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A series of special techniques has been developed to value the benefits from environmental improvement or, conversely, to value the damage done by environmental degradation. Special techniques were necessary because most of the normal valuation techniques that have been used over the years cannot be applied to environmental resources. Benefit/cost analysis requires the monetization of all relevant benefits and costs of a proposed policy or project. As such, it is important to make sure a thorough analysis is conducted. The difficulties, however, are the monetization of those environmental goods and services that are not traded in any market. Even more difficult to grapple with are those nonmarket benefits associated with passive use or nonuse value.

In this chapter we shall examine these valuation methods. We begin with an examination of how benefit/cost can be implemented in an environmental context. In this section we identify and discuss the various valuation techniques that are used to value environmental resources in both *ex ante* and *ex post* settings. This is followed by a discussion of the strategies that exist for using economics to protect the environment when valuation information cannot reliably be obtained. One of these strategies, cost-effectiveness analysis, has become extremely important in guiding pollution control policy. Its popularity is not only due to the very practical consideration that it can be a valuable component of the policy process even when reliable valuation estimates cannot be obtained, but also because it responds to the concerns of those who reject the anthropomorphic basis for economic valuation. It has become the technique of choice for those who recognize the importance of economics for protecting the environment, but are skeptical of any efforts to monetize the value of environmental resources.

Why Value the Environment?

Debate 2.1 highlighted the debate on the monetization of ecosystem services. While it may prove difficult, if not impossible, to place an accurate value on certain environmental amenities, not doing so leaves us with $0 in the equation. Will a value of $0 lead us to the best policy decisions? Probably not!

Many federal agencies require benefit/cost analysis for decision-making. Ideally, the goal is to choose the most economically feasible projects, given limited budgets. A 1982 amendment to the Endangered Species Act, for example, required benefit/cost analysis for the listing of a species. This requirement was subsequently relaxed, however, due to a lack of defensible benefits measurements. The Federal Energy and Regulatory Commission (FERC) requires benefit/cost analysis for dam relicensing applications. These analyses, however, frequently fail to incorporate important nonmarket values associated with rivers. If the analysis does not include all the appropriate values, the results will be flawed. Have we made progress?

Valuing Benefits

While the valuation techniques we shall cover can be applied to both the damage caused by pollution and the services provided by the environment, each context offers its own unique problems. We begin our investigation of valuation techniques by exposing some of the difficulties associated with one of those contexts, pollution control.

In the United States damage estimates are not only used in the design of policies, but also they have become important in the courts. Under the Comprehensive Environmental Response, Compensation, and Liability Act, local, state, or federal governments can seek monetary compensation from responsible parties for natural resources that are injured or destroyed by spills and releases of hazardous wastes. Some basis for deciding the magnitude of the award is necessary.[3]

The damage caused by pollution can take many different forms. The first, and probably most obvious, is the effect on human health. Polluted air and water can cause disease when ingested. Other forms of damage include loss of enjoyment from outdoor activities and damage to vegetation, animals, and materials.

Assessing the magnitude of this damage requires (1) identifying the affected categories; (2) estimating the physical relationship between the pollutant emissions (including natural sources) and the damage caused to the affected categories; (3) estimating responses by the affected parties toward averting or mitigating some portion of the damage; and (4) placing a monetary value on the physical damages. Each step is often difficult to accomplish.

Because the experiments used to track down causal relationships are uncontrolled, identifying the affected categories is a complicated matter. Obviously we cannot run large numbers of people through controlled experiments. If people were subjected to different levels of some pollutant, such as carbon monoxide, so that we could study the short-term and long-term effects, some might become ill and even die. Ethical concern precludes human experimentation of this type.

This leaves us essentially two choices. We can try to infer the impact on humans from controlled laboratory experiments on animals, or we can do statistical analysis of differences in mortality or disease rates for various human populations living in polluted environments to see the extent to which they are correlated with pollution concentrations. Neither approach is completely acceptable.

