THE WORLD BANK ENVIRONMENT DEPARTMENT

ESTIMATING THE COST OF ENVIRONMENTAL DEGRADATION

A Training Manual in **E**nglish, **F**rench and **A**rabic

(DRAFT)

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This manual is the result of several studies undertaken by the Middle East and North Africa Department. The work focused on estimating the monetary value of environmental degradation in eight countries in the region. The manual was used to deliver training courses in Cairo (2002), Beirut (2003) and Marrakech (2004). The decision to translate the manual into Arabic was taken to help compensate for the relative lack of environmental economics literature in that language. It is hoped that this manual will contribute to build capacity in environmental valuation.

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OVERVIEW

Environmental Economics and Valuation – A Basic Toolkit

Environmental management needs economic theory and the economy needs the environment. This very simple principle underpins the realm of Environmental Economics. Long before the environmental revolution in the 1960s, the "world" of economics was generating analytic tools, which would become relevant for environmental management.

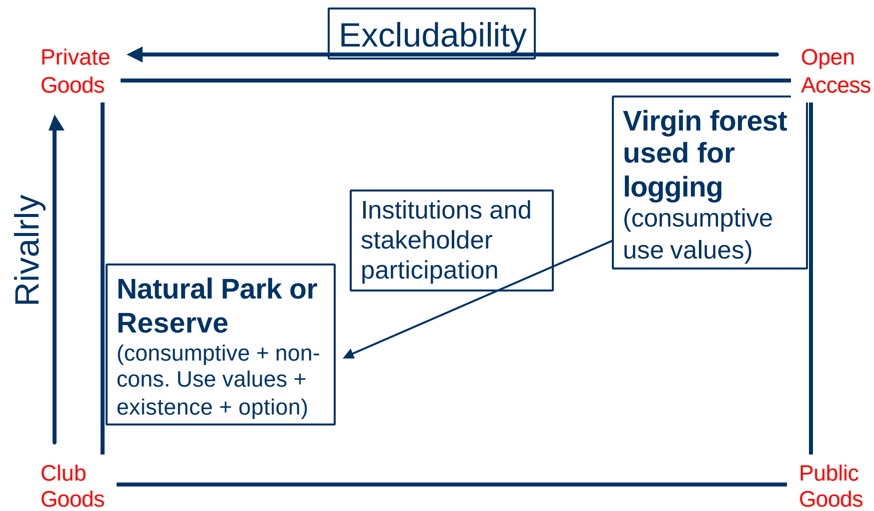
For our purposes, perhaps the most important contributions of economic theory can be synthesized into two elements:
- The concepts of externalities and public goods
- The economics of welfare

The theory of externalities dates backs to the seminal work of Pigou in 1920. An externality occurs when a benefit or a cost incurred by a party is caused by somebody who does not take this effect into account in his or her decisions. While externalities were originally thought to be a theoretical curiosity, only occurring in very specific instances—such as the proverbial case of the bee-keeper and the orchard or the case of the smoker in the room—, environmental science has shown that environmental externalities can be pervasive and affect individuals across space and time dimensions. One of the objectives of economists has been to analyze solutions to the externality problem such as through the use of taxes – named Pigouvian taxes after the economist who proposed them – and regulations. Often governments need to intervene in the case of externalities. However, this perception was modified after the publication of the 1960 paper by Ronald Coase, who suggested that parties could negotiate a solution to externalities in the absence of government intervention. However, such negotiation is unlikely when there are many individuals affected by the externality, as in the case of many pollution externalities.

The concept of a Public Good is intimately related to the concept of an externality. Public goods, such as clear air, coastal views and broadcast radio waves, have two main characteristics (see Figure 1.1):
1. Everybody can use them without depleting their availability for others (economists call this 'non-rivalry') and
2. It is very difficult, technically, to prevent people from using them. In other words, public goods are 'non-excludable'.

The problem with public goods is that everyone has a relatively small incentive to provide the good. Therefore people will tend to free-ride on others providing it and enjoy it for free! As a consequence, public goods are under-provided or, reversing the argument, there will be an over-provision of public bads (such as air pollution or ozone layer depletion). As in the case of externalities, state action is usually required to solve the problem. The question is whether such action is justified or, in other words, whether the benefits balance the necessary costs of publicly providing the good.

Figure 1.1 Public goods and private goods - Rivalry and excludability



Benefit Cost Analysis (BCA) was used for a long time before environmental issues appeared at the top of the public policy agenda. But, the advent of environmental economics led to an increased use of BCA. To understand BCA we need to discuss the theory of Welfare Economics. Developed by economists, such as Hicks and Kaldor, in the 1930s and 1940s, it provided a clear criterion for decision-making in virtually all cases where a public policy action would benefit somebody and cause costs to others. The 'compensation criterion' – as it came to be known – established that an action was justified on efficiency grounds if the winners from the policy could potentially compensate the losers and still be better off compared to the initial situation. This was the case even if no real compensation took place.

