ECONOMY AND ENVIRONMENT PROGRAM
FOR SOUTHEAST ASIA

Basic Concepts and Common Valuation Errors in Cost-Benefit Analysis

Theodore Panayotou
March 1997

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BASIC CONCEPTS AND COMMON VALUATION ERRORS IN COST-BENEFIT ANALYSIS

by

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Basic Concepts and Common Valuation Errors in Cost-Benefit Analysis

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Basic Concepts and Common Valuation Errors in Cost-Benefit Analysis

Environmental Economics

The society has limited resources to meet several objectives such as economic growth, poverty alleviation and environmental protection. These objectives compete for resources and may conflict with each other. For example, economic growth may increase environmental degradation and environmental regulation may constrain growth. Therefore, every effort must be made to reconcile and synergize these diverse social objectives and to prioritize them as to allocate the limited resources among them in the most efficient way.

Environmental economics provides us with the analytical tools to reconcile environmental protection with economic growth and other social objectives, and to protect and improve the environment without wasting scarce resources.

How can we waste scarce resources in our effort to protect and improve the environment, and how can environmental economics help to avoid such waste?

1. Focusing our efforts on wrong priorities (activities or issues of low potential benefit) wastes scarce resources. Environmental economics *help us estimate the social value of environmental improvements and thereby set priorities.*

2. Undertaking unnecessary or costly investments when more cost-effective alternatives exist wastes resources. Environmental economics employs cost-effectiveness in the selection among projects or policies that aim to achieve the same objective.

3. Failing to first eliminate policy failures that subsidize environmental degradation or resource depletion unnecessarily raises the cost of environmental improvement. Environmental economics evaluates the impacts of economic policies such as taxes and subsidies on the environment.

4. Introducing environmental policies (such as uniform emission standards or technological requirements) that are unduly costly or restrictive or distortive of

economic activity such as trade and investment. Environmental economics analyzes the impact of environmental regulation on economic activity and identifies ways to reconcile the conflicts and evaluate the trade-offs.

Like most sub-disciplines of economics, environmental economics employs benefit-cost analysis in determining optimal policies or selecting among alternative projects. Particular attention is paid to the valuation of non-marketed goods and services such as environmental quality, ecological balance and biodiversity, and non-use values such as option and existence values. These values are then integrated into the conventional benefit-cost analysis to obtain fuller, and hence more correct, measures of social profitability of projects. The integration of environmental (and social) values into cost-benefit analysis is known as *extended cost-benefit analysis.* In the past, the environmental impacts of projects and policies were ignored because it was thought that they were unquantifiable or too difficult to value; and, since what is not measured is usually not done, environmental impacts were routinely ignored in project appraisal. In recent years there has been significant progress in quantification and valuation of both natural resources and environmental quality that it is possible to arrive at relatively narrow and robust ranges of values for most impacts, though by no means all. However, since valuation of non-market goods and services is still far from straightforward, involving assumptions, inferences, and direct questioning, it is rather easy to commit serious errors. Such errors may enter in sample selection, in survey design and implementation, in deriving values from observed behavior, in prediction and in aggregation, among others. Here we will review some basic concepts and common valuation errors in cost-benefit analysis. We begin with a review of some basic concepts of social welfare economics, cost-benefit analysis, and valuation.

A. Review of Basic Concepts of Social Welfare Economics, Cost Benefit Analysis, and Valuation[1]

Cost-Benefit Analysis

The purpose of cost-benefit analysis (CBA) is to help social decision making and to facilitate more efficient allocation of resources. Since resources are limited and needs unlimited, it is necessary to set priorities. Priorities are ranked according to their net benefits. CBA has the advantage of balancing the beneficial aspects of a policy or project against the real resources society must give up to implement the policy or project. CBA involves the definition of scenarios of desired changes, the establishment of baselines against which changes are to be measured, estimation (prediction) of physical impacts, valuation of these impacts (to obtain the benefits), and estimation of the costs of achieving the desired changes. Boardman *et al.* (1996) identify nine steps in cost-benefit analysis. Even though only one (step 5) deals directly with valuation, understanding and keeping in mind all nine steps are essential to avoiding valuation errors.

The 9 Steps of Cost-Benefit Analysis[2]

1. Decide whose benefits and costs count (standing)
2. Select the portfolio of alternative projects
3. Catalogue potential (physical) impacts and select measurement indicators
4. Predict quantitative impact over the life of project
5. *Monetize (attach dollar values to) all impacts*
6. Discount for time to find present values
7. Sum: Add up the benefits and costs
8. Perform sensitivity analysis
9. Recommend the alternative with the largest net social benefits

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[1] Draws heavily on Boardman, Anthony, David Greenberg, Aidan Vining and David Weimer. *Cost-Benefit Analysis: Concepts and Practice.* Upper Saddle River, NJ: Prentice-Hall, Inc. (1996).

[2] *SOURCE:* Boardman, Anthony, David Greenberg, Aidan Vining and David Weimer. *Cost-Benefit Analysis: Concepts and Practice.* Upper Saddle River, NJ: Prentice-Hall, Inc. (1996).

Of these nine steps, 1, 3, 4, and 6 (besides 5) are of particular importance to valuation. Deciding who has standing would determine what environmental (and other) impacts are relevant and should be quantified and valued. For example, the citizens of a developing country have standing with regard to pollutants generated by a new power station, but the rest of the world does not unless the country has signed the Framework of Climate Change Convention, or is eligible for international transfers for keeping its CO_2 emissions down. Alternatively, with regard to resettlement resulting from a hydropower project the displaced people have standing, others do not even though they may have standing with regard to other impacts, such as downstream flooding or loss of biodiversity. Identification of physical impacts is important but not sufficient since there are many such impacts; it is important to scope these impacts as to focus in the most relevant and important in the case at hand. (Scoping is an explicit early step in environmental impact assessment). Prediction of the quantitative (physical) impacts is not easy but absolutely necessary. Prediction is done based on past experience with similar projects or thorough simulation. Usually quantification is done for the life of the project, but since environmental impacts could extend beyond the life of the project (as they extend beyond the site of the project), quantification and valuation must also identify the environmentally-effective life of the project over which impacts are to be predicted. Since environmental impacts occur at different years throughout the project (construction, operation, decommissioning and beyond), discounting is crucial for comparability and aggregation of values.

Allocative Efficiency

Economists favor the use of efficiency criterion for allocating resources and prioritizing projects because it captures the tradeoffs between benefits and opportunity costs. Key efficiency concepts include Pareto efficiency, Pareto improvement, willingness to pay (which measures benefits), and opportunity costs (which measures the value of foregone alternatives).

Pareto Efficiency

An allocation of resources is Pareto efficient if there exist no alternative allocations which would improve at least one person's situation without making another's worse.

Pareto Improvement

If a policy has positive net benefits, then it is possible to find a set of transfers or "side payments" that improve at least one person's situation without making another's worse.

Willingness to Pay

Willingness to pay is a measure of an individual's benefit from a project or a policy; it is what the individual is willing to pay (forego in other goods and services) to access the benefits of the policy or project. Willingness to accept is what the individual is willing to accept as compensation for foregoing the benefit of a policy or project. Under certain circumstances willingness to pay is the correct measure for valuing the impacts of a policy, and under other circumstances willingness to accept is the right measure (see below).

Opportunity Costs

The "method" for valuing the resources required to implement the policy. Opportunity costs of using an input to implement a policy is its value in its next best alternative use.

