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COST BENEFIT ANALYSIS AND ENVIRONMENT

K.S. KAVI KUMAR

DISSEMINATION PAPER - 15

Centre of Excellence in Environmental Economics
(Sponsored by Ministry of Environment and Forests, Government of India)
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1.0 Introduction

A theorem in welfare economics states that, under certain conditions, a private enterprise form of economic organization based on competitive markets is superior to alternative organizational forms. This conjecture by Adam Smith's in 1776 has been proved rigorously by Arrow and Debreu in 1952. When markets work well, individual self interest leads to efficient allocation of resources Government interference in such cases is unjustified and constitutes policy failure. However, markets fail due to variety of reasons including, (a) existence of increasing returns to scale leading to monopoly organizational structure; (b) presence of externalities in production/consumption leading to divergence between private cost (benefit) and social cost (benefit) resulting in difference between private and social optimum; (c) presence of public goods/bads leading to under-provision of public goods and over-provision of public bads; and (d) uncertainty that could make inter-generational transactions difficult. Market failure provides a necessary reason for the government intervention. However, the sufficient rationale for the intervention still needs to be established. The sufficient condition is to determine superior efficiency of the particular government intervention relative to the alternatives, including the status-quo. Cost Benefit Analysis (CBA) of the proposed intervention – which could be in the form of policies, programs, or projects – is a method for demonstrating the superior efficiency of the proposed intervention. Application of CBA in the field of environment has attracted wide-spread attention in recent times due to variety of conceptual and empirical complexities that environmental issues pose. Further, as argued by Atkinson and Mourato (2008) the practice of carrying out CBA has undergone significant transformation over the past two decades, especially in the application related to environmental issues. The key stages of CBA are described in Box 1.

Box 1: Key Stages of CBA

While ***Defining the Project or Policy*** as well as identifying the choice that will be analyzed, the analyst must recognize whose welfare is being considered and the time period in question.

Identifying Physical Impacts of the Policy or Project**:** Identify (in appropriate units) the implications of the outcomes – e.g., amount of electricity generated.

Valuing Impacts**:** Value the impact of a specific action or inaction in terms of its marginal social cost or marginal social benefit. The emphasis is to measure the true economic value of the identified physical impacts.

Discounting of Cost and Benefit Flows**:** A very important concept to realize with CBA is that a benefit is considered more valuable the sooner it is received. In the same way, a cost is considered less detrimental the further way in time it is incurred. For this reason all costs and benefits must be discounted to reflect present values. It would be inappropriate to compare receiving one million rupees today and receiving one million rupees in 75 years as being equal. A discount rate is used to translate future values into present values.

Applying the Net Present Value Test**:** Net Present Value (NPV) equals the sum of the benefits in present value minus the sum of the costs in present value. The project should be accepted if the NPV>0. In other words, if the discounted benefits are greater than the discounted costs, the project should be accepted.

Applying Sensitivity Analysis**:** Analysis of this kind refers to "recalculating NPV when the values of certain key parameters are changed". Since there is uncertainty in CBA it is important to know for which parameter the NPV is most sensitive. An example would be if a firm installs 3 filters to reduce water pollution and the pollution is reduced by 30%. Sensitivity analysis would look at the affects of a change in the number of filters. If 4 filters reduce the water pollution by 70%, then it can be inferred that the percentage reduction of water pollution is very sensitive to the number of filters. Other parameters that are often considered in the sensitivity analysis include discount rate and project life-span.

(Source: Hanley *et al.*, 2001)

Perhaps one of the simplest ways to understand the technique of CBA and the specific problems that its application to environmental issues poses could be through an example. Consider for example that a dam is being built for the purpose of electricity generation. Let it take two years to build the dam and that the dam has 18 years of operating life. Assume that the total cost of construction is Rs. 1.1 million, equally spread over the two years, and let the operating costs be Rs. 50,000 for each year over the operating life of the dam. Consider that after the dam is constructed, 5,000,000 kwh of electricity is generated each year at a cost of Rs. 0.05 per kwh. Assume that the electricity so generated provides savings of Rs. 0.02 per kwh compared to the next best method of electricity generation. Besides electricity generation consider that the dam construction would provide recreational benefits to visitors. It has been estimated that 50,000 person days of recreational benefits are possible at a value of Re. 1 per recreation person day. For simplicity let us assume that there is no inflation and that costs and benefits are known with certainty. The following table summarizes the various costs and benefits of the project.

