

Chapter 7

Assessing Benefits for Environmental Decision Making

Risk assessment and risk management are central to the decision-making process that guides environmental policy. Once the degree of environmental risk has been identified, public officials begin the critical task of formulating policy. Ultimately, the objective is to minimize risk, which is a benefit to society. Meeting this objective is not an unconstrained decision, however. There are opportunity costs. Public officials must consider that resources used to reduce smog are no longer available to clean the Great Lakes or to save the California condor or to improve public education. How do policymakers come to grips with such tough decisions? There is no simple answer, and, in fact, most would argue that the public sector wrestles with this problem on an ongoing basis. Yet there are decision-making strategies that can be effective in environmental policy development, among them, **benefit-cost analysis**.

Benefit-cost analysis underlies much of economic theory. For example, the balancing of revenues and costs at the margin to maximize profit is an application of benefit-cost analysis. In the broader context of policy decisions, benefit-cost analysis is used to evaluate the associated gains and losses to society as a whole. In every case, the basic principle is the same: An efficient solution results if benefits and costs are balanced at the margin.

Having said this, it should be apparent that the theoretical footing of benefit-cost analysis is sound. However, applying this theory in practice is not so clear-cut. In order to use benefit-cost analysis to guide environmental decisions, policymakers must quantify the associated social benefits and costs. Yet many intangibles that are difficult to measure in monetary terms are involved, for example, longevity of human life, improved aesthetics, and the preservation of ecosystems. Although the process is difficult, it is critically important. Governments everywhere are spending huge sums to develop and implement environmental policy. In the United States alone, the annual expenditure is about \$120 billion. Such large appropriations cannot be made without understanding the economic implications on both sides of the ledger. Hence, there is no debate that policymakers need reliable measures of social benefits and costs to help guide these important decisions.

In this chapter, we explore the motivation for valuing **environmental benefits** and the methods used to measure them. We start by presenting the conceptual issues of how and why society values natural resources and environmental quality. This theoretical framework supports our subsequent investigation of various benefit estimation methods. Once this side of the analysis is complete, we conduct an analogous study of costs in Chapter 8. All of this lays the groundwork for studying how the two elements come together in a benefit-cost analysis, which is the subject of Chapter 9.

Identifying and Valuing Environmental Benefits: Conceptual Issues

As a starting point, we need to establish the appropriate level of analysis for assessing policy-induced environmental benefits. From previous chapters, we know that these health and ecological gains can be assessed as damage reductions. The key is to recognize that the relevant measure is the *change* in damage reductions brought about by policy. In practice, these changes are called **incremental benefits**.

Defining Incremental Benefits

To assess the social benefits attributable to environmental policy, decision makers must find out how health, ecological, and property damages change as a consequence of that policy. This focus on the *change* in damages instead of on their absolute level is not new. Economic theory is concerned with effects that occur *at the margin*. These too are changes, although they are infinitesimal—measured at a point. When the relevant change is over a discrete range, it is referred to as **incremental** rather than as **marginal**. Because policy evaluation is concerned with identifying damage reductions over some discrete time period, the appropriate measure of benefits is incremental.

To identify incremental benefits, analysts must compare the actual or expected benefits to society after some policy is implemented to a baseline measure of current conditions. Environmental benefits are commonly separated into categories, such as improvements in human health, aesthetics, the economy, recreation, property, and the ecology. Application 7.1 discusses how incremental benefits were estimated to support an important revision in U.S. air quality standards for particulate matter.

Defining Primary and Secondary Environmental Benefits

Within the broad category of incremental benefits are two types of damage-reducing effects: **primary environmental benefits** and **secondary environmental benefits**. A **primary environmental benefit** is a damage-reducing effect that is the *direct* consequence of implementing policy. Compare this with the concept of a **secondary environmental benefit**, which is an *indirect* gain to society associated with the implementation of policy.

Primary Environmental Benefits

Most environmental policy actions are aimed at increasing primary benefits, particularly those associated with human health. Health benefits include both decreased mortality (e.g., a reduction in the risk of cancer deaths) and reduced morbidity (e.g., a lower incidence of respiratory ailments). Other primary benefits include more stable ecosystems and improved aesthetics. Still other primary benefits are economic, such as a more prosperous fishing industry that results from the enactment of clean water regulations. What these benefits have in common is that they are a *direct* outcome of environmental policy.

Secondary Environmental Benefits

Secondary environmental benefits arise *indirectly* from a policy change. One source might be the stimulative effect of a primary benefit, such as higher worker productivity that results from the primary benefit of improved health. Higher productivity increases the availability of goods and services, which may lead to a decline in prices. Because these gains are stimulated by a primary benefit and arise indirectly, they are considered secondary benefits. An alternative source is a demand-induced change, such as the increased demand for labor to implement a new policy. In this case, the economic gains of an improved labor market are a secondary benefit.¹

Conceptually Valuing Environmental Benefits

What is the value to society of cleaner air or cleaner water? What value does society place on cleaning up a hazardous waste site? As we have discussed in previous chapters, both questions could be answered directly if the commodity in each case were a private good traded in the open market. Then demand prices would convey the marginal benefit of each additional unit of the good. The problem is that environmental quality is a public, nonmarketed good. The absence of prices and the dilemma of nonrevelation of preferences cloud a determination of how society values a cleaner environment. In theory, if we could infer society's demand for

incremental benefits
The reduction in health, ecological, and property damages associated with an environmental policy initiative.

primary environmental benefit
A damage-reducing effect that is a direct consequence of implementing environmental policy.

secondary environmental benefit
An indirect gain to society that may arise from a stimulative effect of primary benefits or from a demand-induced effect to implement policy.

¹There is some debate about whether secondary benefits should be considered when assessing public policy proposals. It is argued that these indirect gains in one market or region are offset by losses in another. There is also the practical problem of trying to measure these types of benefits. Hence, many researchers exclude them from their analyses. See, for example, Haveman and Weisbrod (1975).

Application

7.1 Incremental Benefit Estimates for Revising U.S. Particulate Matter Standards

In 1983, the EPA prepared a Regulatory Impact Analysis (RIA) for a proposal to tighten the air quality standard for particulate matter. (The RIA was required under President Reagan's Executive Order 12291.) Particulate matter (PM) refers to a broad class of contaminants that are emitted into the air as small particles. As part of the requirements of the RIA, the EPA had to estimate the incremental benefits of this proposal.

Relying on the findings of scientific studies, the EPA determined that exposure to PM is linked to such health problems as respiratory and cardiovascular disease. The agency further found that the associated welfare effects include (1) soiling of buildings and materials, (2) increased acidic deposition through releases of sulfate particles, and (3) visibility impairment. Using this qualitative assessment as a basis, the EPA had to estimate how much these damages would be reduced by the proposed change in the PM standard and then monetize its findings.

To illustrate the inherent variability in quantifying environmental benefits, the accompanying table presents the series of benefit estimates actually used in the EPA's evaluation. For each benefit class, the letters A through F indicate the various procedures used to derive the estimates.

Procedure A is the most conservative, since its total of \$1.24 billion includes only the

benefits of reduced mortality and chronic illness. At the other end of the spectrum, Procedure F is the most comprehensive. It includes *all* expected health and welfare benefits, that is, the reductions in mortality and morbidity plus the reduced soiling and material damages. According to this latter approach, the incremental benefits of tightening the PM standard are valued at \$52.36 billion.

Beyond the differences in aggregation across the six procedures, there is also variability in how the individual benefit categories are valued. For example, according to Procedures A through C, mortality benefits are monetized at \$1.12 billion, but Procedures D and E place a value on this same category of \$12.72 billion, and Procedure F an even higher value of \$13.84 billion.

An important inference to be made from these data is that benefit assessment is not an exact science. Rather, it relies on approximations based on a consensus of experts and supported by available scientific evidence. Often, as is the case here, a *range* of benefit estimates is considered, with each estimate based on certain underlying assumptions.

Sources: Mathtech Inc. (March 1983), pp. 1–52; U.S. EPA, Office of Policy Analysis, Office of Policy, Planning, and Evaluation (August 1987).