Decision Making

As long as all impacts are valued in terms of willingness-to-pay (or willingness to accept) and all required inputs in terms of opportunity costs, then the sign of the net benefits indicates whether or not it would be possible to compensate those who bear the costs sufficiently so that no one would be made worse off. (Positive net benefits indicate potential for compensation. Negative net benefits indicate absence of such potential.)

Potential Pareto Efficiency Rule

Adopt all policies that have positive net benefits. Choose the combination of policies that maximizes net benefits. This rule allows for both gainers and losers as long

as the gainers can potentially compensate the losers, i.e. their gains are more than enough for potential compensation, even though such compensation may never be paid.

Rationale For Government Intervention

Where markets work well, individual self-interest leads to efficient allocation of resources. Government interference with private choice is thus unjustified and constitutes "policy failure." Politicians and government analysts bear the burden of providing a rationale for government intervention.

Market failures provide a *necessary* but not sufficient rationale for government intervention in the allocation of resources resulting from private choice. The *sufficient* condition is to demonstrate the superior efficiency of the particular government intervention relative to the alternatives, including the status quo. *Cost-benefit analysis* of proposed interventions (policies, regulation, or projects) is a method for demonstrating the superior (compared to alternatives) efficiency of the proposed intervention, i.e. for establishing the sufficient condition.

Valuation of Outcomes of Government Intervention

How are the outcomes of government intervention (policies and projects) to be valued? Government policies and projects result in both benefits and costs:

a) benefits for which people are willing to pay something[3], and
b) opportunity costs that are sacrifice of other benefits by diverting resources from other activities.

The net social benefit of a policy or project is the difference between the gross benefits gained (added) and the benefits given up (opportunity costs). There are two groups of potential beneficiaries: the consumers and the producers. The net benefits of the consumers from a given policy or project is the difference between their willingness to pay to access the policy (or project) and what they actually pay to access it. This difference is known as the consumer surplus (CS). The net benefits of the producers from

a policy is the difference between their incremental revenues and their incremental costs as a result of the policy (or project). This difference is known as the producer surplus (PS). Therefore, the net social benefits (NSB) is the sum of the producer and consumer surplus (PC+CS) also known as the social surplus (SS). The box below summarizes net social benefits as the difference between benefits gained and benefits given up or the sum of consumer and producer benefits (or surplus).

Net Social Benefits
= Benefits gained (added) - Benefits given up (opportunity costs)
= Δ [Net benefits to consumers] + Δ [Net benefits to producers]
= Δ [Willingness to Pay - Actual Payments] + Δ [Revenues - Opportunity Costs]
= Δ [CS] + Δ [PS]

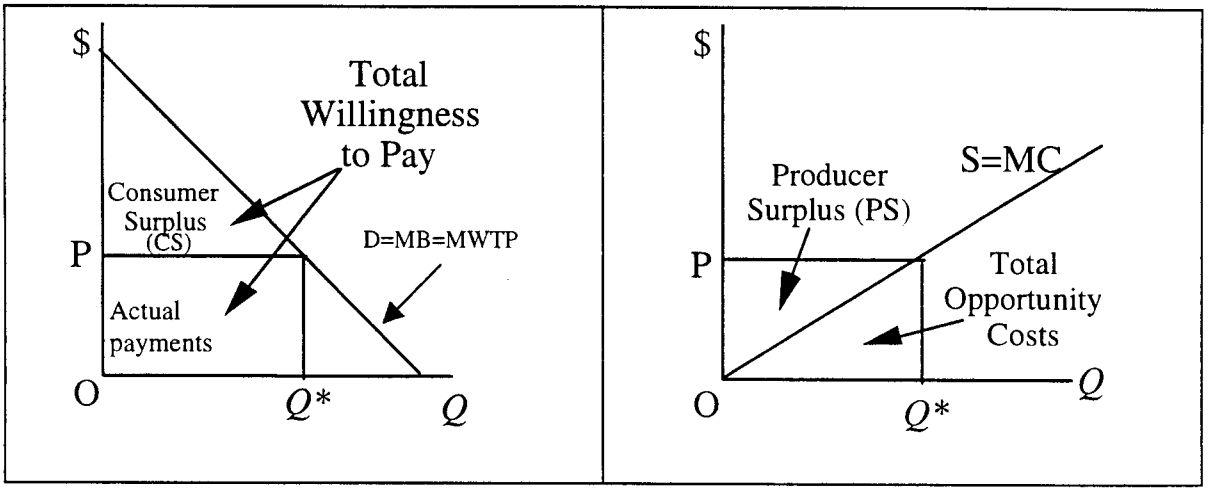
How does benefit-cost analysis relate to the usual marginal analysis of microeconomics? Consumer surplus is always obtained as the area under the demand curve (which represents the marginal benefits of project output) and above the price. Producer surplus is obtained as the area above the supply curve (which represents the marginal opportunity costs) and below the price, as shown below.

[3] Aggregate willingness to pay = sum of willingness to pay of all individuals in society

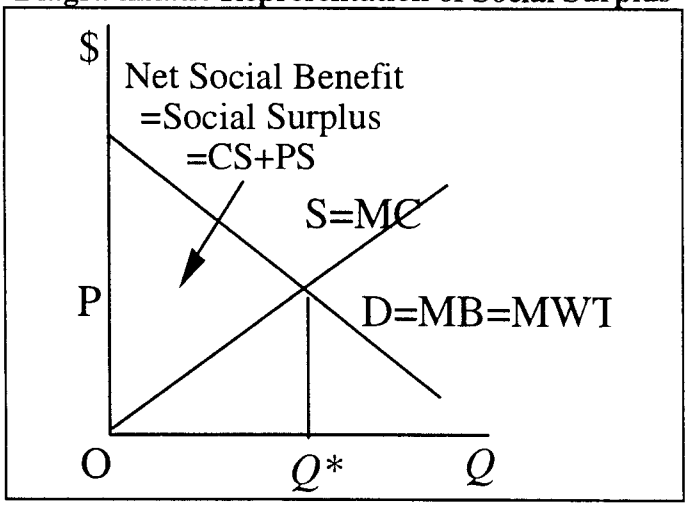
Deriving the Social Surplus: Demand and Supply Factors

Benefits Side	Cost Side
Demand Curve (D)	Supply Curve (S)
Marginal Benefit (MB) (Marginal Willingness to Pay (MWTP)	Marginal Cost (MC) (Incremental Opportunity Costs)
Total Willingness to Pay	Total Opportunity Costs
Consumer Surplus (CS)	Producer Surplus (PS)
Changes in Consumer Surplus	Changes in Producer Surplus
Changes in Social Surplus	

Diagrammatic Representation of Consumer and Producer Surpluses



Diagrammatic Representation of Social Surplus



Under well-functioning competitive markets and in the absence of market failures, the market equilibrium: (1) maximizes social surplus; (2) the outcome is Pareto efficient:

- It is not possible to make someone better off without making someone else worse off by changing the market allocation
- Q* is allocatively efficient: any interference with the competitive process that will change the allocation of resources will reduce the surplus and it is therefore an economic distortion.

Allocative efficiency is obtained only when the price paid by consumers equals the marginal opportunity cost to society. Taxes, subsidies, quantitative restrictions (quotas, rationing), and floor/ceiling prices result in deadweight loss, i.e., inefficient allocation outcomes, as shown in the figures below. In Figure (a) an output quota $\overline{Q}$ below the market equilibrium output Q* (i.e. $\overline{Q} < Q^*$) results in reduction of allocative efficiency or deadweight loss equal to the shaded triangle ABC. What this means is that social welfare is lower by this amount as a result of the quota. Figure (b) shows the deadweight loss for $\overline{Q} > Q^*$. Figure (c) shows the deadweight loss from target pricing $P_T > P^*$ for producers and $P_D < P^*$ for consumers. While both producer and consumer surpluses increase, the society incurs a deadweight loss (an efficiency loss) due to the misallocation of resources that are diverted from other sectors with higher return (opportunity costs). This is seen by the fact that at output level Q: MC>MB or WTP.