Animal experiments are expensive, and the extrapolation from effects on animals to effects on humans is tenuous at best. Many of the significant effects do not appear for a long time. To determine these effects in a reasonable period of time, test animals must be subjected to large doses for relatively short periods. The researcher then extrapolates from the results of these high-dosage, short-duration experiments to estimate the effects of lower doses over a longer period of time on a human population. Because these extrapolations move well beyond the range of experimental experience, many scientists disagree on how the extrapolations should be accomplished.

Statistical studies, on the other hand, deal with human populations subjected to low doses for long periods, but, unfortunately, they have another set of problems—correlation does not imply causation. To illustrate, the fact that death rates are higher in cities with higher pollution levels does not prove that the higher pollution caused

[3]The rules for determining these damages are defined in Department of Interior regulations. See 40 Code of Federal Regulations 300:72–74.

the higher death rates. Perhaps those same cities averaged older populations, which would tend to lead to higher death rates. Or perhaps they had more smokers. The existing studies have been sophisticated enough to account for many of these other possible influences but, because of the relative paucity of data, they have not been able to cover them all.

The problems discussed so far arise when identifying whether a particular effect results from pollution. The next step is to estimate how strong the relationship is between the effect and the pollution concentrations. In other words, it is necessary not only to discover *whether* pollution causes an increased incidence of respiratory disease, but also to estimate *how much* reduction in respiratory illness could be expected from a given reduction in pollution.

The nonexperimental nature of the data makes this a difficult task. It is not uncommon for researchers analyzing the same data to come to remarkably different conclusions. Diagnostic problems are compounded when the effects are synergistic—that is, when the effect depends in a nonadditive way on what other elements are in the surrounding air or water at the time of the analysis.

Once physical damages have been identified, the next step is to place a monetary value on them. It is not difficult to see how complex an undertaking this is. Consider, for example, the difficulties in assigning a value to extending a human life by several years or to the pain, suffering, and grief borne by a cancer victim and the victim's family.

How can these difficulties be overcome? What valuation techniques are available not only to value pollution damage, but also to value the large number of services that the environment provides?

Types of Values

Depending upon the circumstance, we may need to place a value on either a *stock* or a *flow*. For example, the standing forest is a stock of trees, while the harvest of timber from that forest represents one of the service flows. The two are connected in that the value of a stock should be equal to the present value of the stream of services flowing from the stock. If the present value of the stream of services is maximized, then we say the resource is being used efficiently. This is equivalent to maximizing the value of that resource.

Economists have decomposed the total economic value conferred by resources into three main components: (1) use value, (2) option value, and (3) nonuse value. Use value reflects the direct use of the environmental resource. Examples include fish harvested from the sea, timber harvested from the forest, water extracted from a stream for irrigation, even the scenic beauty conferred by a natural vista. Pollution can cause a loss of use value such as when air pollution increases the vulnerability to illness, an oil spill adversely affects a fishery, or when smog enshrouds a scenic vista.

A second category of value, the option value, reflects the value people place on a future ability to use the environment. Option value reflects the willingness to preserve an option to use the environment in the future even if one is not currently using it. Whereas use value reflects the value derived from current use, option value reflects the desire to preserve a potential for possible future use. Are you planning to go to Yellowstone National Park next summer? Perhaps not, but would you like to preserve the option to go someday?

The third and final category of value, nonuse value, reflects the common observation that people are more than willing to pay for improving or preserving resources that they will never use. A pure nonuse value is also called *existence value.* When the Bureau of Reclamation began looking at sites for dams near the Grand Canyon, groups such as the Sierra Club rose up in protest of the potential loss of this unique resource. With Glen Canyon already flooded by Lake Powell, even those who never intended to visit recognized this potential loss. Because this value does not derive either from direct use or potential use, it represents a very different category of value.