Table 1. Costs and Benefits Associated with a Project - Illustration

Year	Costs		Benefits		Total Benefits	Total Costs	Net Benefits
	Construction	Operating	Recreation	Electricity			
1	550	0	0	0	0	550	-550
2	550	0	0	0	0	550	-550
3	0	50	50	100	150	50	+100
4	0	50	50	100	150	50	+100
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
19	0	50	50	100	150	50	+100
20	0	50	50	100	150	50	+100

The costs and benefits in the above table occur at different time points and hence are not comparable. Using discount rate the costs and benefits can be expressed in present-day rupee value. If the discount rate is 10 percent per year, then the present value of net benefits would be about Rs. -509,335 and at 5 percent discount rate they are Rs. 39,485. That is, at a discount rate of 10 percent the dam should not be built as the costs exceed benefits, whereas at 5 percent discount rate the project appears like a good investment as the benefits exceed the costs. In fact, it can be seen that the internal rate of return (i.e., the interest rate at which the present value of net benefits are exactly equal to zero) is around 5.4 percent per year.

While carrying out CBA, the analyst must add things which are not directly comparable. The aggregation problem comes in different forms in CBA and these include:

- Aggregation over goods – how to compare costs which are in one form (e.g., concrete used for the dam) with benefits which are in another form (e.g., electricity generated from the project)? Shadow prices that reflect the true value of goods are used for this purpose.
- Aggregation over time – how to compare costs incurred now with benefits that are expected in future? Discount rate is used to convert all future values into present day values.
- Aggregation over people – how to compare costs and benefits accruing to different people? Is a Rs. 100 cost to a wealthy person to be considered on par with a similar cost to a poor person? Equity weights are sometimes used to address these distributional issues, but the standard CBA stays away from the distributional considerations.
- Aggregation over states of the world – how to deal with uncertainty and risk?

Looking from an environmental perspective a few issues need additional attention in the above example. While the recreational demand and willingness to pay for availing the recreational benefit are assumed to be known they are not easy to estimate as no market exists for the same. The dam construction could have inundated some forest area the loss of which should be accounted for through appropriate valuation of the lost forest benefits including biodiversity loss. Again, it is not easy to estimate these values due to non-existence of concerned markets. Though the life time of the dam in this specific example is taken as 20 years, typically policies relating to environmental issues span a long time horizon. In such cases use of higher discount rates (like the ones used in the above example) imply that the benefits of intervention mean smaller in the present day rupees as they accrue much later in time. It is often argued that the decision relating to climate change issues for example must use a significantly small discount rate (say, 1 percent per year or even smaller) as the benefits in the form of reduced climate change impacts resulting from the policy intervention of reducing greenhouse gases would be realized 50-60 years later. Further, in the above example the costs and benefits could be borne by different people, and hence it is important to address the distributional issues. The standard CBA stays away from the discussion on distributional issues as it is based on the notion of 'potential' compensation (to the losers from the beneficiaries) and mainly focuses on efficiency aspect. However, in case of application of CBA to environmental issues (such as climate change) it is often difficult to separate efficiency from equity issues. Hence it becomes imperative to address distributional issues explicitly in such situations. Further, since most environmental impacts are uncertain the application of CBA to environmental projects must explicitly address risk and uncertainty.

