principle, could be anything. In CBA the numeraire is money.

If we suppose that there are i = 1…n potential policies, with corresponding costs C_i and effectiveness E_i then CEA requires that we rank the policies according to

$$CER_i = \frac{E_i}{C_i} \qquad [18.2]$$

This ranking can be used to select as many projects as fit the available budget $\bar{C}$, *i.e.*:

$$Rank \quad by \quad CER_i \quad s.t \quad \sum_i C_i = \bar{C} \qquad [18.3]$$

A further issue with CEA is the process of selecting the effectiveness measure. In CBA the principle is that benefits are measured by individuals' preferences as revealed by their willingness to pay for them. The underlying value judgement in CBA is "consumer" or "citizen sovereignty". This amounts to saying that individuals are the best judges of their own well-being. Technically, the same value judgement could be used in CEA, *i.e.* the measure of effectiveness could be based on some attitude survey of a random sample of individuals. In practice, CEA tends to proceed with indicators of effectiveness chosen by experts. Rationales for using expert choices are *a)* that experts are better informed than individuals, especially on issues such as habitat conservation, landscape, etc., and *b)* that securing indicators from experts is quicker and cheaper than eliciting individuals' attitudes.

18.11. Multi-Criteria Analysis (MCA)

MCA is similar in many respects to CEA but involves multiple indicators of effectiveness. Technically, CEA also works with multiple indicators but increasingly resembles simple models of MCA since different effectiveness indicators, measured in different units, have to be normalised by converting them to scores and then aggregated via a weighting procedure. Like CEA, policy or scheme cost in an MCA is always (or should always be) one of the indicators chosen. The steps in an MCA are as follows:

- The goals or objectives of the policy or investment are stated.
- These objectives are not pre-ordained, nor are they singular (as they are in CBA which adopts increases in economic efficiency as the primary objective) and are selected by "decision-makers".
- Generally, decision-makers will be civil servants whose choices can be argued to reflect political concerns.
- MCA then tends to work with experts' preferences. Public preferences may or may not be involved.
- "Criteria" or, sometimes, "attributes" which help achieve the objectives are then selected. Sometimes, objectives and criteria tend to be fused, making the distinction difficult to observe. However, criteria will generally be those features of a good that achieve the objective.
- Such criteria may or may not be measured in monetary terms, but MCA differs from CBA in that not all criteria will be monetised.
- Each option (alternative means of securing the objective) is then given a score and a weight. Pursuing the above example, a policy might score 6 out of 10 for one effect, 2 out of 10 for another effect, and 7 out of 10 for yet another. In turn, experts may regard the first effect as being twice as important as the second but only half as important as the third. The weights would then be 2, 1 and 4 respectively.
- In the simplest of MCAs, the final outcome is a weighted average of the scores, with the option providing the highest weighted score being the one that is "best". More sophisticated techniques might be used for more complex decisions.
- To overcome issues relating to the need for criteria to be independent of each other (*i.e.* experts' preferences based on one criterion should be independent of their preferences for that option based on another criterion), more sophisticated techniques might be used, notably "multi-attribute utility theory" (MAUT). MAUT tends to be over-sophisticated for most practical decision-making.

The formula for the final score for a project or policy using the most simple form of MCA is:

$$S_i = \sum_j m_j . S_j \qquad [18.4]$$

where *i* is the ith option, *j* is the jth criterion, *m* is the weight, and *S* is the score.

MCA offers a broader interpretation of CEA since it openly countenances the existence of multiple objectives. Issues relating to MCA and which are the subject of debate are as follows:

- As with CEA, when effectiveness is compared to cost in ratio form MCA cannot say anything about whether or not it is worth adopting any project or policy at all (but

see Annex 18.A1). Its domain is restricted to choices between alternatives in a portfolio of options some of which must be undertaken. Both MCA and CEA are therefore "efficient" in the sense of seeking to secure maximum effectiveness for a given unit of cost, but may be "inefficient" in the sense of economic efficiency. Annex 18.A1 illustrates the problem further and shows that MCA produces the same result as a CBA only when *a)* the scores on the attributes are the same, *b)* the weights in the MCA correspond to shadow prices in the CBA, and *c)*, which follows from *b)*, the weight on cost is unity.