These categories of value can be combined to produce the total willingness to pay (TWP):

$$\text{TWP} = \text{Use Value} + \text{Option Value} + \text{Nonuse value.}$$

Since nonuse values are derived from motivations other than personal use, they are obviously less tangible than use values. Furthermore, as Example 3.1 makes clear,

EXAMPLE 3.1

Valuing the Northern Spotted Owl

The Northern Spotted Owl lives in an area of the Pacific Northwest where its habitat is threatened by logging. Its significance derives not only from its designation under the Endangered Species Act as a threatened species, but also from its role as an indicator of the overall health of the Pacific Northwest's old-growth forest.

In 1990 an interagency scientific committee presented a plan to withdraw certain forested areas from harvesting and preserve them as "habitat conservation areas." Would preserving these areas represent an efficient choice?

To answer this question, a national contingent valuation survey (this technique is outlined in the next section) was conducted to estimate the nonuse value of preservation in this case. Conducted by mail, the survey went to 1,000 households.

The results suggested that the benefits of preservation outweighed the costs by at least 3 to 1, regardless of the assumptions necessitated by the need to resolve such issues as how to treat the nonresponding households. (One calculation, for example, included them all as a zero nonuse value.) Under the assumptions most favorable to preservation, the ratio of benefits to costs was 43 to 1. In this example the nonuse values were large enough to indicate that preservation was the preferred choice.

The authors also point out, however, that the distributional implications of this choice should not be ignored. While the benefits of preservation are distributed widely throughout the entire population, the costs are concentrated on a relatively small group of people in one geographic region. Perhaps the public should be willing to share some of the preservation costs by allocating tax dollars to this area to facilitate the transition and to reduce the hardship. Ultimately this is what happened.

Source: Daniel A. Hagen, James W. Vincent, and Patrick G. Welle. "Benefits of Preserving Old-Growth Forests and the Spotted Owl," *Contemporary Policy Issues* Vol. 10 (April 1992): 13–26.

estimated nonuse values can be quite large. Therefore, it is not surprising that they are controversial. Indeed when the U.S. Department of Interior drew up its regulations on the appropriate procedures for performing natural resource damage assessment, it prohibited the inclusion of nonuse values unless use values for the incident under consideration were zero. A subsequent 1989 decision by the District of Columbia Court of Appeals (880 F. 2nd 432) overruled this decision and allowed nonuse values to be included as long as they could be measured.

Classifying Valuation Methods

Several methods are available to estimate these values. This section will provide a brief overview to convey some sense of the range of possibilities and how they are related. Subsequent sections will provide more specific information about how they are actually used.

The possibilities are presented in Table 3.1. Revealed preference methods are those that are based on actual observable choices and from which actual resource values can be directly inferred. For example, in calculating how much local fishermen lost from the oil spill, the revealed preference method might calculate how much the catch declined and the resulting value of the catch. In this case, prices are directly observable, and their use allows the direct calculation of the loss in value.

Compare this with the direct stated preference case that might be used when the value is not directly observable. In Example 3.1, for example, the nonuse value of the Northern Spotted Owl was not directly observable. Hence, the authors attempted to derive this value by using a survey that attempted to elicit the respondents' willingness to pay (their stated preference) for the preservation of the species.

This approach, called contingent valuation, provides a means of deriving values that cannot be obtained in more traditional ways. The simplest version of this approach merely asks respondents what value they would place on an environmental change (such as the loss of a wetlands or increased exposure to pollution) or on preserving the resource in its current state. More complicated versions ask whether the respondent would pay $X to prevent the change or preserve the species. The

TABLE 3.1 Economic Methods for Measuring Environmental and Resource Values

Methods	Revealed Preference	Stated Preference
Direct	Market Price	Contingent Valuation
	Simulated Markets	
Indirect	Travel Cost	Attribute-Based Models
	Hedonic Property Values	Conjoint Analysis
	Hedonic Wage Values	Choice Experiments
	Avoidance Expenditures	Contingent Ranking

Source: Modified by the author from (Mitchell and Carson, 1989).

answers reveal either an upper bound (in the case of a "no" answer) or a lower bound (in the case of a "yes" answer).