2.0 Environmental Valuation

The notion of total economic value (TEV) provides an all-encompassing measure of the *economic value* of any environmental asset. It decomposes into use and non-use (or passive use) values, and further sub-classifications can be provided if needed. TEV does not encompass other kinds of values, such as intrinsic values which are usually defined as values residing "in" the asset and unrelated to human preferences or even human observation. However, apart from the problems of making the notion of intrinsic value operational, it can be argued that some people's willingness to pay for the conservation of an asset, independently of any use they make of it, is influenced by their own judgments about intrinsic value. This may show up especially in notions of "rights to existence" but also as a form of altruism. Any project or policy that destroys or depreciates an environmental asset needs to include in its costs the TEV of the lost asset. Similarly, in any project or policy that enhances an environmental asset, the change in the TEV of the asset needs to be counted as a benefit. For instance, ecosystems produce many services and hence the TEV of any ecosystem tends to be equal to the discounted value of those services. Broadly the environmental valuation is carried out using either revealed or stated preference approaches.

Revealed Preference Approaches: Economists have developed a range of approaches to estimate the economic value of nonmarket or intangible impacts. There are several procedures that share the common feature of using market information and behaviour to infer the economic value of an associated non-market impact. These approaches have different conceptual bases. Methods based on hedonic pricing utilise the fact that some market goods are in fact bundles of characteristics, some of which are intangible goods (or bads). By trading these market goods, consumers are thereby able to express their values for the intangible goods, and these values can be uncovered through the use of statistical techniques. This process can be hindered, however, by the fact that a market good can have several intangible characteristics, and that these can be collinear. It can also be difficult to measure the intangible characteristics in a meaningful way[1]. Travel cost methods utilise the fact that market and intangible goods can be complements, to the extent that purchase of market goods and services is required to access an intangible good. Specifically, people have to spend time and money travelling to recreational sites, and these costs reveal something of the value of the recreational experience to those people incurring them. The situation is complicated, however, by the fact that travel itself can have value, that the same costs might be incurred to access more than one site, and that some of the costs are themselves intangible (*e.g.* the opportunity costs of time). Averting behaviour and defensive expenditure

[1] For further discussion on 'Hedonic Price Method' refer dissemination paper number 5 (http://coe.mse.ac.in/disseminationpaper.asp)

approaches are similar to the previous two, but differ to the extent that they refer to individual behaviour to avoid negative intangible impacts. Therefore, people might buy goods such as safety helmets to reduce accident risk, and double-glazing to reduce traffic noise, thereby revealing their valuation of these bads. However, again the situation is complicated by the fact that these market goods might have more benefits than simply that of reducing an intangible bad. Finally, methods based on cost of illness and lost output calculations are based on the observation that intangible impacts can, through an often complex pathway of successive physical relationships, ultimately have measurable economic impacts on market quantities. Examples include air pollution, which can lead to an increase in medical costs incurred in treating associated health impacts, as well as a loss in wages and profit. The difficulty with these approaches is often the absence of reliable evidence, not on the economic impacts, but on the preceding physical relationships.

Stated Preference Approaches: These techniques of valuation utilise questionnaires which either directly ask respondents for their willingness to pay (accept), or offer them choices between "bundles" of attributes, from which the analysts can infer willingness to pay (WTP) or willingness to accept (WTA). Stated preference methods more generally offer a direct survey approach to estimating individual or household preferences and more specifically WTP amounts for changes in provision of (non-market) goods, which are related to respondents' underlying preferences in a consistent manner. Hence, this technique is of particular worth when assessing impacts on non-market goods, the value of which cannot be uncovered using revealed preference methods. This growing interest in stated preference approaches has resulted in a substantial evolution of techniques over the past 10 to 15 years. For example, the favoured choice of elicitation formats for WTP questions in contingent valuation[2] surveys has already passed through a number of distinct stages. This does not mean that uniformity in the design of stated preference surveys can be expected any time soon. There remain concerns about the

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[2] For further discussion on 'Contingent Valuation Method' refer dissemination paper number 6 (http://coe.mse.ac.in/disseminationpaper.asp)

validity and reliability of the findings of contingent valuation studies. Indeed, much of the research in this field has sought to construct rigorous tests of the robustness of the methodology across a variety of policy contexts and non-market goods and services. By and large, one can strike an optimistic note about the use of the contingent valuation to estimate the value of non-market goods.