Figure a

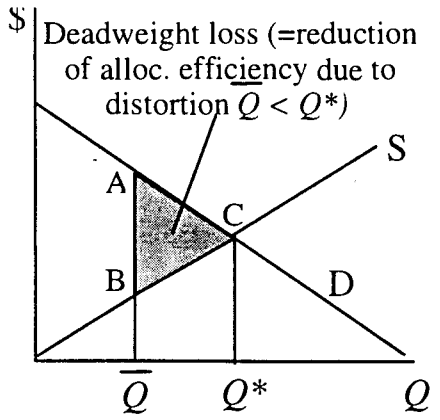


Figure b

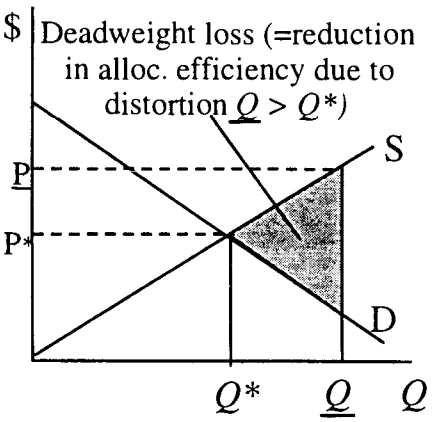
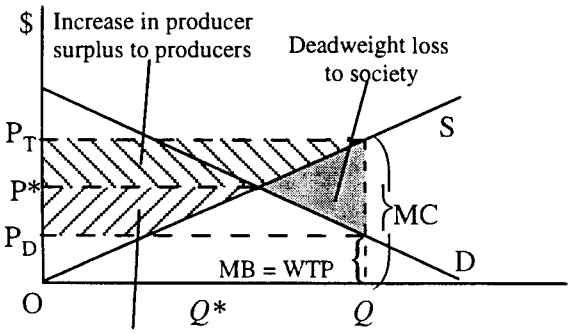


Figure c



P_T = Target Pricing

P_D = Consumers' WTP

The cost of the subsidies to taxpayer = increase in producer and increase in consumer surplus and dead loss.

Net cost of subsidy to society = deadweight loss (= admin. costs of subsidy)

Leakage = deadweight loss total cost to tax payers

SOURCE: Boardman, Anthony, David Greenberg, Aidan Vining and David Weimer. *Cost-Benefit Analysis: Concepts and Practice*. Upper Saddle River, NJ: Prentice-Hall, Inc. (1996).

The Willingness to Pay (and to Accept) as a Measure of Value

The valuation of policy outcomes is based on the concept of the willingness to pay (WTP).

Benefits are the sums of the maximum amounts that people would be willing to pay to gain outcomes that they view as desirable.

Costs are the sums of the maximum amounts that people would be willing to pay to avoid outcomes that they view as undesirable.

We take into account these costs and benefits by estimating the changes in social surpluses in relevant markets resulting from a policy intervention (e.g. a regulation or a project).

Estimates of the changes in consumer surplus are reasonable approximations of:

a) individuals' willingness to pay to obtain the effects of policy changes viewed as desirable

b) individuals' willingness to pay to avoid the effects of policy changes viewed as undesirable.

The maximum amount that a consumer would be willing to pay to avoid a price increase (resulting from a policy change) is the amount required to return him/her to the same level of utility he/she enjoyed prior to the change in the price. This is called *compensating variation.*

If the consumer must spend more than the value of his/her compensating variation to avoid the effects of a policy change, then it would be better to allow the increase to happen. If the consumer would pay any less than the compensating variation, it would be to his/her advantage to pay to avoid the increase. Thus , a loss of consumer surplus resulting from a price increase must correspond exactly to the compensating variation value associated with the price increase in order to equal the consumer's willingness to pay to avoid the increase. For this to happen, it must be measured using the right demand curve (see below).

Compensating variation (CV) is to be contrasted with *equivalent variation* (EV) which is the minimum amount a consumer would be willing to pay to forego a price decrease (resulting from a policy change); it is the amount required to raise him to the same level of utility he/she would enjoy with the change (i.e. to make him as well off as if the price decrease did occur). Willingness to accept provides an alternative monetary measure of the value to the individual of change in well-being resulting from an improvement in environmental quality.

When we consider both improvements and deteriorations of environmental quality we have four welfare measures: (a) willingness to pay (WTP) to avoid a negative change, (b) WTP to obtain a positive change, (c) willingness to accept (WTA) to forego a positive change, and (d) WTA to incur a negative change. These measures are summarized in Box 1 below along with an example/quiz that illustrates the differences.

Box 1 Comparison of Four Welfare Measures

Does Change Occur?	Reference Utility Level	Environmental Change	
		Degradation	Improvement
Yes	Before Change: u^0 (CV)	WTA (to incur)	WTP (to obtain)
No	After Change: u^1 (EV)	WTP (to avoid)	WTA (to forego)

Does WTP = WTA?

What is upper bound on WTP? WTA?

Example/Quiz

Suppose sunscreen is a perfect substitute for the ozone layer: If the layer is $n\%$ thinner, use $n\%$ more sunscreen[4]

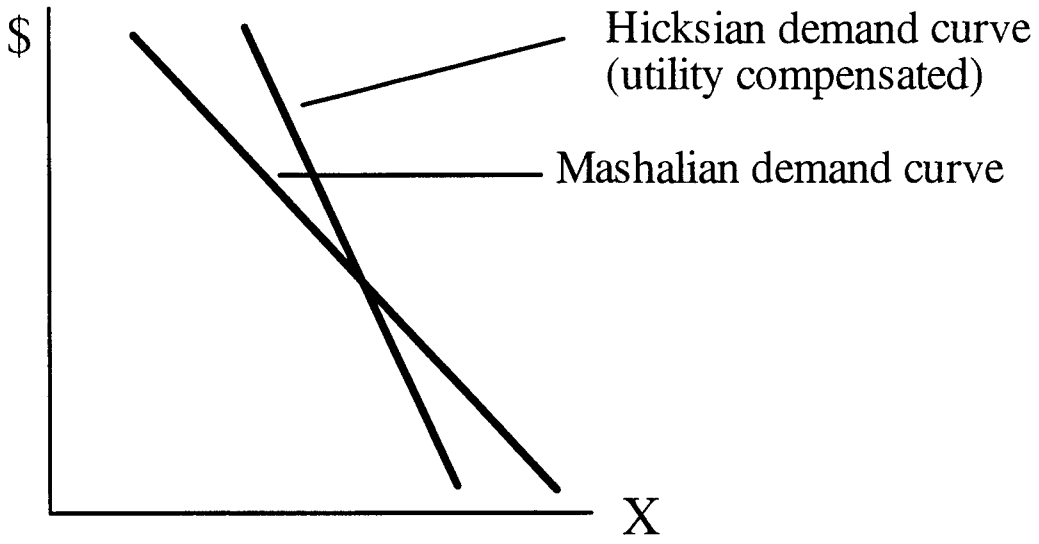
- What is WTA to incur a 30% decrease in the ozone layer, if currently use 10 bottles of sunscreen @ $5? (Is this CV or EV?)
- What is WTP to avoid a 10% decrease in the ozone layer, under the same conditions? (Is this CV or EV?)
- What can you say about property rights?
- What if sunscreen is not a perfect substitute?