The major concern with the use of the contingent valuation method has been the potential for survey respondents to give biased answers. Five types of potential bias have been the focus of a large amount of research: (1) strategic bias, (2) information bias, (3) starting-point bias, (4) hypothetical bias, and (5) the observed discrepancy between willingness to pay (WTP) and willingness to accept (WTA).

Strategic bias arises when the respondent provides a biased answer in order to influence a particular outcome. If a decision to preserve a stretch of river for fishing, for example, depends on whether or not the survey produces a sufficiently large value for fishing, the respondents who enjoy fishing may be tempted to provide an answer that ensures a high value rather than a lower value that reflects their true valuation.

Information bias may arise whenever respondents are forced to value attributes with which they have little or no experience. For example, the valuation by a recreationist of a loss in water quality in one body of water may be based on the ease of substituting recreation on another body of water. If the respondent has no experience using the second body of water, the valuation will be based on an entirely false perception.

Starting-point bias may arise in those survey instruments in which a respondent is asked to check off his or her answers from a predefined range of possibilities. How that range is defined by the designer of the survey may affect the resulting answers. A range of $0 to $100 may produce a valuation by respondents different from, for example, a range of $10 to $100, even if no bids are in the $0 to $10 range.

Hypothetical bias can enter the picture because the respondent is being confronted by a contrived, rather than an actual, set of choices. Since he or she will not actually have to pay the estimated value, the respondent may treat the survey casually, providing ill-considered answers. One survey (Hanemann, 1994) found that ten studies have directly compared willingness-to-pay estimates derived from surveys with actual expenditures. Although some of the studies found that the willingness-to-pay estimates derived from surveys exceeded actual expenditures, the majority of those found that the differences were not statistically significant.[4]

The final source of bias addresses observed gaps between willingness to pay and willingness to accept compensation. Respondents to contingent valuation surveys tend to report much higher values when asked for their willingness to accept compensation for a specified loss than if asked for their willingness to pay for a specified improvement in quantity or quality. Economic theory suggests the two should be equal. Debate 3.1 explores some of the reasons offered for the difference.

Much experimental work has been done on contingent valuation to determine how serious a problem these biases may present. One survey (Carson et al., 1994) uncovered 1,672 contingent valuation studies. Are the results from these surveys reliable enough for the policy process?

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[4]For a much more skeptical view of this evidence, see (Diamond and Hausman, 1994).

DEBATE 3.1

Willingness to Pay Versus Willingness to Accept: Why So Different?

Many contingent valuation studies have found that respondents tend to report much higher values for questions that ask what compensation the respondent would be willing to accept (WTA) to give something up than for questions that ask for the willingness to pay (WTP) for an incremental improvement. Economic theory suggests that differences between WTP and WTA should be small, but experimental findings both in environmental economics and in other microeconomic studies have found large differences. Why?

Some economists have attributed the discrepancy to a psychological endowment effect; the value of something you own is greater than something you do not. In other words, you would require more compensation to be as well off without it than you would be willing to pay to get that same good and as such you would be less willing to give it up (WTA > WTP) (Kahneman, Knetsch, and Thaler, 1990). This is a form of loss aversion; the psychological premise that losses are more highly valued than gains.

Others have suggested that the difference is explainable in terms of the market context. In the absence of good substitutes, large differences between WTA and WTP would be the expected outcome. In the presence of close substitutes, WTP and WTA should not be that different, but the divergence between the two measures should increase as the degree of substitution decreases (Hanemann, 1991 and Shogren et al., 1994).

The characteristics of the good may matter as well. In their review of the evidence provided by experimental studies Horowitz and McConnell (2002) find that for "ordinary goods" the difference between WTA and WTP is smaller than the ratio of WTA/WTP for public and nonmarket goods. Their results support the notion that property rights are not neutral.

The moral context of the valuation may matter as well. Croson et al. (draft) show that WTA increases with culpability as long as the party causing the damage is also paying for the repairs. If, however, a third party is paying, WTA is insensitive to culpability. This difference suggests that the valuation includes an amount levied in punishment for the party who caused the damage (the valuation becomes the lost value plus a sanction).