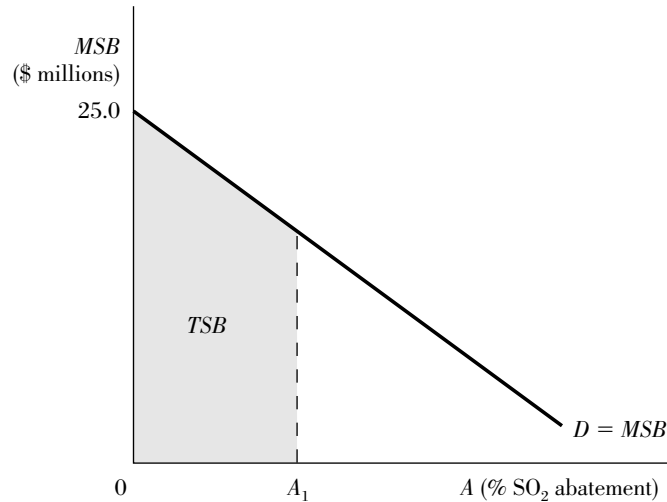
**Incremental Benefit Estimates,
by Aggregation Procedure
(billions of 1980 dollars)**

Benefit Class	A	B	C	D	E	F
Mortality	1.12	1.12	1.12	12.72	12.72	13.84
Acute morbidity	0.00	1.32	10.65	10.65	10.65	11.97
Chronic morbidity	0.12	0.12	0.12	0.12	11.40	11.40
Soiling and materials (household sector)	0.00	0.00	0.73	0.73	3.14	13.85
Soiling and materials (manufacturing sector)	0.00	0.00	0.00	0.00	1.30	1.30
Total incremental benefits	1.24	2.56	12.63	24.24	39.22	52.36

Note: Some totals may not agree due to independent rounding.

Figure 7.1 *Marginal Social Benefit (MSB) and Total Social Benefits (TSB) of Air Quality (% SO₂ Abatement)*

The market demand curve for SO₂ abatement represents the marginal social benefit (*MSB*) of air quality. At the hypothetical level of abatement A_1 , the corresponding *MSB* is the vertical distance from the horizontal axis at that point up to the curve. The total social benefits (*TSB*) associated with A_1 are shown as the shaded area under the *MSB* up to that point.



environmental quality, we could then measure the incremental benefits associated with any environmental policy.

To illustrate this assertion, we return to our model of air quality based on SO₂ pollution abatement, which we introduced in Chapter 3. Recall that since demand for this public good represents society's decisions, it is both the marginal private benefit (*MPB*) and the marginal social benefit (*MSB*) of air quality. Thus, we can refer to the demand for SO₂ abatement as $MSB = 25 - 0.3A$, where *MSB* is measured in millions of dollars and *A* is the percentage of SO₂ abated.

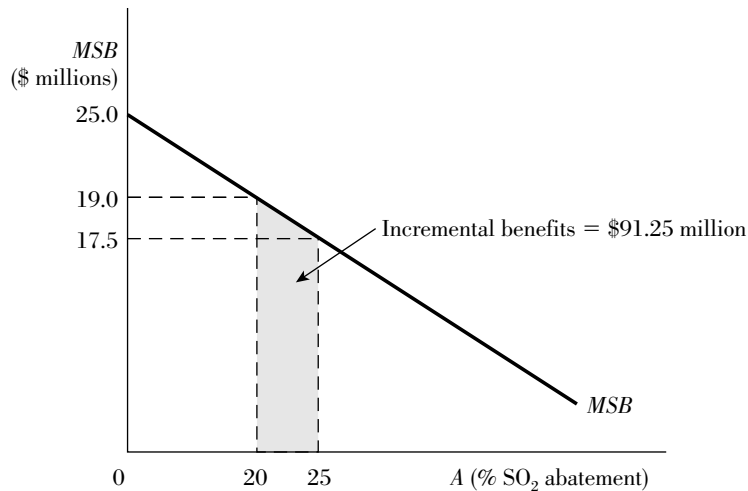
The graph of this relationship is shown in Figure 7.1. At each level of abatement, *MSB* is measured as the vertical distance from the horizontal axis up to the demand curve. The total social benefits (*TSB*) for any abatement level are measured as the aggregation of these vertical distances, or the area under the *MSB* curve up to that point.² In Figure 7.1, the *TSB* for some hypothetical abatement level A_1 is shown as the shaded area under the demand curve up to A_1 . Using this model, we can measure the incremental benefits from a policy-induced increase in SO₂ abatement in three steps:

1. Find the baseline level of *TSB* before the policy is undertaken
2. Find the new level of *TSB* that would arise after the policy is implemented
3. Subtract the baseline *TSB* from the post-policy *TSB* to determine incremental benefits.

²Recall from Chapter 2 that the area beneath the demand curve and above the market price is consumer surplus, or the *net* benefit enjoyed by consumers. Notice that this net benefit is exactly equal to the total benefits received minus the total dollar value paid for the good. In fact, if a commodity has a zero market price, the total benefits would be exactly equal to consumer surplus.

Figure 7.2 Modeling Incremental Social Benefits for Air Quality (% SO₂ Abatement) Using the MSB Function

The *MSB* at the baseline abatement level of 20 percent is \$19 million, and the *TSB* are shown as the area under the *MSB* curve up to that point, or \$440 million. If a policy were proposed to increase SO₂ abatement to 25 percent, *MSB* would be \$17.5 million and *TSB* would rise to \$531.25 million. Thus, the incremental benefits are measured as the difference between the two *TSB* values, or \$91.25 million. In this model, incremental benefits are shown as the shaded area under the *MSB* curve between the two abatement levels.



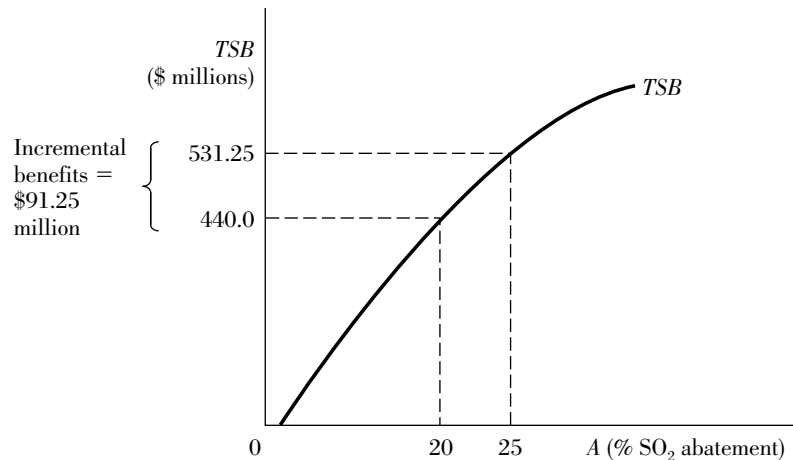
Suppose that the current level of SO₂ abatement is 20 percent and the objective is to find the incremental benefits of a policy that increases abatement to 25 percent. First, find the baseline *TSB*. Referring to Figure 7.2, notice that *MSB* at the 20 percent abatement level is \$19 million. *TSB* at this level are shown as the area under the *MSB* curve up to that point, or \$440 million. This dollar value represents society's **willingness to pay (WTP)** for the benefits achieved when 20 percent of SO₂ emissions are abated. Next, do the analogous calculations for the proposed abatement increase to 25 percent. At this post-policy abatement level, *MSB* is \$17.5 million and *TSB* equal \$531.25 million. Finally, the incremental benefits are found as the difference between the two *TSB* values, or \$91.25 million. This is shown as the shaded area in Figure 7.2.

An alternative model of the same result is shown in Figure 7.3, where the *TSB* are graphed directly with SO₂ abatement. In this model, the *TSB* associated with a given abatement level are measured simply as the vertical distance up to the curve and not as an area. Identify on the graph the pre- and post-policy levels of *TSB* corresponding to the 20 percent and 25 percent abatement levels. Notice that the incremental benefits of \$91.25 million are measured as the vertical distance between these two *TSB* levels.

Both models assume that society's valuation of environmental quality, or, equivalently, its demand for pollution abatement, can be identified. However, because there is no explicit market for this commodity, the valuation cannot be obtained from observing market-determined prices. Instead, inferences must be made about *how* society derives value or utility from various levels of environmental quality.