CV = compensated variation; EV = equivalent variation

The willingness to pay (and accept) and hence consumer surplus can be read off two different types of demand curves: Marshalian and Hicksian.

a) **Marshalian:** is the usually empirically estimated demand curve that incorporates both substitution and income effects resulting from price changes.

b) **Hicksian**: is net of income effects. The income effects of a price change are compensated to keep the consumer on the same utility function as before the price change. Hicksian demand curves reflect only substitution effects, and they are also called utility-compensated demand curves, and they are usually more steeply sloped than the Marshalian demand curves.



The Hicksian demand curve: accurately measures the compensating variation associated with price changes and hence the true willingness to pay of the consumer to avoid the change.

The Marshalian demand curve: is more often available and commonly used in cost-benefit analysis. It results in somewhat biased estimates of the willingness to pay (WTP):

a) overestimates WTP for price reductions

b) underestimates WTP for price increases

The magnitude of the bias depends on the size of the income effect associated with the price change. Usually the income effect is small e.g. for government policies that affect

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[4] I owe this example to Jeffrey Vincent.

the prices of most commodities with the possible exception of changes in prices of housing and automobiles and in wage rates.

To sum up, valuation is the process of assigning values (or prices) to goods and services that are not priced by markets or not priced correctly. Valuation is necessary since relative prices determine resource allocation. To allocate public resources efficiently and to correct the prevailing market resource allocation, it is necessary to have the relative social values for all goods and services in all their uses, regardless of whether they are valued by markets. The value of a good is measured by what people are willing to give up from their endowment of resources to acquire one additional unit of the good; this is known as their willingness to pay. Alternatively, value can be represented by what people are willing to accept to tolerate a loss of a unit of the good or to forego a gain of a unit of the good. Box 2 summarizes in question and answer form the rationale for valuation and the various measures of value. While WTP and WTA are simply measures of efficiency, which one we use in practice should depend among others on the assignment of property rights and our distributional objectives (i.e. non-economic considerations or political judgment). However, since WTA is not bounded by a budget constraint and is often "exaggerated,"[5] the most common measure of value used is WTP which is analogous to the price paid for marketed goods.

[5] There are techniques for obtaining accurate measures of WTA and sound reasons for why a policy maker may want to use WTA rather than WTP. For a discussion of this point, see OECD, *Project and Policy Appraisal: Integrating Economics and Environment* (Paris: OECD, 1994) 43-45.

Box 2 Why Valuation?

Q: Why valuation?

A: For cost-benefit analysis.

Q: Why cost-benefit analysis?

A: For allocative efficiency.

Q: Why allocative efficiency?

A: To ensure that scarce resources are put where they have most value.

Q: What is value?

A: What an agent is willing to give up out of his/her endowment for an additional unit of the good (i.e., his or her WTP).

Q: What is willingness to pay (WTP)?

A: WTP is what achieves the following equality:

$U_1(Y-WTP,Q^1)=U_0(Y,Q^0)$ (maintain U_0) $\rightarrow$ CV

where Q^0 = is the quantity of the good before the change

Q^1 = is the quantity of the good after the change

$Q^1>Q^0$: WTP = willingness to pay to obtain an improvement

Or

$U(Y-WTP,Q^0)=U(Y,Q^1)$ (maintain U_1) $\rightarrow$ EV

where $Q^1<Q^0$: WTP = willingness to pay to avoid damage

Q: What is willingness to accept?

A: WTA is what achieves the following equality:

$U(Y+WTA,Q^1)=U(Y,Q^0)$ (maintain U_0) $\rightarrow$ CV

where $Q^1<Q^0$: WTA = willingness to accept to incur damage

Or

$U(Y+WTA,Q^0)=U(Y,Q^1)$ (maintain U_1) $\rightarrow$ EV

where $Q_1>Q_0$: WTA = willingness to accept to forego an improvement

B. Common Errors in Valuation

The valuation of marketed goods and services is straight-forward. In the absence of policy distortions and market failures, market prices reflect both individual and social relative values. If there are policy distortions such as taxes, subsidies, quotas, or overvalued exchanges rates, valuation becomes a bit more complex because one has to predict what prices would have prevailed in the absence of these distortions, a process known as shadow pricing. Fortunately, Planning or Development Ministries of most countries and the World Bank have developed conversion factors for converting market prices into efficiency prices. It is when prices are inefficient or totally absent because of market failures (e.g. undefined property rights or externalities) that valuation becomes a difficult and potentially error-prone exercise. Even in the simplest case where the environmental change results in changes in marketed products (e.g. soil erosion resulting in loss of crop output), the researcher must ask whether the loss of output is large enough to affect market prices and the prices of substitutes and what the producers' and consumers' reactions to these prices would be. If valuation is made before these adaptations take place, the effects of the environmental charge would be overestimated; if valuation is done after these adaptations, the impacts of the environmental charge on producers and consumers would be overestimated. Prices should be adjusted to their market-clearing levels. If the output is not marketed (e.g. fuelwood) we may use the prices of similar goods or substitutes; this introduces another area of possible error as goods are rarely perfect substitutes.

Valuation methods that are based on inferences from observed behavior or surrogate markets have an even larger scope for confusion and error. For example, it is not uncommon to assume that non-response, i.e. zero defensive or replacement expenditures means zero value while in fact indivisibilities of possible response (e.g. relocation of residence) and capital market imperfections are preventing a response. Other common errors here are inferences from non-representative samples, failure to consider lags in response (it takes time to respond or information asymmetries (environmental change not perceived by those affected). The remediation approach to valuation, often favored by engineers, is based on the unquestioned implicit assumption

that remediation pays. This may or may not be the case, depending on incremental benefits and costs.

Another common error is to value environmental damages by costing a shadow project (actual or hypothetical) without considering that shadow project's own environmental effects. In valuation using dose response functions, the most common error is failing to separate multiple causative factors and thereby overestimating the value of environmental (or health) damages. In the presence of minimum wage laws, unemployment and subsidized medical care, shadow pricing of labor and medical services is essential to valuing health losses correctly but many studies inappropriately use unadjusted market prices.