Ultimately, the choice of which concept to use in environmental valuation comes down to how the associated property right is allocated. If someone owns the right to the resource, asking how much compensation they would take is the appropriate question. If the respondent does not have the right, using WTP is the right approach. However, as Horowitz and McConnell point out, since the holders and nonholders of "rights" value them differently, the initial allocation of property rights will have strong influence on valuation decisions for environmental amenities.

Sources: Croson, R., J. J. Rachlinski, and J. Johnston. "Culpability as an Explanation of the WTA-WTP Discrepancy in Contingent Valuation." (Draft 2005). Hanemann, W. M. "Willingness to Pay and Willingness to Accept: How Much Can They Differ?" *American Economic Review*, 81, 635–647, 1991. Horowitz, J. K., and K. E. McConnell. "A Review of WTA/WTP Studies," *Journal of Environmental Economics and Management*, 44, 426–447, 2002. Kahneman, D., J. Knetsch, and R. Thaler. "Experimental Tests of the Endowment Effect and the Coase Theorem," *Journal of Political Economy*, 98, 1325–1348, 1990. Shogren, J. F., Senung Y. Shin, D. J. Hayes, and J. B. Kliebenstein. "Resoloving Differences in Willingness to Pay and Willingness to Accept." *American Economic Review* Vol. 84 (1), 1994: 255–270.

Faced with the need to answer this question in order to compute damages from oil spills, the National Oceanic and Atmospheric Administration (NOAA) convened a panel of independent economic experts (including two Nobel Prize laureates) to evaluate the use of contingent valuation methods for determining lost passive use or nonuse values. Their report, issued on January 15, 1993 (58 FR 4602), was cautiously supportive.

The committee made clear that it had several concerns with the technique. Among those concerns, the panel listed: (1) the tendency for contingent valuation willingness-to-pay estimates to seem unreasonably large; (2) the difficulty in assuring the respondents have understood and absorbed the issues in the survey; and (3) the difficulty in assuring that respondents are responding to the specific issues in the survey rather than reflecting general warm feelings about public-spiritedness or the "warm glow" of giving.[5]

But the panel also made clear its conclusion that suitably designed surveys could eliminate or reduce these biases to acceptable levels and it provided in an appendix specific guidelines for determining whether a particular study was suitably designed. The panel suggested that when practitioners follow these guidelines they

> *can produce estimates reliable enough to be the starting point of a judicial process of damage assessment, including lost passive-use values. ... [A well-constructed contingent valuation study] contains information that judges and juries will wish to use, in combination with other estimates, including the testimony of expert witnesses.*

These guidelines have been influential in shaping more recent studies. For example, Example 3.2 shares the results of a large contingent valuation survey designed to estimate the value of preventing future spills. The NOAA panel report has created an interesting dilemma. Although it has legitimized the use of contingent valuation for estimating passive-use (nonconsumptive use) and nonuse values, the panel has also set some rather rigid guidelines that reliable studies should follow. The cost of completing an "acceptable" contingent valuation study will be sufficiently high that they will only be useful for incidents in which the damages are high enough to justify their use. Yet due to the paucity of other techniques, the failure to use contingent valuation may, by default, result in passive-use values of zero, which isn't right either.[6]

One key to resolving this dilemma may be provided by a technique called meta-analysis. Meta-analysis, sometimes called the "analysis of analyses" takes empirical estimates from a sample of studies, statistically relates them to the characteristics of the studies and asks whether the reported differences can be attributed to differences in location, subject matter, or methodology. Meta-analysis would use this cross section of contingent valuation studies as a basis for isolating the determinants of nonuse value. Once these determinants have been isolated and related to specific

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[5]A more detailed description of the methodological issues and concerns with contingent valuation with respect to the actual Exxon Valdez contingent valuation survey can be found in Mitchell (2002).

[6]Whittington (2002) examines the reasons why so many contingent valuation studies in developing countries are unhelpful. Poorly designed or rapidly implemented surveys could result in costly policy mistakes on topics that are very important in the developing world. The current push for cheaper, quicker studies is risky and researchers need to be very cautious.