Figure 7.3 *Modeling Incremental Social Benefits for Air Quality (% SO₂ Abatement) Using the TSB Function*

An alternative way to model the incremental benefits of improving air quality is to graph the relationship between the *TSB* and SO₂ abatement. At each abatement level, the *TSB* are shown as the vertical distance from the horizontal axis up to the curve. The model shows the *TSB* for the 20 percent baseline abatement level and for the 25 percent post-policy abatement level as \$440 million and \$531.25 million, respectively. The incremental benefits are shown as the vertical distance between the two points on the *TSB* curve, or \$91.25 million.



User Versus Existence Value³

Discovering how society values a good is difficult in the absence of market prices. Even if the dilemma of nonrevelation of preferences could be overcome, the value of a good like clean air or water is difficult to quantify because of the many intangibles involved. Although economists recognize that some of these intangibles are immeasurable, they still need some sense of how the benefits of environmental quality are *perceived* by society. Fortunately, theories have been advanced that can help.

From a purely conceptual vantage point, it is generally recognized that society derives utility from environmental quality through two sources of value: **user value** and **existence value**. **User value** refers to the utility or benefit received from usage of or access to an environmental good. In contrast, **existence value** is the utility or benefit received from an environmental good simply through its continuance as a good or service. Collectively, these components measure society's total valuation of an environmental good, expressed as follows:

$$\text{Total value of environmental quality} = \text{User value} + \text{Existence value.}$$

User Value

To better understand user value, consider the benefits of using a lake. If an individual swims in a lake, that person is deriving utility from physically using the natural resource. Likewise, a commercial fishing fleet derives user benefit from catching fish from the lake. In both cases,

user value

Benefit derived from physical use or access to an environmental good.

existence value

Benefit received from the continuance of an environmental good.

³Much of the following discussion is drawn from Mitchell and Carson (1989), chap. 3.

direct user value

Benefit derived from directly consuming services provided by an environmental good.

indirect user value

Benefit derived from indirect consumption of an environmental good.

vicarious consumption

The utility associated with knowing that others derive benefits from an environmental good.

stewardship

The sense of obligation to preserve the environment for future generations.

benefits are derived from directly consuming services provided by the resource. These activities, both recreational and commercial, generate benefits that yield **direct user value**. This valuation helps to determine what the individual or the fishing fleet would be willing to pay to maintain or improve the lake's quality.

Continuing with the same example, another individual might receive utility from simply looking at a view of the lake. Here, the utility is derived from the lake's aesthetic qualities. This type of activity involves using the lake in a less immediate way than swimming in it or fishing from it. Hence, the lake is said to yield **indirect user value**. Both direct and indirect user value are elements of society's total valuation of environmental quality.⁴

Existence Value

Society also receives benefits from environmental goods beyond the utility associated with direct or indirect use. Think about how people value such natural resources as the great rain forests, the Grand Canyon, or the bald eagle. Consumption does not explain how or why society values these resources. Yet we know that society as a whole is willing to pay to preserve them. In such circumstances, benefits accrue to society from simply knowing that these resources exist and are being preserved. This component of total valuation is referred to as **existence value**.

While seemingly abstract, existence value is an important motivation for privately funded conservation efforts and for many environmental policy initiatives. A case in point is the Endangered Species Act, which provides for the protection and preservation of certain animals, birds, fish, and plants threatened with extinction.⁵ As discussed in Application 7.2, this act is an example of the U.S. government's recognition of existence value. Other tangible evidence is the willingness of society to support the work of environmental groups, such as the National Wildlife Federation, the Sierra Club, and the National Audubon Society—groups whose agendas focus on preserving resources that many of their benefactors never expect to use or even see firsthand.

One of the earlier discussions of existence value is presented by Krutilla (1967), who asserts: "When the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals."⁶ Since this early work, economists have been studying various theories about the motivations for existence value. In a text about valuing public goods, Mitchell and Carson (1989) classify the motives for existence value as **vicarious consumption** and **stewardship**, among others.

Vicarious consumption refers to the notion that individuals value a public good for the benefit it provides to others whether or not these others are known personally. This suggests that the utility derived is *interdependent*, that is, that an individual can and does receive benefit from the knowledge that others are enjoying the public good. **Stewardship** arises both from a sense of obligation to preserve the environment for future generations *and* from the recognition of the intrinsic value of natural resources. In sum, we can express the total valuation of environmental quality as:

$$\text{Total value} = \text{User value} + \text{Existence value.}$$

(direct and indirect user value) (vicarious consumption and stewardship value)

⁴ Although these examples involve present period consumption, economists also have begun to examine how society expects to benefit from consumption in some future period. This valuation concept, which adds uncertainty to benefit assessment, is referred to as option value. For detail on this concept, see Mitchell and Carson (1989), chap. 3, and Johansson (1991).

⁵ To view the text of the Endangered Species Act and to research information on endangered species, visit http://www.nmfs.noaa.gov/prot_res/laws/ESA/esatext/esacont.html.

⁶ Krutilla (1967), p. 779. Krutilla attributes the birth of conservation economics to A. C. Pigou, an English economist who wrote: "It is the clear duty of government, which is the trustee for unborn generations as well as for its present citizens, to watch over, and if need be, by legislative enactment, to defend, the exhaustible natural resources of the country from rash and reckless spoliation" (Krutilla 1967, p. 777, citing Pigou 1952).

7.2 The Endangered Species Act

In 1973, Congress passed the Endangered Species Act to “provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved” (sec. 2b). Officially, the act protects the biodiversity of the earth: the diversity of genes, species, ecosystems, and the interaction among them. An important outcome of this act was the creation of a formal list of biological organisms in danger of extinction, *regardless of their direct or indirect use to humans*. Originally numbering 109 in 1973, the list of endangered and threatened species in the United States has grown to include over 1,250 species as of 2002.

When the Endangered Species Act was originally proposed and when it went through its subsequent reauthorizations, arguments were made to justify its passage on economic grounds. One argument was that species were to be protected because they may serve a direct benefit to mankind that scientific study has not yet discovered. Some justification for this argument can be found in the recent discovery of taxol. This compound, found in the bark of Pacific yew trees, holds promise for the treatment of certain cancers.

Approximately 60 pounds of yew bark are needed to produce enough taxol to treat one cancer patient, and the Pacific yew is a slow-growing species being harvested by timber companies at a rapid rate. Notice that this discourse focuses on the **user value** of environmental resources.

Just as strong in their position were those who asserted that environmental resources offer benefits that span a much broader range than their direct or indirect value in human consumption. Here, the premise is that species should be protected based on a presumed right of survival—evidence of the role of **existence value** in benefit assessment.

There is not now, nor is there likely to be, a consensus about whether user value is relevant to the benefit assessment of biodiversity. What *is* clear is that society recognizes and appreciates existence value—an issue that continues to emerge in the ongoing deliberation about biodiversity and economic development.

Sources: *Endangered Species Act of 1973*, 16 U.S.C. § 153–44; Adler and Hager (April/May 1992); Council on Environmental Quality (January 1993), pp. 17–28.

Recognizing how society values an environmental resource is important for identifying the social benefits of a policy proposal. It also helps economists decide which estimation method might be most effective in quantifying those benefits. Yet the question remains: How do economists assign dollar values to nonmarketed environmental goods such as clean water, human health, and the spotted owl? Remember that the objective is to *monetize* or find the WTP for changes in user and existence value arising from a policy-driven increase in environmental quality.

Approaches to Measuring Environmental Benefits: Overview⁷

Economists have made great strides in developing methods to estimate the benefit of environmental quality improvements. For the most part, these methods are aimed at estimating primary benefits, implicitly assuming that secondary benefits are insignificant and likely offset by secondary costs. A review of the extensive literature on the subject shows that several methods are used in practice. Some are better than others at quantifying the more intangible benefits of improved environmental quality, including the somewhat elusive concept of existence value.

⁷This section is drawn mainly from Mitchell and Carson (1989), particularly pp. 74–78, and from Cropper and Oates (June 1992).