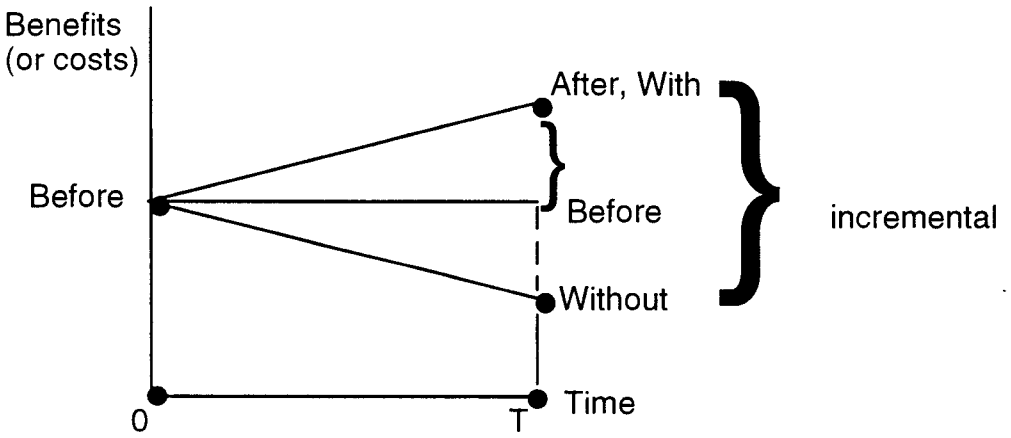
The potential for error is compounded when we move from these relatively simple methods to the more sophisticated methods of hedonic pricing, travel cost, and contingent valuation (CVM). These techniques require large data sets and sophisticated statistical techniques to generate, analyze, and interpret the results. The first two assume a well-functioning and competitive market (in properties, labor, or travel), and the third one tries to construct a hypothetical market that behaves like a real one. CVM is therefore most prone to error since it is based on hypothetical not actual behavior. If the researcher does not carefully follow a number of established rule and guidelines, it is more likely than not to introduce biases at every step of the way from sample selection and the design of the questionnaire, through the conduct of interviews to the analysis and interpretation of the results. To have any confidence in the results of survey techniques, the researcher must both guard against introducing biases in the responses he/she receives and must test formally for the presence of these biases (hypothetical, strategic, starting point, payment instrument, third person presence, etc.). To be able to do so, the researcher must anticipate the likely biases while selecting the sample and designing the survey instrument so that appropriate questions are asked and sufficient degrees of freedom exist to afford such tests. A good part of the errors in contingent valuation are in sample selection and survey design and implementation.

It is beyond the scope of this paper to provide a comprehensive list of the potential dangers in the use of each valuation technique. The above discussion was meant as a sample of technique-specific errors. Below we review common errors in valuation that cut across all techniques.

With and Without vs. Before and After

1. Only additional or incremental benefits and costs count; sunk costs are not incremental and should not be included.

2. Only incremental benefits and costs attributable to the project should be included. A "before and after" comparison provides estimates of values which are gross of benefits and costs which are not attributable to the project but to other projects or changes that would have taken place anyway. A with and without comparison provides estimates of values that are net of these extraneous influences



Example:

The government is contemplating a once-and-for-all soil conservation subsidy of $1000 per hectare to encourage farmers to improve the terracing of their fields. Farmers are already planning to spend $30 per hectare per year to maintain the existing terraces, which is expected to reduce soil erosion from 100 tons per hectare this year to 90 tons per hectare next year and to keep it at that level as long as they maintain the same level of

maintenance. However, the government feels that they can cut down the soil erosion to 70 tons per hectare per year if they structurally improve the terraces of their fields. Evaluation of the soil conservation subsidy of the relationship between soil erosion (E) and crop production (Q) is described by the following relationship: $Q = 10 - 0.0004\ E^2$, and the terraces require a maintenance of \$50 per hectare per year. The crop price is \$100 per ton (net of input cost), and the discount rate 10%. As many as 10,000 hectares would benefit from the subsidy.

With and Without Valuation

Investment cost = $[IVC]_{WITH} - [IVC]_{WITHOUT} = [1{,}000 \times 1000] - [0] = 1{,}000{,}000$ (stock)

Incremental annual maintenance cost =

$[MNC]_{WITH} - [MNC]_{WITHOUT} = [80 \times 1000] - [30 \times 1000] = 80{,}000 - 30{,}000 = 50{,}000$ (flow)

$$\text{PV (Incremental MNC)} = \frac{50{,}000}{r} = \frac{50{,}000}{.10} = 500{,}000 \quad \text{(stock)}$$

PV (Total incremental costs) =

$$IVC + PV(MNC) = 1{,}000{,}000 + 500{,}000 = \$1{,}500{,}000 \quad \text{(stock + stock)}$$

Incremental annual benefits (B) $= [\text{Revenues}]_{WITH} - [\text{Revenues}]_{WITHOUT}$

$$= P \bullet Q_{WITH} - P \bullet Q_{WITHOUT}$$

$B = 100 \{ [10-1.004(80)^2] - [10-1.004(100)^2]\ 1000 \}$

$= 100{,}000\ [10-2.56]\ [10-4] = 100{,}000\ (1.44)$

$= \$144{,}000$ (flow)

$$PV(B) = \frac{144{,}000}{r} = \frac{144{,}000}{.10} = \$1{,}440{,}000 \quad \text{(stock)}$$

$$PV \text{ (Net benefits)} = PV(B) - PV(C) = \$1{,}440{,}000 - \$1{,}500{,}000 = -60{,}000 \quad \text{(stock)}$$

Conclusion: Reject the project.

Before and After Valuation

Investment Cost (IVC) =

$$[IVC]_{AFTER} - [IVC]_{BEFORE} = [\$1000x1000] - [0x1000] = 1{,}000{,}000$$

Annual Maintenance Cost (MNC) =

$$[MNC]_{AFTER}\ [MNC]_{BEFORE} = [(30+50)(1000)] - [0] = 80{,}000$$

$$PV\ (MNC) = \frac{80{,}000}{r} = \frac{80{,}000}{0.10} = 800{,}000$$

$$PV\ (\text{Total costs}) = IC + PV(MC) = 1{,}000{,}000 + 800{,}000 = \$1{,}800{,}000$$

Annual benefits: $[\text{Revenues}]_{AFTER} - [\text{Revenues}]_{BEFORE} = P \bullet Q_{AFTER} - P \bullet Q_{BEFORE}$

$$= 100\ \{\ [10\text{-}0.0004\ (70)^2 - [10\text{-}0.0004\ (100)^2]\ \}\ 1{,}000$$

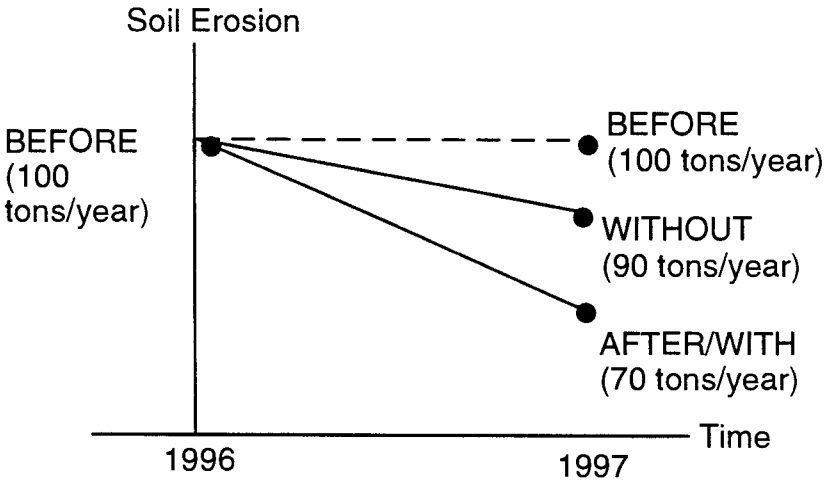
$$= 100{,}000\ [10\text{-}1.96] - [10\text{-}4] = 100{,}000\ (8.04\text{-}6)$$

$$= \$204{,}000 \text{ per year}$$

$$PV\ (\text{Benefits}) = \frac{204{,}000}{r} = \frac{204{,}000}{.10} = \$2{,}040{,}000$$

$$PV\ (\text{Net benefits}) = PV(B) - PV(C) = 2{,}040{,}500 - 1{,}800{,}000 = 240{,}000$$

Conclusion: Carry out the project. The decision here is more favorable for the project because by using "before and after" valuation (rather than with and without), the project has counted in benefits and costs that are not incremental or attributable to the project.