EXAMPLE 3.2

Leave No Behavioral Trace: Using the Contingent Valuation Method to Measure Passive Use Values

Until the Exxon Valdez tanker spilled 11 million gallons of crude oil into Prince William Sound in Alaska, the calculation of nonuse (or passive use) values was not a widely researched topic. However, following the 1989 court ruling in *Ohio v. U.S. Department of the Interior* that said lost passive use values could now be compensated within natural resources damages assessments and the passage of The Oil Pollution Act of 1990, the estimation of nonuse and passive use values became not only a topic of great debate, but also a rapidly growing research area within the economics community.

One study (Carson et al., 2003) discusses the design, implementation, and results of a large survey designed to estimate the passive use values related to large oil spills. In particular, the survey asked respondents their willingness to pay to prevent a similar disaster in the future by funding an escort ship program that would help prevent and/or contain a future spill. The survey was conducted for the State of Alaska in preparation for litigation in the case against Exxon Valdez.

The survey followed the recommendations made by the NOAA panel for conducting contingent valuation surveys and for ensuring reliable estimates. It relied upon face-to-face interviews and the sample was drawn from the national population. The study used a binary discrete choice (yes or no) question where the respondent was asked whether he or she would be willing to pay a specific amount with the amount varying across four versions of the survey. Of possible payment vehicles, the researchers chose a one-time increase in taxes as the method of payment. They also avoided potential embedding bias (where respondents may have difficulty valuing multiple goods) by using a survey that valued a single good. The survey also contained numerous pictures, maps, and background information to make sure the respondent was familiar with the good they were being asked to value.

Using the survey data, the researchers were able statistically to estimate a valuation function by regressing the respondent's willingness to pay (WTP) on respondent characteristics. After multiplying the estimate of the median willingness to pay by the population sampled, they reported aggregate lost passive use values at $2.8 billion (in 1990 dollars). They point out that this number is a lower bound since willingness-to-accept (WTA) compensation would be a more appropriate measure of actual lost passive use from the spill (see Debate 3.1) and because median willingness to pay is less than the mean.

The Exxon Valdez spill sparked a debate about the measurement of nonuse and passive use values. Laws put into place after the spill have ensured that passive use values will be included in natural resource damage assessments. Should other parts of the world follow suit?

Source: Richard T. Carson, Robert C. Mitchell, Michael Hanemann, Raymond J. Kopp, Stanley Presser, and Paul A. Ruud, "Contingent Valuation and Lost Passive Use: Damages from the Exxon Valdez Oil Spill," *Environmental and Resource Economics* Vol. 25 (2003): 257–286.

policy contexts, it may be possible to transfer estimates from one context to another without incurring the time and expense of conducting new surveys each time.

Another possible solution is to use *benefits transfer*. Benefits transfer involves the use of estimates from other places and other times being used for similar analysis elsewhere. It has the advantage of being quick and inexpensive, but the accuracy of the estimates deteriorates the further the new context deviates temporally or spatially from the context used to derive the estimates.[7]

The third category is indirect revealed preference methods, which are "observable" because they involve actual behavior and "indirect" because they infer a value rather than estimate it directly. Suppose, for example, a particular sport fishery is being threatened by pollution, and one of the damages caused by that pollution is a reduction in sportfishing. How is this loss to be valued when access to the fishery is free?

One way is through travel-cost methods. Travel-cost methods may infer the value of a recreational resource (such as a sport fishery, a park, or a wildlife preserve where visitors hunt with a camera) by using information on how much the visitors spent in getting to the site to construct a demand curve for willingness to pay for a "visitor day."

Freeman (2003) identifies two variants of this approach. In the first, analysts examine the number of trips visitors make to a site. In the second, the analysts examine whether people decide to visit a site and, if so, which site. This second variant includes using random utility models to value quality changes.