Table 7.1 *Synopsis of Benefit Estimation Methods*

Approach and Method	Description
Physical linkage approach	
Damage function method	Uses a model of the relationship between levels of a contaminant and observed (or statistically inferred) environmental damage to estimate the damage reduction arising from a policy-induced decline in the contaminant.
Behavioral linkage approach	
<i>Direct methods</i>	
Political referendum method	Uses the <i>actual</i> market of a public good by monitoring voting results from political referenda on proposed changes in environmental quality.
Contingent valuation method (CVM)	Uses surveys to inquire about individuals' willingness to pay (WTP) for environmental improvements based on <i>hypothetical</i> market conditions.
<i>Indirect methods</i>	
Averting expenditure method (AEM)	Assesses changes in an individual's spending on goods and services that are <i>substitutes</i> for personal environmental quality to assign value to changes in the overall environment.
Travel cost method (TCM)	Values a change in the quality of an environmental resource by assessing the effect of that change on the demand for a <i>complementary</i> good.
Hedonic price method (HPM)	Uses the theory that a good is valued for the attributes it possesses to estimate the implicit or hedonic price of an environmental attribute and identify its demand as a means to assign value to policy-driven improvements in quality.

To organize our discussion of benefit measurement methods, we rely upon a general classification introduced by Smith and Krutilla (1982), which places the various measurement techniques into two broad categories: the **physical linkage approach** and the **behavioral linkage approach**. A summary of selected benefit valuation methods within each approach is presented in Table 7.1.

physical linkage approach

Estimates benefits based on a technical relationship between an environmental resource and the user of that resource.

behavioral linkage approach

Estimates benefits using observations of behavior in actual markets or survey responses about hypothetical markets.

Physical Linkage Approach to Environmental Benefit Valuation

Methods in the **physical linkage approach** use some tangible attribute of the environment to make a connection to an individual through which benefits can be observed or inferred and subsequently valued. More formally, the **physical linkage approach** measures benefits based on a technical relationship between an environmental resource and the user of that resource. A common estimation procedure that uses this approach is the **damage function method**. This method uses a functional relationship to capture the link between a contaminant and any associated damages. Based on this function, incremental benefits are measured as the reduction in damages arising from a policy-induced decrease in the contaminant. This damage reduction is then monetized to obtain a dollar value of the benefits brought about by the policy.

Behavioral Linkage Approach to Environmental Benefit Valuation

In general, the **behavioral linkage approach** to quantifying benefits is based upon observations of behavior in *actual* markets or survey responses about *hypothetical* markets for environmental goods. Another element of behavioral linkage methods deals with how closely the behavior or responses are linked to the environmental good. Techniques that assess responses

immediately related to environmental changes are broadly termed **direct methods**. As shown in Table 7.1, two types of direct methods are the **political referendum method**, which relies on *actual* market information, and the **contingent valuation method (CVM)**, which uses *hypothetical* market data. **Indirect methods** are those that examine responses not about the environmental good itself but about some set of market conditions related to it. Three examples of indirect benefit estimation methods are the **averting expenditure method (AEM)**, the **travel cost method (TCM)**, and the **hedonic price method (HPM)**.

The published literature on benefit valuation methods is extensive. Many research papers present specific empirical findings, and numerous texts focus on the methodology itself. We offer only an overview of the operational issues associated with the more common methods used by researchers.⁸

Estimation Under the Physical Linkage Approach

Damage Function Method

When using the **damage function method**, the researcher specifies a model of the relationship between an environmental contaminant and some type of observed damage.⁹ A generalized damage function is shown in Figure 7.4. The levels of some environmental contaminant (C) are measured horizontally, and the total damages (TD) resulting from exposure to that contaminant are measured vertically.¹⁰ Once the function is specified, the analyst uses the model to estimate the damage reduction from any policy-induced decline in the contaminant. At this point, the reduction is measured in nonmonetary units, for example, the number of acidified lakes, acres of damaged forests, or number of premature deaths. Ultimately, this reduction must be assigned a monetary value, either by using market prices (if available) or by employing some estimation technique.

To illustrate the procedure, look at Figure 7.4, and assume that a policy initiative is expected to reduce the contaminant from C_0 to C_1 . Based on the damage function model, this proposal would reduce damage (or, equivalently, increase benefits) by the vertical distance between TD_0 and TD_1 . If, for example, the damage reduction was diminished injury to wheat crops, this vertical distance might be measured as thousands of bushels of wheat. Having quantified the incremental benefit, a simple way to monetize it would be to multiply the number of bushels by the market-determined price.

Assessing the Damage Function Method

Although the damage function method is useful, it has limitations. First, by construction, it estimates only one aspect of incremental benefits. In our example, the measured benefits are increased wheat crops. In most cases, a contaminant reduction would give rise to other types of gains, perhaps increases in other crops or improvements in human health. Hence, a full assessment of benefits using the damage function approach would require that the same estimating procedure be performed for every type of damage reduction. Second, the procedure is only a first-step approach in that it is not capable of simultaneously monetizing the benefits it quantifies.

Applications of the Damage Function Method

Recognizing the limitations of the damage function method, analysts typically use it for measuring a specific type of incremental benefit as opposed to performing a comprehensive benefit assessment. Furthermore, the context is often one in which market-determined prices can be used to monetize the gain.

damage function method

Models the relationship between a contaminant and its observed effects as a way to estimate damage reductions arising from policy.

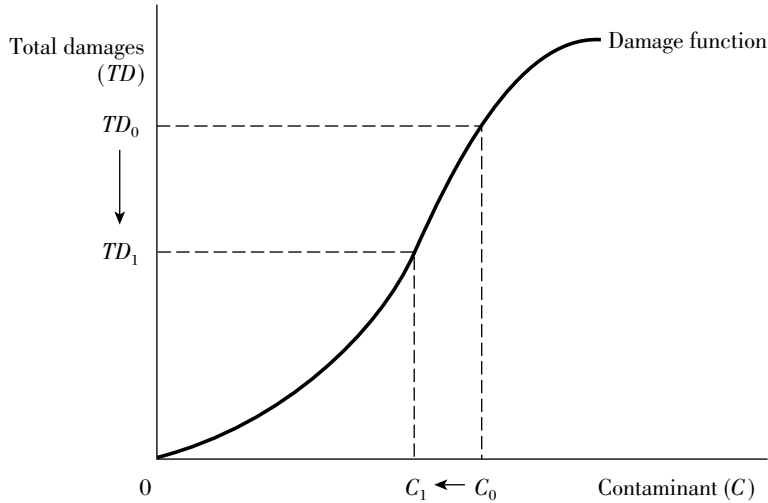
⁸To study any of these methods in detail, consult the references cited along the way and the list of additional readings given at the end of the chapter.

⁹If the benefit assessment is the reduction in adverse effects to a *biological organism*, the analyst would use a **dose-response function**, which is a particular type of damage function. Recall from Chapter 6 that scientists use dose-response functions in the risk assessment process.

¹⁰The model in Figure 7.4 is a cubic relationship, but this is just one possible functional form for a damage function. For more on this issue, see, for example, Halvorsen and Ruby (1981), p. 106.

Figure 7.4 *Measuring Incremental Benefits Using the Damage Function Method: A Physical Linkage Approach*

A damage function shows the relationship between an environmental contaminant (C) and the total damages (TD) due to exposure to that contaminant. Once the function is specified, the analyst can use it to estimate the damage reduction from any policy-induced decline in the contaminant. This damage reduction represents incremental benefits measured in non-monetary units.



To illustrate, consider a benefit assessment of the Clean Air Act provisions aimed at reducing ozone in the lower atmosphere or troposphere. According to scientific evidence, one type of benefit associated with reducing tropospheric ozone is an increase in crop yields.¹¹ Conceptually, these agricultural benefits could be modeled by measuring the change in consumer and producer surpluses associated with an increase in crop yields. Figure 7.5 models this policy-induced effect as an increase in crop supply from S_0 to S_1 , which in turn causes a price decline from P_0 to P_1 .

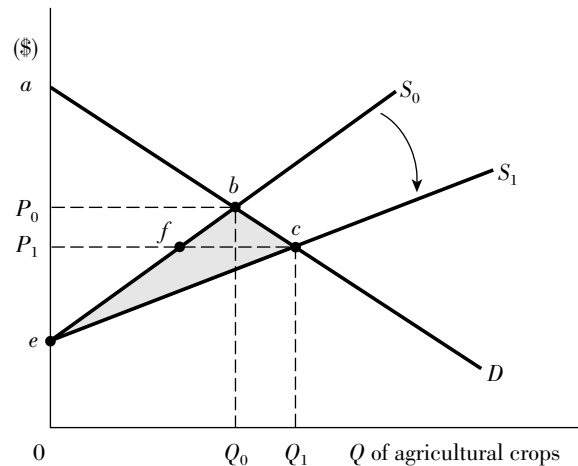
Consider first the size of the surpluses before any policy change, using supply curve S_0 . Consumer surplus is the area below the demand curve and above the market price, or area P_0ab . Producer surplus is the area above the supply curve and below the market price, or area P_0be . Thus, the total surplus *before* a policy change is area eab . After the ozone-reducing policy is implemented and supply shifts to S_1 , consumer surplus becomes area P_1ac , and producer surplus becomes area P_1ce . Thus, the total surplus *after* the policy change is area eac . The operative question is whether society is better off as a result. Since the total surplus increased from eab to eac , the answer is yes, and the incremental benefit can be quantified as area ebc (i.e., $eac - eab$).