Choice Modeling: Many types of environmental impact are multidimensional in character. Hence, an environmental asset that is affected by a proposed project or policy often will give rise to changes in component attributes each of which command distinct valuations. The application of choice modeling (CM) approaches to valuing multidimensional environmental problems has been growing steadily in recent years. CM is now routinely discussed alongside the arguably better-known contingent valuation method in state-of-the-art manuals regarding the design, analysis and use of stated preference studies. While there are a number of different approaches under the CM umbrella, it is arguably the *choice experiment* variant (and to some extent, *contingent ranking*) that has become the dominant CM approach with regard to applications to environmental goods. In a choice experiment, respondents are asked to choose their most preferred option from a choice set of at least two options, one of which is the status quo. It is this CM approach that can be interpreted in standard welfare economic terms. Much of the discussion about, for example, validity and reliability issues in the context of contingent valuation (CV) studies applies in the context of the CM. While it is possible that on some criteria, CM is likely to perform better than CV – and *vice versa* – the evidence for such assertions is largely lacking at present. Both approaches are likely to have their role in cost-benefit appraisals.

Traditionally, economists have been fairly indifferent about the welfare measure to be used for economic valuation: willingness to pay (WTP) and willingness to accept compensation (WTA) have both been acceptable. By and large, the literature has focused on WTP. However, the development of stated preference studies has, fairly repeatedly, discovered divergences, sometimes substantial ones, between WTA and WTP. These differences still would not matter if the nature of property rights regimes were always clear. WTP in the context of a potential improvement is clearly linked to right to retain the status quo. Similarly, if the context is one of losing the status quo, then WTA for that loss is the relevant measure. By and large, environmental policy tends to deal with improvements rather than deliberate degradation of the environment, so there is a presumption that WTP is the right measure.

Since many projects/programs may have adverse implications for the services provided by the ecosystems, there is widespread interest to estimate the total economic value (TEV) of ecosystem change. The problems with valuing changes in ecosystem services arise from the interaction of ecosystem products and services, and from the often extensive uncertainty about how ecosystems function internally, and what they do in terms of life support functions. Considerable efforts have been made to value specific services, such as the provision of genetic information for pharmaceutical purposes. The debate on that issue usually shows how complex valuing ecosystem services can be. But even that literature is still developing, and it does not address the interactive nature of ecosystem products and services. Once it is acknowledged that ecosystem functioning may be characterised by extensive uncertainty, irreversibility and non-linearities that generate potentially large negative effects from ecosystem loss or degradation, the focus shifts to how to behave in the face of this combination of features. The short answer is that decision-making favours precaution[3].

Benefits or value transfer involves taking economic values from one context and applying them to another. Since it is often difficult to design and implement fresh environmental valuation studies due to time and resource constraints, policy analysis typically uses transfer approach. That is, analysts must fall back on the information that can be gleaned from past studies. Almost inevitably, benefits transfer introduces subjectivity and greater uncertainty into appraisals in that analysts must make a number of *additional* assumptions and

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[3] For further discussion on ‘Precautionary Principle’ refer dissemination paper number 8 (http://coe.mse.ac.in/disseminationpaper.asp)

judgments to those contained in original studies. Surprisingly given its potentially central role in environmental decision-making, there are no generally accepted practical transfer protocols to guide analysts. However, a number of elements of what might constitute best practice in benefits transfer might include the following. First, the studies included in the analysis must themselves be sound. Second, in conducting a benefits transfer, the study and policy sites must be similar in terms of population and population characteristics. If not then differences in population, and their implications for WTP values, need to be taken into account. Just as importantly, the change in the provision of the good being valued at the two sites also should be similar. A competent application of transfer methods demands informed judgment and expertise.

3.0 Discounting and Environmental Projects

In the application of CBA to the climate change problem, recent influential report by Sir Nicholas Stern has called for prompt and strong action to address climate change concerns. The reports claims that, 'if we do not act, the overall costs and risks of climate change will be equivalent to losing at least 5 percent of global GDP each year, now and forever' (Stern, 2006). Nordhaus (2007) has observed that these strong results are 'dramatically different' from those prescribed by existing economic analyses, which call for more modest cuts in greenhouse gas emissions. So, what contributes these different prescriptions by two of the prominent economists who have worked on climate change issues for a long time? One of the potential reasons could be the choice of interest rate used for balancing future damages avoided versus present costs of abatement.