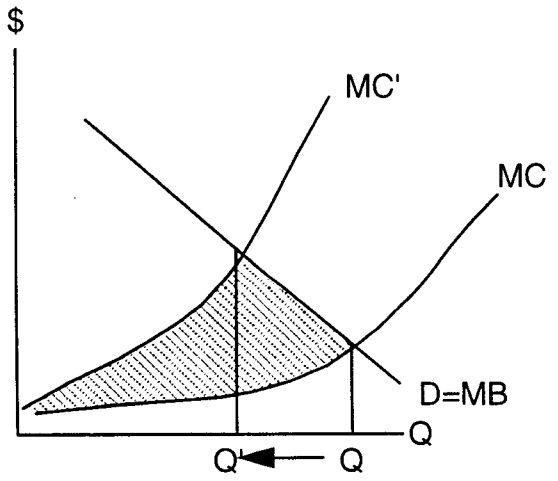


Stocks vs. Flows

The above example has also demonstrated that benefits and costs must either all be converted to flows (annual amounts) or all to stocks (present values) before they can be added, subtracted, or compared. For example, the loss of timber from deforestation is not additive with the loss of non-timber products or environmental services. The last two are annual, while timber can be harvested, say every 50 years. Either we must annualize the timber losses by multiplying by the interest rate (since for all intents and purposes, 50 years is an infinite horizon at the rates of discount used in project appraisal), or the non-timber forest product and services lost must be capitalized into present values.

Total vs. Marginal Values or Benefits (Or, when do we need the demand function?)

Our interest is not in the total values, or average values, but in marginal values. Usually we are not trying to estimate the total cost of environmental damage, or the total benefit of environmental improvements but the incremental. In the case of revealed preference methods, the way we get the value of the change (the incremental gain or loss)



is by first estimating the demand curve and then reading from the demand curve the value of the change (improvement or damage). We need the demand curve in order to learn how WTP to obtain an improvement (or to avoid a damage) varies with the level of improvement damages. In the case of survey methods, we obtain the value of the change directly by asking the respondents what their willingness to pay is to secure

improvements or to avoid the damage, or their willingness to accept to bear the damage or forego the improvement. Therefore, there is no point of attempting to construct a demand function out of contingent valuation estimates of WTP or WTA.

With regard to total vs. marginal value, it must be remembered that what we are doing is comparing two situations: the status quo with an improvement (or a deterioration). We are trying to value incremental changes not to estimate the total value of assets unless the change we are evaluating is the total loss of the asset. For example, if we are concerned with the value of the damages caused by increased levels of pollutants flowing into a lake, the relevant question is what is the value of services lost due to the increased level of pollutants, i.e., what are the incremental damages. For example, in the case of an oil spill such as the Exxon Valdez, the question was not what is the total value of the ocean that was polluted, or the total value of the resources that were degraded, but what was the lost value of the natural resources and services that were damaged.

The whole valuation is based on increments or decrements of welfare from a given level. Environmental improvements increase welfare by the amount of their benefits (as measured by WTP) and reduce welfare by the amount of their costs (as measured by the opportunity costs and hence benefits foregone from alternative uses of resources used in obtaining the environmental improvement). Similarly, environmental damage reduces welfare by the value of goods and services lost (foregone benefits) and increase welfare by the saved opportunity costs of inputs not used to abate the damage. If nothing is given up, i.e., scarcities have not increased (and hence there is no opportunity cost), the mere increased levels of pollution do not imply the loss of value.

There is a useful symmetry between benefits and costs: A benefit is a foregone cost; a cost is a foregone benefit.

Environmental damage has both a benefit, which is the cost avoided (abatement cost saved), and cost, which is the benefit foregone (amenity or service or output lost).

Environmental improvement has both a benefit, which is damage cost avoided, and a cost, which is benefit foregone from alternative uses of resources devoted to environmental improvement.

We can approach valuation from both the benefit and the cost side. Consider, for example, the valuation of improved industrial waste treatment.

benefits: reduced downstream water-purification cost, reduced morbidity, i.e., cost avoided.

costs: capital costs, operating costs, maintenance costs, i.e., benefits forgone from alternative uses of these resources.

Using Costs to Value Benefits

Several methods use costs to value benefits; i.e., the cost that one pays to obtain a good or service (including environmental improvement) is taken or his/her willingness to pay for the good or service at the margin. This is based on the fact that if the good or service was worth less, the consumer would not have been willing to pay the cost. If it is worth more than the cost, she would have bought more because her willingness to pay would have been higher than the cost, and she would have gained from doing so. Hence, the cost that is paid freely by the consumer in a competitive market represents his/her willingness to pay at the margin. But what about her WTP for all the intramarginal units? That is certainly higher than the cost, involving consumer surplus, but there is no way to know that unless we either ask the individual (which takes us to contingent valuation) or, we can somehow infer the demand curve and read from it to the individual's willingness to pay for different quantities of the good or for different levels of environmental improvement. This is why methods such as the travel cost and hedonic price involve a demand derivation step, which is unnecessary for contingent valuation. From variations of travel cost or property values, with environmental quality, we derive a demand function for environmental quality, which in turn enables us to read the WTP for different levels of environmental improvement (or deterioration). The net benefit is the consumer surplus from all the intramarginal units. Of course, the consumer surplus for the marginal unit is zero.

A particularly inappropriate use of costs to measure benefits is the replacement cost approach, especially when it is not based on revealed preference (as in the cases of

aversive or preventive behavior, or shadow project approach). Engineering replacement or remediation cost estimates are totally devoid of any "revealed preference" content; therefore, they have no foundation in social welfare economics and cannot be taken as measures of value. They lie along a supply curve, but we have no information at what point this curve interacts with a demand (or preference) function.

Using Benefits to Value Costs

Using benefits to value costs is more problematic. For example, using WTP for forest protection (or rather for the services that forest protection provides) as a measure of the cost of forest protection is inappropriate because there is no reason why the two would be equal or even close. In the absence of actual market behavior or revealed preference, WTP could be much higher or much lower than the supply cost. The only thing that we can say is that "no more than an amount equal to the total willingness to pay for forest protection should be paid on forest protection." But how much needs to be paid would depend on the costs of necessary inputs for the desired level of protection. The cost could be marginal or negative (as in the case of subsidy removal) or could be prohibitively high. Knowing the WTP provides us with an upper limit, but it does not absolve us from the need to estimate (and minimize) the supply cost (in this case, the cost of forest protection). Fortunately, often costs (opportunity costs) are easier to estimate than benefits (WTP).

Valuation Methods and Willingness to Pay

Willingness to pay (or to accept) is the theoretically correct measure of total economic value. Total economic value includes both use and non-use values. (See Box 3). The revealed preference method usually gives us only use values, and, therefore, an incomplete measure of total economic value, and hence of the willingness to pay for the change in environmental quality being valued. Only the contingent valuation method gives a complete measure of total economic value (inclusive of both use and non-use values, such option, bequest and existence values) and therefore a complete measure of

WTP. This may confuse some people in thinking that WTP is identical with contingent valuation. This is not correct. All methods seek an estimate of WTP, but only contingent valuation can obtain a complete estimate when there are non-use values that are not "priced" either by actual or surrogate markets, and, therefore, we have no behavioral footprint to base inferences about non-use values on. Where non-use values are not important relative to use values, or there are instruments or institutions that internalize non-use values (e.g., contributions to environmental groups, international transfers), then revealed preference methods give a fairly complete measure of total economic value.