Notice, however, that the *distribution* of benefits is not as easily determined. Consumers definitely gain, because consumer surplus rises from P_0ab to P_1ac , but the same assertion cannot be made about producers. Some of the original producer surplus, area P_0bfP_1 , has

¹¹The interested reader may wish to consult Kopp and Krupnick (December 1987) for results of an empirical investigation that estimates the agricultural benefits of ozone reduction.

Figure 7.5 *Modeling Incremental Benefits of an Ozone-Reducing Policy*

The increase in crop yields associated with a hypothetical ozone-reducing policy can be modeled as a shift in crop supply from S_0 to S_1 . Before the policy is implemented, consumer surplus is area P_0ab and producer surplus is area P_0be , for a total of area eab . After the policy is implemented and supply shifts to S_1 , consumer surplus becomes area P_1ac and producer surplus becomes area P_1ce , for a total of area eac . Thus, the incremental benefit is area ebc (i.e., $eac - eab$).



been transferred to consumers, but there is also a gain to producers of area efc . Whether or not the gain of efc exceeds the transfer of P_0b/P_1 depends on the shapes of the supply and demand curves and the magnitude of the shift in supply. Consequently, to measure the incremental benefits of policy *and* to determine the distribution of these benefits, sophisticated models must be used. Application 7.3 presents the actual results of such a benefit estimation conducted as part of a U.S. air quality assessment.

Direct Estimation Methods Under the Behavioral Linkage Approach

The so-called **direct methods** under the behavioral linkage approach estimate environmental benefits according to responses or observed behaviors directly tied to environmental quality. Although a number of direct methods are available to researchers, we consider only one representative example: the **contingent valuation method (CVM)**.

Contingent Valuation Method (CVM)

When market data are unavailable or unreliable, economists can use alternative estimation methods that rely on *hypothetical* market conditions. Such methods typically use surveys to inquire about individuals' willingness to pay (WTP) for some environmental initiative. This survey approach to benefit estimation is known as the **contingent valuation method**

contingent valuation method (CVM)

Uses surveys to elicit responses about WTP for environmental quality based on hypothetical market conditions.

Application

7.3 Valuing Agricultural Benefits: The Case of Tropospheric Ozone Reductions

The National Acid Precipitation Assessment Program (NAPAP) was launched as an investigative plan to gather information for formulating policy on acidic deposition. According to NAPAP's 1990 report, scientific research has been unable to find a consistent adverse effect on crop yields caused by acidic deposition. However, there is well-documented evidence that elevated levels of tropospheric ozone can diminish crop yields. In fact, estimates of this damage range from 2 to 56 percent, depending on such factors as crop species, location, and exposure levels. Thus, a key part of NAPAP's research dealt with quantifying the incremental benefits that would result from an ozone-reducing policy initiative.

Modeling techniques to measure environmental benefits were used in the NAPAP study of ozone's effects on agricultural yields. The final report presents estimates of changes in consumer and producer surplus for alternative ozone policies (see accompanying table). Under the first scenario, a 10 percent reduction in ozone concentrations is esti-

mated to increase total surplus by approximately \$739 million. Of this amount, consumer surplus would increase by \$785 million, and producer surplus would decline by \$46 million. A more restrictive ozone policy, such as a 25 percent reduction, would increase the benefits to both producers and consumers and elevate the change in total surplus to \$1,732 million.

These findings have important implications about the distribution of these incremental benefits across buyers and sellers. Notice that consumers and producers do not respond symmetrically to increases in ozone levels. In fact, if ozone levels were to *increase* by either 10 or 25 percent, society as a whole would lose but producers would actually benefit. According to the NAPAP report, this gain to producers arises because of farmers' ability to pass on the higher costs of depleted supplies to consumers in the form of higher prices.

Source: NAPAP (November 1991), pp. 55, 154–56, 398–401.

Changes in Ozone (%)	Change in Surplus (billions of 1989 dollars)		
	Consumer Surplus	Producer Surplus	Total Surplus
–10	0.785	–0.046	0.739
–25	1.637	0.095	1.732
+10	–1.044	0.215	–0.829
+25	–2.659	0.453	–2.206

Source: NAPAP (November 1991), p. 401, table 4.9–6.

(CVM) because the results are dependent or *contingent* on the devised hypothetical market. This market serves as the context for a series of survey questions. The critical assumption is that properly designed surveys can elicit responses comparable to those arising in actual situations. In some sense, the survey instrument helps to finesse the problem of nonrevelation of preferences that characterizes public goods.

Implementing this survey approach involves the following three tasks:¹²

- Constructing a detailed model of the hypothetical market, including the characteristics of the good and any conditions that affect the market
- Designing a survey instrument to obtain an unbiased estimate of individuals' WTP.
- Evaluating the truthfulness of survey respondents' answers

¹²For more detail on the specific elements of a CVM analysis, see Mitchell and Carson (1989), Cummings, Brookshire, and Schulze (1986), and Smith and Desvousges (1986).

Assessing the CVM

The CVM is favored by researchers because it can be applied to a variety of environmental goods and because it can assess existence value as well as user value. However, because this approach makes inferences about actual markets from a hypothetical model, it is subject to the biases that typically plague a survey-dependent study, such as an individual's unwillingness to reveal a WTP because of the free-ridership problem. See Exhibit A.1 in the Appendix for common sources of bias associated with the CVM.

Responding to the potential biases, economists continue to make improvements to the CVM. For instance, some researchers add more detail to their hypothetical models. Others improve the design of the survey instrument. Some surveys include maps to illustrate the location of the good or photographs of the commodity and the area affected by its provision.¹³ Whatever the form, the objective is the same: to make the hypothetical market situation as factual and as close to actual conditions as possible.

Applications of the CVM

Researchers have used the CVM in a variety of contexts to estimate environmental benefits. An important application is estimating the value of a statistical human life.¹⁴ In a recent review of these findings, estimates were reported as falling within a range of \$1.6 million to \$4.0 million (\$1986).¹⁵

Another common focus of CVM studies is to measure society's WTP for water quality improvements. Two examples are a study by Smith and Desvousges (1986), which examines a specific water body (the Monongahela River in Pennsylvania), and an analysis by Carson and Mitchell (1988), which estimates a generalized measure across all U.S. water sites. The study by Smith and Desvousges (1986) finds that the average household in five western Pennsylvania counties is willing to pay \$25 (\$1981) per year to improve the Monongahela River from boatable to fishable quality. Carson and Mitchell's (1988) nationwide survey shows that the average respondent is willing to pay \$80 (\$1983) per year for water quality improvements. How can the difference be explained?

Since the valuation in the national survey is higher than the more localized finding of Smith and Desvousges (1986), the difference may be attributable to existence value. Why? Because the respondents in the more general survey are willing to pay for water quality improvements throughout the United States, even though they do not expect to use these water bodies themselves.¹⁶

Incremental benefits from air quality improvements also have been estimated using the CVM. In fact, some argue that the CVM is particularly useful for valuing visibility improvements at national parks, where existence value is likely to be significant. One study by Schulze and Brookshire (1983) seems to support this hypothesis. These researchers find that the *user value* of improving visibility at the Grand Canyon from 70 to 100 miles is under \$2.00 (\$1988) per visitor per day. In contrast, they estimate the comparable *existence value* at \$95 (\$1988) per household per year to prevent diminished visibility at the Grand Canyon.¹⁷

Because the CVM is capable of capturing existence value, it has been used to value ecological benefits, such as preserving an endangered species. For example, one study estimates that individuals would be willing to pay \$22 (\$1983) per year to save the whooping crane.¹⁸

¹³ Brookshire and Crocker (1981).