At the same time, welfare economics provided the theoretical foundations for considering the environment and natural resources as goods for which society and individuals' willingness to pay could be measured. Along with the historical development of the environmental applications of economic theory, the use of valuation became more and more important. A famous example is that of the Exxon-Valdez oil spill in Alaska in 1989 where the compensation to affected individuals was estimated by placing values on the externalities. Balancing winners and losers of a policy would eventually be made easier by the use of valuation techniques.

The Object of these Guidelines: Environmental and Natural Resources Values

The expression 'valuing the environment' is a contentious one. The main debatable issue is whether it is actually possible to put a monetary value on natural resources and the environment. This is not a major problem when one prices fish resources, oil reserves or tin exports whose use is excludable. However, is it technically possible or ethically sound to place a value on 'clean air' or 'migratory birds'?

Environmental economists are interested in the concept of value from a strictly anthropocentric point of view. What is being examined is the willingness of individuals to spend scarce resources on the environment that could very well be used for alternative purposes. This means that if individuals consider migratory birds as very important, their propensity to spend money for bird conservation will be high. But what is being valued is not the 'intrinsic' worth of birds, which is totally independent of the existence of man, but rather, the importance that man attaches to such birds. Yet another form of positive 'economic value' arises even when the good in question is consumed, exhausted or even seen. Individuals in fact may have a propensity to pay for a good they will never see, just to ensure somebody in the future will.

Economists define 'economic value' as the maximum willingness to pay for an environmental or natural resource. This is defined as the area below the demand curve for the resource. Again, assuming that the environmental good has some importance to individuals, a demand for the good must exist even if no explicit market transaction takes place. No markets for clean air can be observed in the real world, but if we look into individuals' behavior we may notice that they actually give up other resources to mitigate the effects of dirty air around them. For example individuals spend money on air filters to avoid exposure to air pollution or on asthma treatments to ameliorate its effects. This information is what allows economists to measure 'economic values' and will be the object of our attention.

What is this Guide Likely to Tell You?

The following chapters describe a wide range of economic valuation techniques used to estimate the benefits of policies or projects yielding environmental improvements. It keeps technical jargon to a minimum and is intended as an introduction to the subject for project task managers, policy makers, businessmen, and NGO officials dealing with environmental management issues.

The guide addresses the following questions:

- When is a valuation technique a useful tool for decision-making?
- What is the theoretical basis of economic valuation?
- What are the technical and human resources needed to engage in a valuation process?
- How is valuation used in practice?

Economic valuation of environmental and natural resources has benefited from a growing body of academic literature, but the use of such valuation in policy making is far from pervasive, particularly in developing countries where the difficult tradeoff between growth and the environment creates opportunities for its use.

It should always be remembered that an economic valuation study is only as good as the data that underlies it. Environmental information underpins good decision making, and in the real world data gaps can be a significant constraint. This guide identifies the data requirements for each technique, thus contributing to understanding the statistical challenges of good environmental management.

Using the Guide

The next chapter of the guide formally introduces benefit-cost analysis (BCA) and continues the discussion of valuation techniques. A given valuation method can be used to value more than one environmental impacts. The table that follows presents a 'roadmap' that identifies various environmental problems, the impacts associated with them, and possible techniques to value these impacts (although others may also be used). For a broader discussion of environmental economics techniques and their applications the reader may refer to Pearce & Turner (1990), Kolstad (2000), Cropper and Oates (1992), Freeman (1992).

Table 1.1 Environmental degradation and economic valuation – A 'roadmap'

Pollution	**Impacts**	
Air pollution	Health impacts	Medical cost Human capital method Averting behavior Hedonic wages Contingent valuation
	Infrastructure damages	Cost of replacement
	Amenity impacts	Hedonic prices
Water pollution	Health impacts	Medical cost Human capital Averting behavior Contingent valuation
	Loss of ecosystems	Change in productivity Cost of replacement Hedonic prices Contingent valuation
Soil degradation	Agricultural losses	Change in production Cost of replacement Averting behavior
	Increase in vulnerability to disasters	Human capital Averting behavior Hedonic prices
Noise pollution	Discomfort	Hedonic prices
	Health impacts	Averting behavior
Natural resources	**Impacts**	
Forests and protected areas	Loss of green areas (deforestation)	Changes in production Replacement cost Hedonic prices Travel cost Contingent valuation
Coastal ecosystems	Loss of ecosystems (coral reef eutrofication, mangroves destruction, beach erosion)	Changes in production Hedonic prices Travel cost Contingent valuation
Water resources	Water resources depletion	Changes in production Cost of replacement Hedonic prices Contingent valuation
Biodiversity	Biodiversity loss	Hedonic prices Travel cost Contingent valuation

2
VALUES AND DECISIONS

Everyday decisions require information. For example, entrepreneurs decide whether to invest in new machinery; workers decide whether to accept a job; and families decide where to go on vacation. In the same way, governments have to decide whether to spend more money on defense, hospitals, or protecting the environment. Ideally, implementing such decisions should mean trading off the net benefit of the action with the net benefits of alternative actions.