Contingent valuation is not an opinion or attitude survey but a rigorous elicitation of individual preference functions. To be valid it requires a representative sample, careful design of questionnaires, scientific conduct of survey (including adequate information and time to respond), test for a large number of possible biases (strategic, starting point, hypothetical, payment instrument, third person presence, etc.) and econometric analysis of the results to identify the determinants of variations in WTP within the sample, and to make inferences about the population at large or benefit transfers to other projects.

Box 3 Total Economic Value

Total Economic Value (TEV) = Use Value (UV) + Non-Use Value (NUV)

Use Value = Direct Use Value (DUV) + Indirect Use Value (IUV) + Option Value (OV)
Non-Use Value = Existence Value (EV) + Bequest Value (BV)

Therefore:

TEV = (DUV + IUV + OV) + (EV + BV)
use value non-use value

Double Counting

Double counting is a distinct possibility in valuation because environmental damages and improvements get capitalized into property values. For example, it would be a double counting to add both the increased depreciation of buildings and equipment as a result of

acid rain, and the reduction in property values. Similarly, health losses and reduction of property values are not additive, but material damages and health losses are additive. Another example is soil erosion. It would be triple counting to add erosion-related (a) production losses, (b) additional fertilizer needed to restore the productivity of the soil, and (c) reduction in the prices of agricultural land suffering from soil erosion. Each of these suffices as a measure of the environmental damage. Of course one can, and should, use more than one of these methods of valuation to cross-check and reduce the variance in the estimates. But they should not be added up.

C. Full Marginal-Cost Pricing

Valuation of externalities is one step towards full-cost pricing of goods and services which have external costs or benefits. Only one type of cost matters in economics, opportunity costs, which is a reflection of foregone benefits from doing one thing rather than another. If nothing is given up, there are no costs incurred, regardless of expenditure. Implications follow: (1) not all out-of-pocket expenses are costs and (2) many costs do not involve out-of-pocket expenditures. Only one type of costs helps us make decisions—marginal costs (or, incremental costs)—which indicate the opportunity costs of producing one additional unit of output. It matters greatly how much output we are already producing. Total cost is a poor guide to decision making, and average cost is equally bad unless the marginal cost is constant and, hence, equal to the average.

From the society's point of view, it makes no difference whatsoever whether the costs are incurred in terms of labor, capital, energy, or materials purchased in the market, or through damages imposed on other activities or on the society at large through environmental degradation. A cost is a cost, as long as something of value has been given up by the society as a whole (i.e., it is not a mere transfer). Therefore, the social cost is equal to private or internal cost plus external cost.

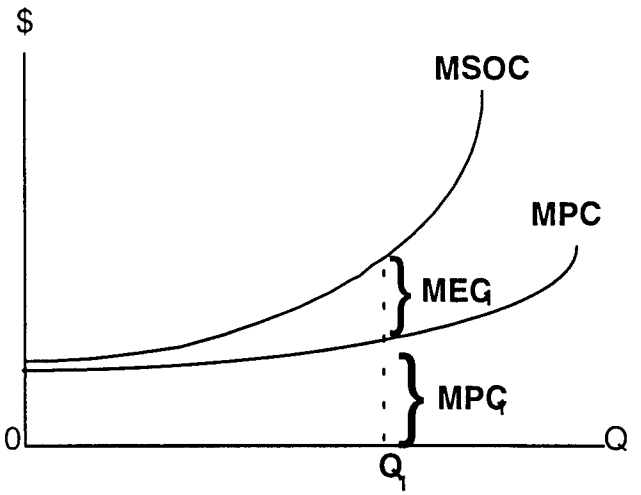
To make correct social decisions we must take into account the marginal social opportunity costs (MSOC).

MSOC = MPC + MEC

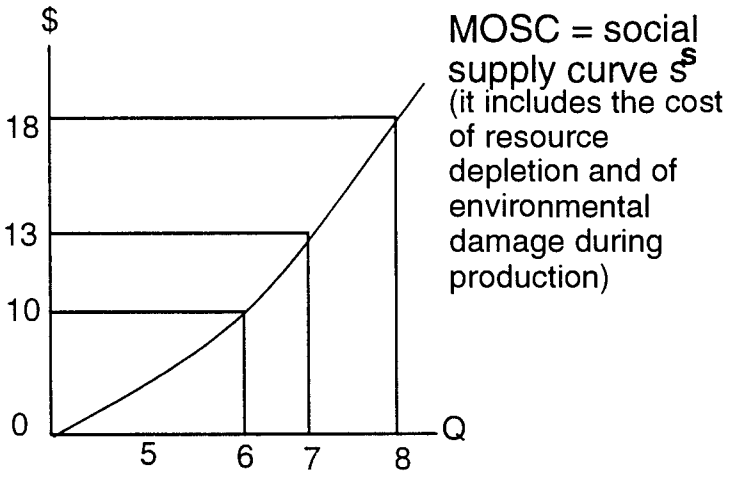
MSOC = marginal social opportunity costs

MPC = marginal private costs

MEC = marginal external costs

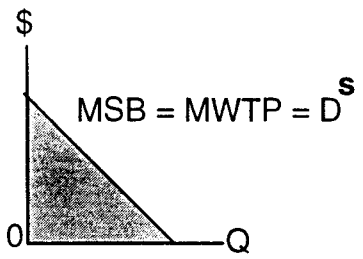


MOSC is the social supply curve; i.e., it indicates the least cost (sacrifice of alternatives) at which the society can produce additional units of output Q. For example, if we already produce 5 units of Q, to produce the sixth unit will cost $10; to produce the seventh unit will cost $13; and the eight unit will cost $18.



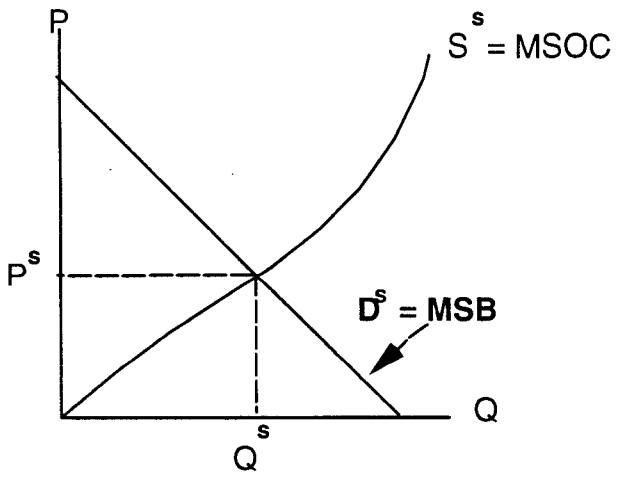
How much output would actually be produced would depend on the society's willingness to pay (WTP) for additional units of the good in question. The society's willingness to pay is in turn dependent on the expected benefit from the additional units of good, or, the marginal social benefit that reflects the individual or private benefit (or the sum of private benefits in the case of public goods) plus or minus any external benefits or costs not reflected in private benefit (e.g., sanitation and education have social benefits above private benefits; smoking has lower social than private benefits). MSB = MPB + MEB (MEB can be negative).

The marginal social benefit or marginal willingness to pay is the society's demand function which indicates the price at which the society is willing to buy (produce) additional units of a good.