¹⁴ A statistical life saved is related to the concept of environmental risk introduced in Chapter 6. For example, if an environmental policy lowers the risk of death from 2 in 100,000 persons exposed to 1 in 100,000 exposed, the incremental benefit of that policy is one human life saved. To give this context, in a recent EPA study, a statistical life saved is valued at \$4.8 million in 1990 dollars (U.S. EPA, Office of Air and Radiation, November 1999).

¹⁵ Cropper and Oates (June 1992), p. 713. Note that the notation, (\$1986), means that the values are expressed in 1986 dollars.

¹⁶ Cropper and Oates (June 1992), pp. 716–17.

¹⁷ Notice that for user value the WTP is appropriately given on a *per visitor* basis, whereas the existence value is quoted for *households* who may never visit the site.

¹⁸ Bowker and Stoll (May 1988).

Another finds that people would pay \$11 per year to preserve the bald eagle.¹⁹ There is, however, an important caveat. Although the value of preserving an entire ecosystem is typically what is of interest in policy analysis, many CVM studies focus on a single species. Yet the sum of species-specific valuations is generally higher than the valuation of an entire area.²⁰

Indirect Estimation Methods Under the Behavioral Linkage Approach

For some environmental proposals, direct estimation procedures such as the CVM might not be viable. In these cases, economists use **indirect methods**, which make inferences about markets or conditions that are linked to the environmental good under investigation. Three such methods dominate the literature: the **averting expenditure method (AEM)**, the **travel cost method (TCM)**, and the **hedonic price method (HPM)**.

Averting Expenditure Method (AEM): An Indirect Approach Using Substitutes

To indirectly estimate the WTP for such nonmarketed commodities as cleaner air or water, the **averting expenditure method (AEM)** uses changes in spending on goods that are *substitutes* for environmental quality. The motivation for this approach is quite intuitive. Exposure to pollution causes damages that negatively affect an individual’s utility. Consequently, people undertake averting action by purchasing goods and services that improve their *personal* environmental quality, such as the indoor air or a private drinking water supply.²¹

Table 7.2 gives some common examples of what individuals do to reduce the effects of pollution on their personal environment. Notice that in each case the averting action involves an expenditure on a substitute good or service. Therefore, if the general environment is improved by some policy initiative, the individual can spend *less* on these substitute goods. It is pre-

averting expenditure method (AEM)

Estimates benefits as the change in spending on goods that are *substitutes* for a cleaner environment.

Table 7.2 *Averting Actions to Reduce Risks of Exposure to Pollution*

Pollution	Effect	Averting Action
Air pollution	Material soiling	Clean or repaint material surfaces; use protective covers; move to new location.
	Health problems	Install air purifiers or air conditioners; schedule more frequent visits for medical examinations; purchase medications to alleviate respiratory symptoms; move to new location.
Water pollution	Material soiling	Install water filtration system; purchase cleaning products and rust removers; move to new location.
	Health problems	Install water filtration system; purchase bottled water; move to new location.
Hazardous waste site	Aesthetic degradation	Install fencing or shrubbery; move to new location.
	Health problems	Test water supply for contamination; install air filtration or air conditioner; move to new location.
Noise pollution	Health problems	Install sound-deadening insulation; purchase medication to aid sleeping; move to new location.

Source: Adapted from Bartik (1988), pp. 111–126, table 1.

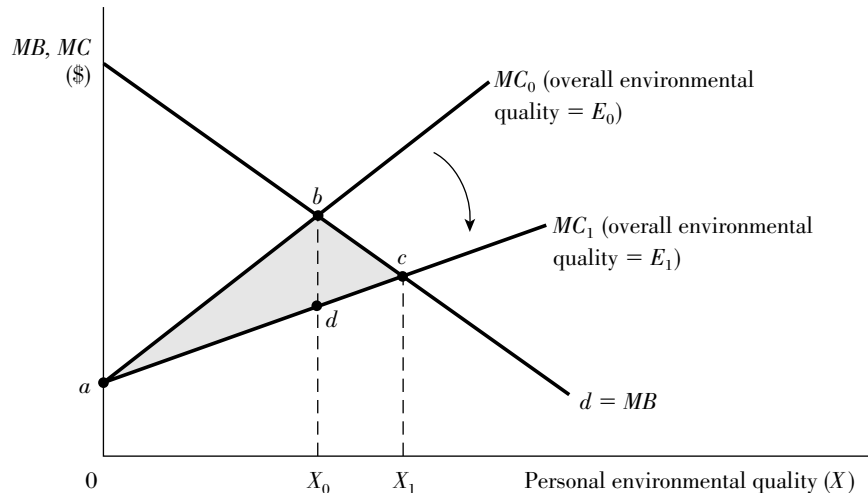
¹⁹Boyle and Bishop (1987).

²⁰Cropper and Oates (June 1992), pp. 719–20.

²¹The reference to an individual’s “personal” environment was first used by Bartik (1988) to describe the use of the AEM to value nonmarginal improvements in the environment.

Figure 7.6 *Measuring Incremental Benefits Using the Averting Expenditure Method (AEM): A Behavioral Linkage Approach*

When overall environmental quality is E_0 , personal environmental quality is X_0 , and averting expenditures are area $0abX_0$. After a policy increases overall environmental quality to E_1 , personal environmental quality increases to X_1 , and averting expenditures change to area $0acX_1$. To achieve X_1 in the absence of the policy change, the individual would be willing to spend an amount equal to area $0abcX_1$. Thus, the individual's WTP for the incremental benefits is the difference between $0abcX_1$ and $0acX_1$, or triangular area abc .



cisely this decline in averting expenditures that gives an *indirect* estimate of the individual's WTP for the associated incremental benefits. For instance, faced with a contaminated drinking water supply, an individual might purchase bottled water or install a water-filtering system. If a government policy improves the public drinking water supply, the individual can spend less on these substitute commodities. This reduction in spending identifies the incremental benefits provided by the drinking water policy.

We model the AEM in Figure 7.6, where the relevant market is defined as *personal* environmental quality (X). The demand curve (d) is also the marginal benefit (MB) function, and each supply (s) relationship is modeled as a marginal cost (MC) curve.²² The critical assumption is that each MC curve represents the averting expenditures on environmental quality substitutes to achieve various levels of *personal* environmental quality (X), given some level of *overall* environmental quality (E). In our diagram, MC_0 represents the marginal cost of averting expenditures at the existing level of overall environmental quality, E_0 . As overall environmental quality improves to E_1 , the individual spends less (or incurs lower costs) to achieve each level of personal environmental quality, and the MC curve moves downward to the right, becoming MC_1 .

At the initial equilibrium when overall environmental quality is E_0 , the individual's personal environmental quality is X_0 , where MB and MC_0 intersect. At this point, total averting expenditures are the area under the MC_0 curve up to X_0 , or area $0abX_0$. After the policy improves overall environmental quality to E_1 , the individual's marginal cost curve shifts to

²²Because we are modeling *personal* environmental quality, the marginal benefits and costs accrue to a single individual. To avoid confusion, we use the simple labels of MB and MC so as not to infer a distinction between private and social decisions, which is irrelevant in this unique situation.

MC_1 . At the new equilibrium, where MB and MC_1 intersect, personal environmental quality increases to X_1 , and averting expenditures change to area $OacX_1$. Now, we can use this information to monetize the incremental benefits of the improvement in overall environmental quality from E_0 to E_1 .

The key is to compare averting expenditure levels before and after the policy change *for the same level of personal environmental quality*. As we determined, post-policy averting expenditures for X_1 are represented by area $OacX_1$. Let's compare this to what the individual would be willing to spend to achieve X_1 without the influence of the policy. This is found by calculating the area under the original MC_0 curve up to X_1 and bounded by MB , or area $OabcX_1$. Thus, the individual's WTP for the incremental benefit is the difference between the two areas ($OabcX_1$ and $OacX_1$), or the triangular area abc .