The first variant allows the construction of a travel-cost demand function. The value of the flow of services from that site is the area under the estimated demand curve for those services or for access to the site, aggregated over all who visit the site.

The second variant allows the analysis of how specific site characteristics influence choice and, therefore, indirectly how valuable those characteristics are. Knowledge of how the value of each site varies with respect to its characteristics allows the analyst to value how degradation of those characteristics (for example, from pollution) would lower the value of the site.

Travel-cost models have been used to value beach closures during oil spills, fish consumption advisories, and the cost of development that has eliminated a recreation area. The methodology for both variants is detailed in (Parsons, 2003). In the random utility model, a person choosing a particular site takes into consideration site characteristics and its price (trip cost). Characteristics affecting the site choice include ease of access and environmental quality. Each site results in a unique level of utility and a person is assumed to choose the site giving the highest level of utility. Welfare losses from an event such as an oil spill can then be measured by the resulting change in utility should the person have to choose an alternate site.

Two other indirect observable methods are known as the hedonic property value and hedonic wage approaches. They share the characteristic that they use a statistical technique known as multiple regression analysis to "tease out" the environmen-

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[7]Several examples of the use of meta-analysis and benefit transfer are given in (Florx et al., 2002). A critique and alternative to benefits transfer is offered in (Smith et al., 2002).

tal component of value in a related market. For example, it is possible to discover that, all other things being equal, property values are lower in polluted neighborhoods than in clean neighborhoods. (Property values fall in polluted neighborhoods because they are less desirable places to live.) Freeman (2003) examines the hedonic approach in detail. Hedonic property value models use market data (house prices) and then break down the house sales price into its components including the house characteristics (for example, number of bedrooms, lot size, and features); the neighborhood characteristics (for example, crime rates, school quality, and so on); and environmental characteristics (for example, air quality, percentage of open space nearby, distance to a local landfill, and so on). Hedonic models allow for the measurement of the marginal willingness to pay for discrete changes in an attribute. Numerous studies have utilized this approach to examine the effect on property value of things such as distance to a hazardous waste site (Michaels and Smith, 1990); large farm operations (Palmquist et al., 1997); and open space and land use patterns (Bockstael, 1996; Geoghegan et al., 1997; and Acharya and Bennett, 2001). Quite a few studies incorporate air quality variables. (For a meta-analysis on air pollution and housing prices see Smith and Huang, (1993).)

Hedonic wage approaches are similar except that they attempt to isolate the component of wages, which serves to compensate workers in risky occupations for taking on the risk. It is well known that workers in high-risk occupations demand higher wages in order to be induced to undertake the risks. When the risk is environmental (such as exposure to a toxic substance), the results of the multiple regression analysis can be used to construct a willingness to pay to avoid this kind of environmental risk. Additionally, the compensating wage differential can be used to calculate the value of a statistical life (Taylor, 2003).

A final example of an indirect observable method involves examining "averting or defensive expenditures." Averting expenditures are those designed to reduce the damage caused by pollution by taking some kind of averting or defensive action. An example would be to install indoor air purifiers in response to an influx of polluted air or to rely on bottled water as a response to the pollution of local drinking water supplies (Example 3.3). Since people would not normally spend more to prevent a problem than would be caused by the problem itself, averting expenditures can provide a lower-bound estimate of the damage caused by pollution.

A final category, indirect hypothetical methods, includes several attribute-based methods. Attribute-based methods such as contingent ranking and choice-based, conjoint models are useful when project options have multiple levels of different attributes. Like contingent valuation, conjoint analysis is also a survey-based technique, but instead of stating a willingness to pay, respondents choose between alternate states of the world. Each state of the world has a set of attributes and a price.

Consider an example (Boyle et al., 2001) that surveyed Maine residents on their preferences for alternative forest harvesting practices. The State of Maine was considering purchasing a 23,000 acre tract of forest land to manage. Attributes used in the survey included the number of live trees, management practice for dead trees, percent of land set aside, and a tax payment. Three levels of each management attribute and 13 different tax prices were considered. Table 3.2 reproduces the attributes and levels.