Environmental management does not escape this simple rule. Pollution control and regulation are not cost-free activities; they use financial resources that could be spent elsewhere. In order to make an informed decision about whether to undertake the activity, it must be known if the benefits of doing so exceed the costs.

Information is crucial to making good decisions. The first step is to analyze what the elements of a good decision making process are. We will do so from an economic point of view. This will require understanding the principles of benefit cost analysis (BCA) and its advantages and limitations.

The second step is to identify the costs and benefits of controlling environmental degradation. Costs are often relatively easy to identify and calculate although not without the help of scientists, engineers, doctors, geographers, and ecologists amongst others. However, once we have decided how much it costs, say, to phase out diesel engines, we have only half the answer. We still need to know what the benefits are.

The third step is to explore the range of techniques that are available to calculate the monetary value of benefits. This manual is intended to be a guide through the mechanics and practicalities of 'environmental valuation'.

Making Good Decisions – the Art of Setting Priorities

Balancing winners and losers

Setting priorities is not an easy task. The impacts of a decision will often favor some sectors of society more than others. Economics can help to weigh up the costs and benefits to help inform decision-making. In particular, the benefit-cost framework is designed to capture the balance between winners and losers by measuring the flow of costs and benefits over time of a given policy or project. While financial analysis often considers only market costs and revenues, a full benefit cost analysis (BCA) includes two additional and very important aspects:

1. The *valuation of environmental benefits*. This allows the non-financial *benefits* of improved environmental quality, such as health and recreation, to be taken into account.
2. The *consideration of costs to society as opposed to costs to private individuals*. A typical case is that of subsidies. For example, the cost of fertilizers to the farmer may be less than the cost to society if there are subsidies.

Box 2.1 Benefits and damage costs

The reader will notice that the expressions 'damage costs' and 'benefits' are often used interchangeably in environmental economics discussions. For example, we said that our objective is to present the techniques for evaluating environmental BENEFITS. Sometimes however we read the expression "Evaluating the COSTS of environmental degradation". This just refers to whether we are valuing a negative (cost) or positive (benefit) impact. For example, 'damage costs' of say air pollution refer to the negative consequences of environmental degradation. In an equivalent way we can refer to the 'benefit' of the corresponding clean up. For this reason we invite the reader, especially when going through the material that follows for the first time, to carefully question the impact that the words 'benefits' or 'costs' are referring to.
One way to do so is by considering whether the environmental impact referred to constitutes a 'good' or a 'bad'. 'Goods' are those commodities for which more is better. Clean air is a 'good'. Moreover it is a public good in the sense that everybody can enjoy it. Valuation techniques can be used to estimate society's willingness-to-pay for clean air's benefits. On the other hand, pollution is a 'bad'. Analogously it can become a public 'bad' if all individuals are affected by it. Also in this case, valuation techniques measure society's willingness-to-pay to avoid the damages from pollution. Bads and goods are opposite sides of the same coin.

The mathematics of BCA is very simple. The ultimate goal is to calculate the sum of the discounted flow of net benefits (benefits minus costs) over time arising from the project. This is known as the Net Present Value (NPV).

$$NPV = \sum_i \frac{B_i - C_i}{(1+r)^i} = \sum_i \frac{B_i}{(1+r)^i} - \sum_i \frac{C_i}{(1+r)^i}$$

Where:
B_i = Benefits of the project in year i
C_i = Costs of the project in year i
r = discount rate
i = year

The main advantage of BCA is that it includes costs and benefits that are not necessarily reflected in market transactions (i.e. the benefit of reducing air pollution). At the same time, it provides a common framework and language for analyzing all policies in all sectors.

Consider the air pollution problem. In 1994, the World Bank conducted a study to evaluate different policy options to control air pollution in Santiago, Chile. One option was to reduce emissions from fixed sources: these can be relatively easy to identify and monitor, so costs of control are not very high. Alternative control options considered interventions on mobile sources. Table 2.1 presents the costs and benefits for the different options considered. In this example, the best option (the one providing highest net benefits) is to control emissions from gasoline vehicles.