- MCA generally proceeds by adopting scores and weights chosen by experts. To this extent MCA is not as "accountable" as CBA where the money units reflect individuals' preferences rather than expert preferences. Put another way, the raw material of CBA is a set of individuals' votes, albeit votes weighted by income, whereas experts are unelected and may not be accountable to individual voters.
- MCA tends to be more "transparent" than CBA since objectives and criteria are usually clearly stated, rather than assumed. Because of its adoption of multiple objectives, however, MCA tends to be less transparent than CEA with a single objective.
- It is unclear how far MCA deals with issues of time discounting and changing relative valuations.
- Distributional implications are usually chosen as one of the objectives in an MCA and hence distributional impacts should be clearly accommodated in an MCA.

18.12. Summary and guidance for decision-makers

A significant array of decision-guiding procedures are available. This chapter shows that they vary in the degree of comprehensiveness where this is defined as the extent to which all costs and benefits are incorporated. In general, only MCA is as comprehensive as CBA and may be more comprehensive once goals beyond efficiency and distributional incidence are considered. All the remaining procedures either deliberately narrow the focus on benefits, *e.g.* to health or environment, or ignore cost. Procedures also vary in the way they treat time. EIA and LCA are essential inputs into a CBA, although the way these impacts are dealt with in "physical terms" may not be the same in a CBA. Risk assessments, of which HHA and RRA are also variants, tend to be focused on human health only. The essential message is that the procedures are not substitutes for each other.

ANNEX 18.A1

Multi-criteria Analysis and the "Do Nothing" Option

For the "do nothing" option to be included correctly in an evaluation it is necessary for costs and benefits to be measured in the same units. When MCA adopts the form of cost-effectiveness, with the multiple criteria of effectiveness being compared *in ratio form* to cost, then MCA cannot evaluate the "do nothing" option. This is because the units of effectiveness are weighted scores whilst the measure of cost is money. Numerator and denominator are not in the same units. The "escape" from this problem is for costs to be given a score (usually the absolute level of money cost) and a weight. If we think of the weighted scores as "utils" (or any other unit of account) then MCA can handle the "do nothing" option. If the ratio of benefits to costs is less than unity, the "do something" option is rejected. Similarly, if utils of benefits minus utils of costs is negative, the do something option would also be rejected.

In this way, MCA can be modified to handle the do nothing option. However, it can easily be shown that MCA will give the same result as CBA under very limited conditions.

Table 18.A1.1 shows the procedure adopted in a simple MCA. Let the score for E1 be 10, E2 = 5 and E3 = 30. The scores are multiplied by chosen weights, assumed to be W1 = 4, W2 = 6, W3 = 10. Cost is weighted at unity. The sum of the weighted scores shows that "do something" is a "correct" choice. If the weights W1 … W3 are prices, then Table 18.A1.1 would appear as a CBA, *i.e.* MCA and CBA would produce formally identical results.

Table 18.A1.1. **Weighted input data for an MCA: cost weighted at unity**

	Do something: raw scores	Do something: weighted scores
Cost	-50	-50
E1	+10	+40
E2	+5	+30
E3	+30	+300
Sum of (weighted) scores	-5	+320

Table 18.A1.1 shows that the selection of weights is important. An "unweighted" approach (which means raw scores are weighted at unity) would reject the policy but the weighted approach would accept it. As long as the weights in Table 18.A1.1 correspond to the prices in a CBA, however, then CBA and MCA would generate the same result.

Finally, if we assume shadow prices and MCA weights are the same, but that the weight applied to cost in the MCA is, say, 8, then weighted cost would appear as –400 in Table 18.A1.1 and weighted MCA would reject the do something option.

We can summarise the conditions for CBA and MCA to generate the same result:

a) Attribute scores must be the same.

b) MCA weights must correspond to shadow prices and, in particular.

c) Costs must be weighted at unity.

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