EXAMPLE 3.3

Valuing Damage from Groundwater Contamination Using Averting Expenditures

How many resources should be allocated to the prevention of groundwater contamination? In part that depends on how serious a risk is posed by the contamination. How much damage would be caused? One way to obtain a lower-bound estimate on the damage caused is to discover how much people are willing to spend to defend themselves against the threat.

In late 1987 trichloroethylene (TCE) was detected in one of the town wells in Perkasie, a town in southeastern Pennsylvania. Concentrations of the chemical were seven times the EPA's safety standard. Since no temporary solution was available to reduce concentrations to safe levels, the county required the town to notify customers of the contamination.

Once notified, consumers took one or more of the following actions: (1) they purchased more bottled water; (2) they started using bottled water; (3) they installed home water treatment systems; (4) they hauled water from alternative sources; and (5) they boiled water. Through a survey, analysts were able to discover the extent of each of these actions and combine that information with their associated costs.

The results indicated that residents spent between $61,313.29 and $131,334.06 over the 88-week period of the contamination to protect themselves from the effects. They further indicated that families with young children were more likely to take averting actions and, among those families who took averting actions, to spend more on those actions than childless families.

Source: Charles W. Abdalla et al. "Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination," *Land Economics* Vol. 68, No. 2 (1992): 163–169.

TABLE 3.2 Attributes in the Maine Forest Harvesting Conjoint Analysis

Attribute	Level
Live Trees After Harvesting	No trees (clear-cut)
	153 trees/acre
	459 trees/acre
Dead Trees After Harvesting	Remove all
	5 trees/acre
	10 trees/acre
Percent of forest set aside from harvest	20%
	50%
	80%

Source: (Boyle et al., 2001) and (Holmes and Adamowicz, 2003).

Respondents were given a choice set of four different alternative management plans and the status quo (no purchase). Table 3.3 demonstrates a sample survey question. This type of survey has evolved from both contingent valuation and marketing studies. This approach allows the respondent to make a familiar choice (choose a bundle) and allows the researcher to derive marginal willingness to pay for an attribute from that choice.

Contingent ranking, another survey method, also falls within this final category. Respondents are given a set of hypothetical situations that differ in terms of the environmental amenity available (instead of a bundle of attributes) and are asked to rank order them. These rankings can then be compared to see the implicit trade-offs between more of the environmental amenity and less of the other characteristics. When one or more of these characteristics can be expressed in terms of a monetary value, it is possible to use this information and the rankings to impute a value to the environmental amenity.

Sometimes a valuation exercise may use more than one of these techniques simultaneously. In some cases it is necessary to capture the total economic value; in other cases it is done to provide independent estimates of the value being sought.

Using Geographic Information Systems for Economic Valuation

Geographic Information Systems (GIS) are computerized mapping models and analysis tools. A GIS map is made up of layers such that many variables can be visualized simultaneously using overlays. Use of geographic information systems (GIS) to inform economic analysis is a relatively recent addition to the economist's tool kit. GIS offers a powerful collection of tools for depicting and examining spatial relationships. Most simply, GIS can be used to produce compelling graphics that communicate the spatial structure of data and analytic results with a force and clarity otherwise impossible. But the technology's real value lies in the potential it brings to ask novel questions and enrich our understanding of social and economic

TABLE 3.3 A Sample Conjoint Analysis Survey Questionnaire

Attribute	Alternatives				
	A	B	C	D	No change
Live Trees Remaining	No trees	459/acre	No trees	153/acre	
Dead Trees Remaining	Remove all	Remove all	5/acre	10/acre	
Percent Set Aside	80%	20%	50%	20%	
Tax	$40	$200	$10	$80	
I would vote for (please check off)	—	—	—	—	—

Source: Taken from Thomas P. Holmes and Wiktor L. Adamowicz. "Attribute-Based Methods," Chapter 6 in Ian Bateman, ed. *A Primer on Nonmarket Valuation* (New York: Kluwer Academic Publishers, 2003).