An alternative valuation could be based on a constraint that holds personal environmental quality level at its original level (X_0). This approach might be preferred because the calculation is simpler, requiring information on only the two MC curves rather than on both the MC curves and the MB curve. Under this scenario, the incremental benefits would be the difference between areas $OabX_0$ and $OadX_0$, or the area abd . This smaller area can be interpreted as a lower bound for the WTP valuation.²³

Assessing the AEM

A drawback of the AEM arises from the phenomenon known as *jointness of production*. This refers to the fact that some averting expenditures yield benefits beyond those associated with a cleaner environment. Consider, for example, the averting expenditures on an air-conditioning system. While the system does reduce certain health risks of air pollution, it also provides comfort. Hence, the savings in expenditures arising from a clean air policy initiative cannot be attributed solely to the incremental benefits of that policy.

Applications of the AEM

A number of studies have used the AEM to value a statistical life. Blomquist (1979) focuses on the averting activity of wearing seat belts in automobiles to reduce mortality risk. This study estimates the incremental benefit of a life saved between \$380,000 and \$1.4 million (\$1986). Dardis (1980) conducts the same sort of analysis using expenditures on smoke detectors and monetizes the value of a statistical life at \$460,000 (\$1986).²⁴ Notice how these estimates are lower than those derived using the CVM. One explanation is that the averting behavior of using seat belts and smoke detectors is not a decision of degree but rather one of use versus nonuse. Consequently, individuals answer affirmatively as long as the marginal benefit exceeds the marginal cost. In such instances, the risk-reduction estimate is based upon the marginal individual who just finds that the averting behavior is worthwhile, causing the resulting estimate to be generally undervalued.²⁵

Travel Cost Method (TCM): An Indirect Approach Using Complements

An alternative approach to valuing environmental benefits is the **travel cost method (TCM)**, which uses the *complementary* relationship between the quality of a natural resource and its recreational use value. Simple observation suggests that the demand for the recreational use of an environmental resource, such as a lake or a national forest, increases as its quality improves. Therefore, as this demand function shifts with a change in environmental quality, the resulting change in consumer surplus can be used to assess the associated incremental benefits.

We model the travel cost method in Figure 7.7, assuming that recreational demand has been properly identified.²⁶ Two demand curves for the recreational use of a lake are shown in

travel cost method (TCM)

Values benefits by using the *complementary* relationship between the quality of a natural resource and its recreational use value.

²³Bartik (1988).

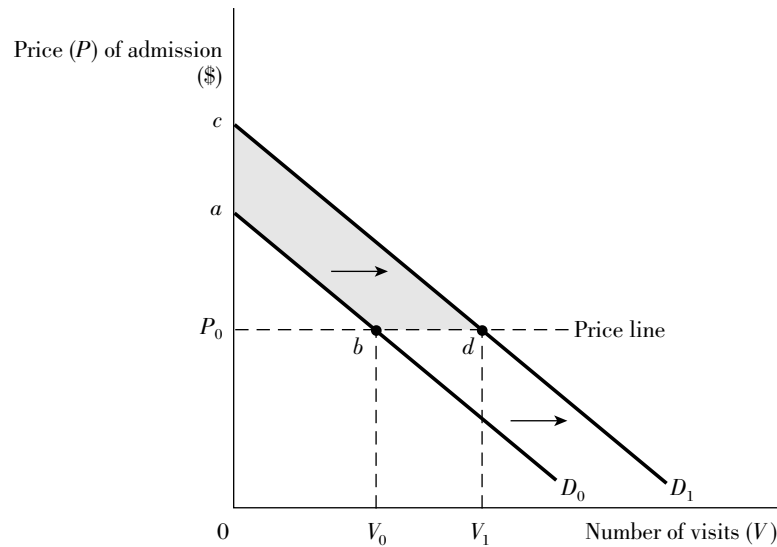
²⁴These estimates are reported by Fisher, Violette, and Chestnut (1989).

²⁵Cropper and Oates (June 1992), pp. 713–14.

²⁶One technique used to identify a recreational demand curve is called the Clawson-Knetch method (Clawson and Knetch, 1966). This method uses travel costs to a recreational site, visitation rates, and other socioeconomic data to estimate recreational demand. Smith and Desvousges (1986) provide an excellent review of how this approach has been revised over time.

Figure 7.7 *Measuring Incremental Benefits Using the Travel Cost Method (TCM): A Behavioral Linkage Approach*

D_0 is the recreational demand for a lake at some preexisting environmental quality level, E_0 . D_1 is the new demand curve after a policy improves the lake's quality to E_1 . The price line at P_0 is the admission fee. Before the policy is implemented, the number of visits to the site is V_0 , and consumer surplus is area abP_0 . After the policy is put into effect, the number of visits increases to V_1 , and consumer surplus increases to area cdP_0 . The *change* in consumer surplus, area $acdb$, represents the incremental benefits of improving the lake's quality from E_0 to E_1 .



the diagram, D_0 and D_1 . D_0 is the relevant demand at some preexisting environmental quality level E_0 . D_1 is the new demand curve after a policy has been implemented to improve the lake's quality to E_1 . A price line is drawn at P_0 to represent the admission fee to use the lake. Before the policy is implemented, the number of visits to the site is V_0 , where visitors enjoy a consumer surplus equal to area abP_0 . After the policy is put into effect, the total number of visits increases to V_1 , and consumer surplus increases to area cdP_0 . The resulting *change* in consumer surplus, shown as area $acdb$ (i.e., area cdP_0 minus area abP_0), estimates the incremental benefits to visitors associated with improving the lake's quality.²⁷

Assessing the TCM

One disadvantage of the TCM is that it estimates only user value and not existence value—an omission likely to create bias. Another is that it focuses on recreational use, making it ineffective for estimating benefits that might accrue to commercial users of a resource. Finally, the TCM has been found to generate estimates that are biased downward if access to a site is deterred by congestion.²⁸

²⁷Notice that even if there were no entry fee to use the lake, the model would be the same, except that consumer surplus would be the entire area under each demand curve. In such an instance, the resulting change in consumer surplus would extend to the horizontal axis.

²⁸Smith and Desvousges (1986), p. 220.

Applications of the TCM

Because of its limitations, the TCM is commonly used to value improvements to water bodies used mainly for recreation. For example, a study by Mullen and Menz (1985) uses the TCM to value the effect of acid rain damages to the Adirondack, New York, lake region. Other studies have used the procedure to value the benefits of improving water quality from boatable to fishable conditions. These findings tend to vary considerably. Consider the following results from three independent analyses, all measured as WTP per person per day in 1982 dollars:

- Vaughan and Russell (1982): Between \$4.68 and \$9.37.
- Smith and Desvousges (1985): Between \$0.06 and \$29.92.
- Smith, Desvousges, and McGivney (1983): Between \$1.04 and \$2.15.²⁹

Part of the reason for the inconsistent valuations is that TCM estimates tend to be sensitive to the site under study. Although demographic variables across regions can be controlled for, other site differences, such as aesthetics, access to major highways, and substitute recreational opportunities, are difficult to quantify and control. Consequently, it is unlikely that the TCM can determine a *generalized* value of improved water quality.³⁰

Hedonic Price Method (HPM): An Indirect Approach Using Product Attributes

The **hedonic price method (HPM)** is based on the theory that a good or service is valued for the attributes or characteristics it possesses.³¹ This perception of value suggests that *implicit* or *hedonic prices* exist for product attributes and that these prices can be determined from the explicit price of the product. In environmental economics, researchers use this technique to value the environmental attributes of certain commodities.

Housing markets have been a classic context for hedonic environmental pricing studies. Such analyses assume that the market price of a home is determined by the implicit value of its many characteristics, such as location, number of baths, lot size, and the environmental quality of the community. Therefore, changes in any of these characteristics are capitalized into the price of the property. The conventional model specifies the market price of a house, P , as a function of its attributes. A simplified version of such a model is:

$$P = f(X_1, X_2, \dots, X_n, E),$$

where each X variable represents some housing attribute, such as lot size or number of baths, and E signifies the associated environmental quality. As any one of these characteristics increases in magnitude, the price of the property P increases.³² It is this *marginal price* that is the implicit value of that attribute. Thus, as environmental quality improves, the resulting increase in property value can be used to estimate the associated incremental benefits.

Another common context for the HPM is wage analysis. Here, the method is used to explain wage differentials that might be associated with occupational risks, including those of environmental origin. Similar to hedonic studies of housing prices, hedonic wage (w) models generally are specified as:

$$w = g(Z_1, Z_2, \dots, Z_n, E).$$

the Z variables would include such attributes as the age, gender, education, and experience of the worker. The E variable would be some measure of occupation-specific environmental risk, such as the dangers faced by hazardous waste handlers or by engineers in a nuclear

hedonic price method (HPM)

Uses the estimated hedonic price of an environmental attribute to value a policy-driven improvement.