Greenhouse gas emission reduction involves an economic tradeoff on large temporal scale – as costs for emission reduction are incurred ***now*** while the benefits due to emission reduction (in the form of avoided damages) accrue over ***several centuries.*** If Re. 1 is spent to reduce emissions today, that one rupee is lost in terms of the investment which could make the society wealthier tomorrow. With expenditure on emission reduction today, the society is better off tomorrow because of the reduced impacts from climate change, but is also worse off because of the lost opportunity to invest that would have made society wealthier tomorrow. This trade-off is reflected in the discount rate used. While Nordhaus uses a discount rate of about 3.6 to 4.3 percent, Stern uses 1.4 percent.

The discount rate constitutes of pure rate of social time preference (ρ), rate of growth of consumption (g), and consumption elasticity (η)[4]. The discount rate (r) is given by: $r = \rho + g\eta$. While Stern and Nordhaus use same η (=1) and similar g (around 1.3 percent), they differ in their choice of pure rate of social time preference. Against Nordhaus's choice of 2.3 to 3 percent, Stern uses 0.1 percent as ρ. Since such wide difference in the discount rate used results significantly different results, as has been the case in the climate change debate, a natural question that merits answer is: what is the appropriate pure rate of social time preference? There is no clear answer to this as it depends on ethical judgment. Several economists have preferred using lower value of ρ as used by Stern, but preferred the analysis to be more transparent.

While discounting is theoretically justifiable, it poses concerns regarding the fairness. This unacceptability arises from the fact that distant future costs and benefits may appear as insignificant present values when discounting is practised. In turn, this appears to be inconsistent with notions of intergenerational fairness. Current activities imposing large costs on future generations may appear insignificant in a cost-benefit analysis. Similarly, actions now that will benefit future generations may not be undertaken in light of a cost-benefit analysis. The weakness of the conventional approach, which assumes that one positive discount rate is applied for all time. Many studies find that very often (but not always), people actually discount "hyperbolically", *i.e.* people actually do use time-declining discount rates. If what people do reflects their preferences, and if preferences are paramount, there is a justification for adopting time-declining discount rates.

[4] For further discussion on 'Social Discount Rate, Intergenerational Equity and Climate Change' refer dissemination paper number 11 (http://coe.mse.ac.in/disseminationpaper.asp)

4.0 Equity and CBA

In evaluating projects there is a need for some sort of a rule about what makes a project desirable or undesirable. Such rules include:

- Pareto criterion – if a project helps at least one person while hurting no one, then it satisfies Pareto criterion. However, it is often considered to be restrictive as it rejects projects/policies that result in losses to any individual – and virtually all projects affect some or other adversely.
- Social Welfare criterion – wherein sum of each person's net benefit multiplied by his/her marginal social significance is calculated; the project is considered as desirable if the sum is positive. This requires large amount of information and hence considered difficult to implement.
- Potential Compensation (or, Kaldor-Hicks) criterion – according to which a project/policy is desirable if the sum of the rupee value of the net benefits of the project/policy to the gainers and losers is positive. In other words this criterion explores whether the net gainers from the project can compensate the net losers so as to make them as well off as they would be without the project/policy.

For example, consider a project that yields the net-benefits to two individuals in the society as shown in Table 2. As per the Pareto criterion the project fails because person 2 is incurring negative net-benefits. As per the Social Welfare criterion also the project fails as the sum of SMUY*Net-Benefits is negative. On the other hand, as per the Potential Compensation criterion the project is desirable since the net beneficiaries of the project (namely, person 1) can in principle compensate the net losers of the project (namely, person 2) for all his/her losses and still be better off. The Potential Compensation criterion ensures that the resources are put to their most highly valued uses and thus the total wealth of the society is maximized.

Table 2. Project Evaluation Criterion – Illustration

Person	SMUY	Net Benefits	SMUY*Net Benefits
1	0.8	+250	+200
2	1.2	-200	-240
Total		+50	-40

Note: SMUY – social marginal utility of income, that captures the weight attached to each individual in the society.