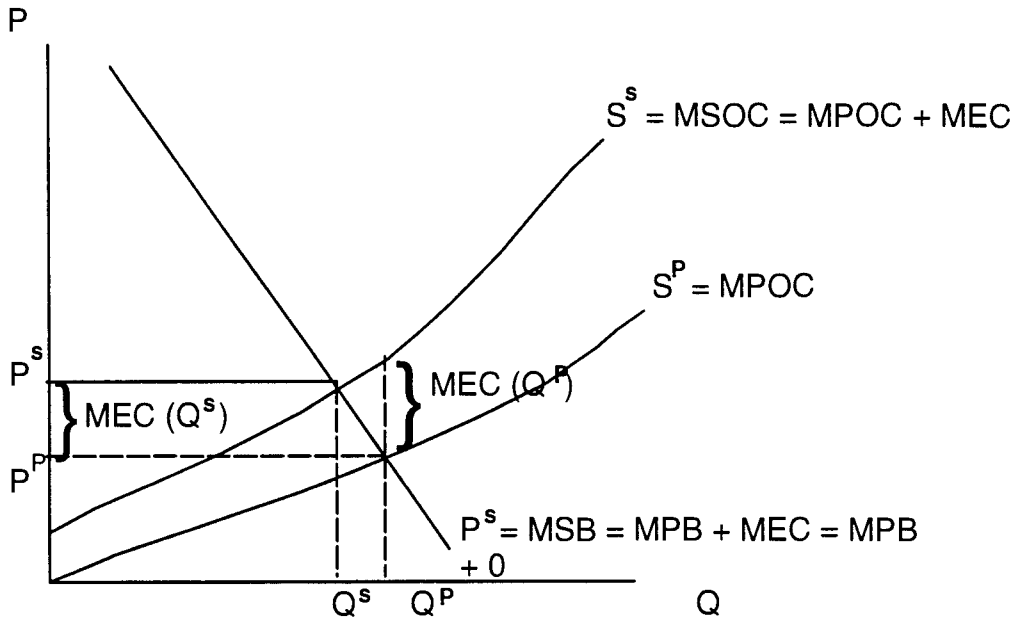
Recall that the MSOC, or social supply curve, reflects the price at which the society is able to produce additional units of the good (taking into account all sacrifices, i.e., all opportunity costs involved).

Putting social supply (S^s) and social demand (D^s) together, we obtain the socially optimal output (Q^s), and the socially optimal price (P^s), also known as full-cost price.



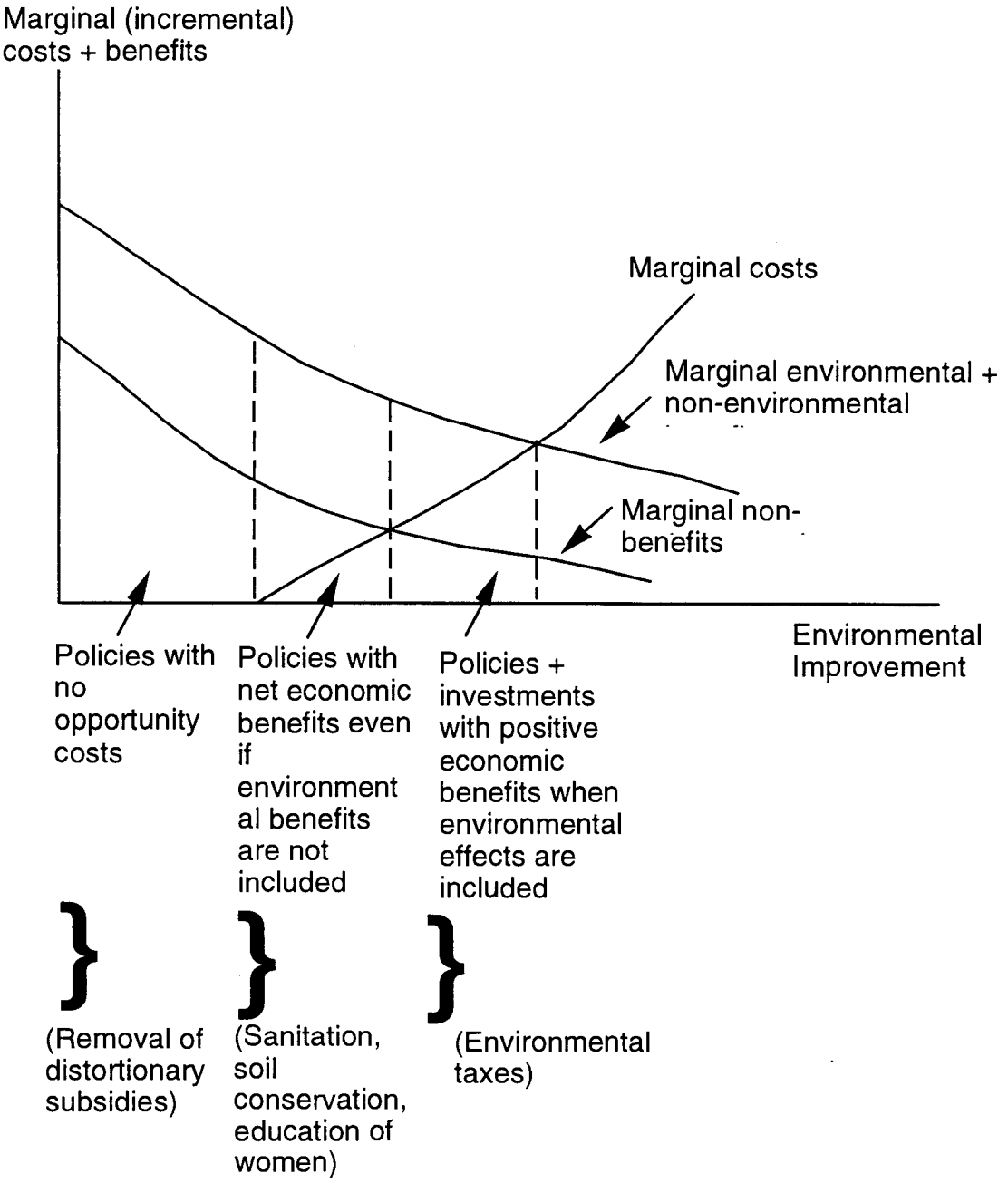
Social optimum

In the presence of external costs, the private optimum output of Q^P is higher than the social optimum output of Q^s and the private optimum price P^s because it is not a full cost price (it does not include external costs).



To bridge the gap between private and social costs, i.e. to effect full-cost pricing, we may use fiscal instruments such as taxes. The appropriate tax rate equals the marginal external cost at the optimum level of output (i.e. where the MSB curve intersects the MSC curve). When the demand curve accurately reflects social benefits and the supply cure fully reflects social costs, market clearing produces the Pareto efficient allocation of resources. This may or may not be a welfare maximum depending on the social acceptance of the prevailing distribution of income.

While valuation in the case of products with negative environmental impacts results in reduction in the socially optimal level of production of these products, in the case of environmental improvement projects valuation (and inclusion) results in a larger level of such improvements being socially optimal than otherwise as seen in the figure below.



D. Conclusion

Valuation of environmental impacts of policies, projects and processes, is essential for accurate appraisal of public projects and policies as well as for full-cost pricing of natural resource-and-environment-intensive commodities. Valuation helps determine mitigation measures for projects and environmental tax rates for goods and services. But valuation is a difficult exercise, done with limited data and ample room for

error. Since errors tend to be compounded in valuation exercises with both quantity and "price" uncertainty, it is important that care is taken to avoid common valuation errors of the type discussed in this paper. Of course, the coverage was more indicative than exhaustive, but it is safe to say that the more serious (both qualitatively and quantitatively) are basic errors such as "before and after" rather than "with" and "without", stocks versus flows, and double counting. Survey methods introduce a host of additional errors and biases due to the subjective and hypothetical nature of the approach. However, these difficulties can be mitigated with careful design of survey instruments and rigorous statistical tests of potential biases.