²⁹These comparisons are discussed by Smith and Desvousges (October 1985).

³⁰For more detail on the TCM, readers should consult Cropper and Oates (June 1992) or Mitchell and Carson (1989), chap. 3.

³¹Lancaster (1966).

³²This assumes that each attribute is specified as a favorable property characteristic.

power plant. These workers are expected to receive a higher wage than those not so exposed to compensate them for the added risk exposure. This wage differential is used to value the incremental benefits to workers of reducing occupational risk.

The HPM uses a statistical procedure known as regression analysis to determine the implicit price of any environmental variable. In simple terms, the idea is to decompose an *explicit* price, such as the price of a house or the wage rate, into its *implicit* price components, one of which is the price of environmental quality (E). Once the implicit price of E is determined, the demand for environmental quality can be estimated. This in turn can be used to measure changes in consumer surplus arising from policy-driven improvements in environmental quality.

Assessing the HPM

The appeal of the HPM is that it is highly intuitive. It approaches the problem of monetizing incremental benefits in a logical way, directly using market prices. Its major disadvantage is that it requires a fairly complicated empirical model. Furthermore, the method calls for extensive data on product characteristics, which often are unavailable or incomplete. If an important product attribute is missing, it will not be possible to determine the connection between a change in an explicit price and a change in environmental quality.

Applications of the HPM

One application of the HPM is in measuring how the siting of hazardous waste facilities affects prices of nearby properties. An example is a study by Kohlhase (1991), who finds that housing prices in the Houston area are positively affected by distance from a declared Superfund site up to 6.2 miles. According to this research, an additional mile in distance from a site adds \$2,364 (\$1985) to a property's value. In a similar study of single-family homes in Woburn, Massachusetts, Kiel (1995) estimates the analogous marginal benefit to be \$1,377 for the period when the waste facilities were declared Superfund sites.³³ Hedonic wage differential studies have been used to estimate the value of a statistical life saved as a result of reducing occupational risk. For example, Thaler and Rosen (1976) estimate that society's WTP for saving one additional life is between \$440,000 and \$840,000 (\$1986). Another finding is presented by Moore and Viscusi (1988), who estimate the value at approximately \$5.4 million.³⁴ The complex specification and data requirements of the HPM are partly responsible for the varying results across studies.

Conclusions

As a risk management strategy, benefit-cost analysis can be used to set policy objectives and to select the best available control instrument to achieve those objectives. However, its success in guiding these important decisions hinges on the accuracy of benefit and cost measurements. In this chapter, we have focused on the conceptual issues of benefit valuation and some of the estimation methods used in practice. Of all the available benefit valuation techniques, there is no clear consensus about which is consistently superior. The diversity of approaches reflects both the complexity of the task *and* a recognition of its importance in public policy decision making.

For each estimation method, we examined the underlying theory and the measurement technique, assessed the effectiveness of the approach, and surveyed a selection of empirical results. From a general perspective, our investigation uncovered some of the difficulties inherent in any social benefit estimation—difficulties that often are magnified in an environmental context. The primary challenge is in monetizing gains that involve many intangibles

³³Examples of hedonic price models that attempt to value air quality include a study by Harrison and Rubinfeld (March 1978) and an analysis done by Freeman (1979). Freeman also provides an excellent survey of the major issues surrounding the HPM.

³⁴These results are reported by Fisher, Violette, and Chestnut (1989).

not traded in the marketplace. Hence, economists have had to devise methods to quantify these intangibles using something other than explicit prices.

On balance, research efforts in measuring social benefits have been fruitful. Progress has been made in fine-tuning estimation procedures, in recognizing which methods are most useful for which contexts, and in interpreting the results. The efforts are important to support the use of benefit-cost analysis as a risk management strategy and ultimately to devise better policy solutions. Of course, all of this necessitates that comparable progress be made on the cost side of the analysis, which is the focus of the next chapter.

Summary

- To assess incremental benefits attributable to environmental policy, policymakers must determine how health, ecological, and property damages change as a result of that policy initiative.
- A primary environmental benefit arises as a *direct* consequence of implementing policy, whereas a secondary environmental benefit is an *indirect* gain arising either from the primary benefit or from some demand-induced effect.
- If we could infer society's demand for environmental quality, we could measure incremental benefits, because this demand represents the marginal social benefit of abatement.
- It is generally recognized that society derives utility from environmental quality based on its user value and its existence value.
- User value refers to the benefit received from physical utilization or access to an environmental resource. Existence value is the benefit received from the continuance of the resource based on motives of vicarious consumption and stewardship.
- There are two major types of benefit measurement techniques: the physical linkage approach and the behavioral linkage approach.
- A common procedure that uses the physical linkage approach is the damage function method. This method is based on a model of the relationship between levels of a contaminant and the associated damages. Incremental benefits are estimated as the damage reduction achieved from any policy-induced decline in the contaminant.
- Two direct methods that use the behavioral linkage approach are the political referendum method and the contingent valuation method (CVM). Examples of indirect methods using this approach are the averting expenditure method (AEM), the travel cost method (TCM), and the hedonic price method (HPM).
- The contingent valuation method (CVM) is a survey approach that determines individuals' willingness to pay (WTP) for some environmental improvement based on hypothetical market conditions.
- The averting expenditure method (AEM) uses expenditures on goods that are substitutes for environmental quality to indirectly determine the willingness to pay for a cleaner environment.
- The travel cost method (TCM) relies on identifying the recreational demand for an environmental resource, which is a complementary good to environmental quality. As environmental quality improves, recreational demand increases, and the associated benefits can be estimated as the change in consumer surplus.
- The hedonic price method (HPM) is based on the theory that implicit or hedonic prices exist for individual product attributes, including those related to environmental quality.

Key Concepts

incremental benefits	stewardship
primary environmental benefits	physical linkage approach
secondary environmental benefits	behavioral linkage approach
user value	damage function method
existence value	contingent valuation method (CVM)
direct user value	averting expenditure method (AEM)
indirect user value	travel cost method (TCM)
vicarious consumption	hedonic price method (HPM)



Use the Key Concepts listed above to begin your search for additional articles and information using the InfoTrac College Edition database.

Review Questions

1. Is it possible for an *individual's* valuation of an environmental commodity to include both user value and existence value? Explain briefly.
2. Contrast the averting expenditure method (AEM) with the travel cost method (TCM) and discuss the relative strengths and weaknesses of each.
3. Refer to Application 7.3 and the estimated changes in consumer and producer surplus reported by the NAPAP for various ozone policies. Graphically model the result of a 25 percent *increase* in tropospheric ozone to *qualitatively* show the distribution of benefits reported by the NAPAP. (Do not attempt to arrive at the numerical values for the changes in surplus values. Show only how the consumer, producer, and total surpluses *change* in accordance with the reported findings.)
4. One of the strengths of the contingent valuation method (CVM) is its ability to capture existence value. How can the researcher take advantage of this, yet avoid some of the biases of such a survey-based approach?
5.
 - a. Suppose you are part of a research team evaluating a proposal to clean up a hazardous waste site. You are in charge of assessing the incremental benefits. Which method would you choose to derive the estimation? Explain briefly.
 - b. Based on your selection, outline your research plan for this specific estimation problem. Be sure to identify the following in your outline: a general description of your model, the relevant market for your model, the primary variables of interest, the data requirements, and any potential bias in your results.

Additional Readings

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Related Web Sites

http://

Economics and the Endangered
Species Act (at Resources for
the Future)

**[http://www.rff.org/proj_summaries/files/
ando_econ_esa.htm](http://www.rff.org/proj_summaries/files/ando_econ_esa.htm)**

Endangered Species Act (full text)

**[http://www.nmfs.noaa.gov/prot_res/laws/
ESA/esatext/esacont.html](http://www.nmfs.noaa.gov/prot_res/laws/ESA/esatext/esacont.html)**

Environmental Valuation Reference
Inventory (EVRI)

**[http://www.evri.ec.gc.ca/evri/english/
default.htm](http://www.evri.ec.gc.ca/evri/english/default.htm)**