While CBA traditionally focused on efficiency issues and hence identified desirable projects on the basis of the Potential Compensation criterion, its reluctance to include equity and distributional aspects in the analysis attracted criticism. Such criticism gained more momentum in the field of environmental issues as it is difficult to clearly separate efficiency from equity concerns. Thus, while applying CBA to environmental issues such as climate change it is argued that it is appropriate to use some variant of Social Welfare criterion to assess the desirability of projects. This in turn would necessitate the analyst to identify appropriate equity weights that are applicable for the project. Debate about what form these weights should take has surrounded different conceivable functions and forms that describe social welfare and, more specifically, the measure of inequality aversion (reflecting in turn a judgment about the relatively higher value associated with say the damages due to climate change suffered by a poor person compared to a rich person). Atkinson and Mourato (2008) argue that the available evidence suggests that although equity weighting could make a significant difference to CBA analysis, the range of plausible values that these weights could take is possible large – thus making their usage impractical.

5.0 Dealing with Uncertainty

The way in which CBA deals with uncertainty in project appraisal has not undergone substantial changes over years. It is typically addressed through sensitivity analysis of uncertain parameters. Alternatively when probability distributions are known sometimes expected impacts are also calculated. However, possibility of irreversible changes in the environmental systems has given rise to new concepts such as quasi option value (QOV) in CBA applications. The notion of QOV was introduced in the environmental economics literature some three decades ago. QOV is the difference between the net benefits of making an optimal decision and one that is not optimal because the former ignores the gains that may be made by delaying a decision and learning during the period of delay. For example, if a development option involves the permanent conversion of tropical forestland to agricultural land, then it must be debited with the potential forgone costs of not waiting to learn more about the benefits of forest conservation. QOV can only emerge if there is uncertainty which can be resolved by learning. If the potential to learn is not there, QOV cannot arise. Potentially QOV can make a significant difference to decision-making.

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DISSEMINATION PAPER SERIES

The Centre of Excellence in Environmental Economics was asked by the Ministry of Environment and Forests to explain the concepts of environmental economics to non-economists through a series of short dissemination papers. The authors welcome feedback on the papers from readers. The following fifteen dissemination papers have been posted on the Centre Website (http://coe.mse.ac.in).

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1.	Environmental Externalities	Dr.U.Sankar
2.	Vehicular Pollution Control	Dr.Vinish Kathuria
3.	Environmental Accounting	Dr.G.S.Haripriya
4.	Public Disclosures Using Information to reduce pollution	Dr. Vinish Kathuria
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Centre of Excellence in Environmental Economics

The Ministry of Environment and Forests, Government of India has designated Madras School of Economics as a Centre of Excellence in the area of Environmental Economics for a period of ten years from April 1, 2002. The centre carries out research work on: Development of Economic Instruments, Trade and Environment, and Cost-Benefit Analysis. The Centre is primarily engaged in research projects, training programmes, and providing policy assistance to the Ministry on various topics. The Centre is also responsible for the development and maintenance of a website (http://coe.mse.ac.in), and for the dissemination of concept papers on Environmental Economics.

Madras School of Economics

Madras School of Economics was founded in 1993 as a private post-graduate institution for teaching and research in economics. MSE offers a two-year Master's program in Economics and Financial Economics affiliated to Anna University, and a Ph.D programme affiliated to both Madras and Anna Universities. MSE has undertaken a large number of research projects since its inception, including the World Bank sponsored Capacity Building Programme in Environmental Economics. The World Bank project involved research, training, curriculum, and overseas fellowship components which were coordinated by MSE. Subsequently, the Ministry of Environment and Forests approved the proposal to set up a Centre of Excellence in Environmental Economics at MSE. MSE has also been designated as an ENVIS Centre in Environmental Economics under the Environmental Information System (ENVIS) of the Ministry of Environment and Forests, Government of India. A dedicated program on Trade and Environment, with support from the Ministry of Environment and Forests, Government of India, has also been started recently at MSE.