Table 2.1 Benefit-cost analysis in Santiago, Chile

Annualized benefits and costs of air pollution control in Santiago, Chile (US$ mn)

Program Component	**Benefits**	**Costs**	**Net Benefits**
Fixed Sources	27	11	16
Gasoline Vehicles	33	14	19
Buses	37	30	7
Trucks	8	4	4
Total	105	59	46

Source: World Bank (1994)

The most difficult component of the analysis is on the benefits side. Reducing air pollution can produce some financial returns (i.e. avoided damages to buildings or avoided costs of window cleaning!), but it also causes other benefits, principally improved human health. No price exists for health, but there are techniques available to measure individuals' willingness to pay for it, as we will see in the following sessions.

Benefit-cost analysis may not be feasible or even desirable in some cases. This is due to the fact that benefits are often difficult–or impossible–to calculate (i.e. a unique park or a wilderness area that might be lost forever). In addition laws often set a given standard for environmental quality, specifying a threshold beyond which serious losses may occur. This may prevent a project with the greatest net benefits from being implemented as its implementation would break the law. A final, and politically very important issue, is that of equity. If a project's impacts fall disproportionately on one segment of society, it may be deemed inappropriate.

Discounting the future[i]

We have observed that BCA aims to calculate the sum of all discounted benefits and costs of a project over time. This requires an 'appropriate' discount rate. The effect of the discount rate is that costs and benefits far into the future are given a lower weight than current cost and benefits. But why do economists discount the future?

Suppose that an individual is offered the following choice: either to accept US$1,000 now or wait and be given the same US$1,000 ten years from now. The answer will certainly depend on the individual's characteristics, but in general one can answer that most people asked such a question would choose to receive the US$1,000 now. There are several reasons for doing so:

- First, the individual might be able to invest the amount received today in a productive activity that could yield a ***rate of return*** (r). For example, $1,000 invested today at a rate of 5 percent would be worth $1,050 the following year.
- Human beings are ***impatient***. Even if investing was not possible, individuals may show preference to consume something today rather than tomorrow.
- Related to the 'impatience' argument, is the fact that the individual might not be alive in 10 years. The ***risk of death*** might thus be another reason to prefer the US$1,000 today.
- The individual cannot be certain that the US$1,000 will be there in 10 years' time! Anything could happen in the meantime. In other words there is ***uncertainty*** about the future.
- A slightly more complex argument relates to the ***diminishing marginal utility*** of money. Suppose the individual is a young student. Her wealth today is nearly zero as she is investing in her education and not receiving any income. In 10 years she can expect to have a job with a good salary. In this situation, US$1,000 is likely to be worth more to the today's 'poor' student than to tomorrow's 'rich' professional. Thus, another reason to prefer the payment today.

The bottom line is that individuals may have several reasons to prefer the US$1,000 today rather than in 10 years. This preference is the basic justification for the use of a discount rate.

When applied to environmental issues, there have been a number of interesting critiques of the use of discounting. The main reason is that discounting tends to favor present benefits over future environmental benefits. Consider the case of using the risk of death as a justification for the use of a positive rate of time preference. It has been argued that this should not be a reason for discounting in BCA, since the benefits will not accrue to a particular individual but rather to society as a whole. Moreover, this consideration would implicitly reflect the interest of future generations. This is in fact one of the reasons to distinguish between the *private* and *social rate of discount*.

A second critique of discounting relates to irreversible investments. The development of some resources is irreversible. Developing a new area (i.e. building a dam) to obtain some finite benefits may not be desirable due to the loss of a wilderness area forever. Environmental critiques of the discount rate suggest that the discount rate used in BCA should be lower than the market rate of discount. It is generally accepted that both the consideration of future generations and uncertainty need to be taken into account in the choice of discount rate; however, this argument applies equally to environmental and non-environmental projects.

Indeed, there are compelling reasons why the discount rate should not be lower for environmental projects than for other projects (e.g. capital investments of a non-environmental nature). One of them is the fact that any correction would result in an *ad hoc* decision. For example, why choose a lower discount rate and not a zero discount rate? Which projects would qualify for a lower discount rate, and under what criterion? But even if an environmental project could be easily differentiated from non-environmental projects and a different discount rate applied, there are alternative ways to deal with many of the environmental concerns. A more attractive way to take into account factors such as uncertainty is to consider the actual risk of a cost arising and include that risk factor in the actual stream of costs and benefits. Concern for future generations can be reflected in current preferences (this is called bequest value). The real issue is to measure such preferences. Finally, remember that BCA is only one criterion to use in making choices. A government may consider other criteria as important, for example using a more comprehensive sustainability criterion for planning.

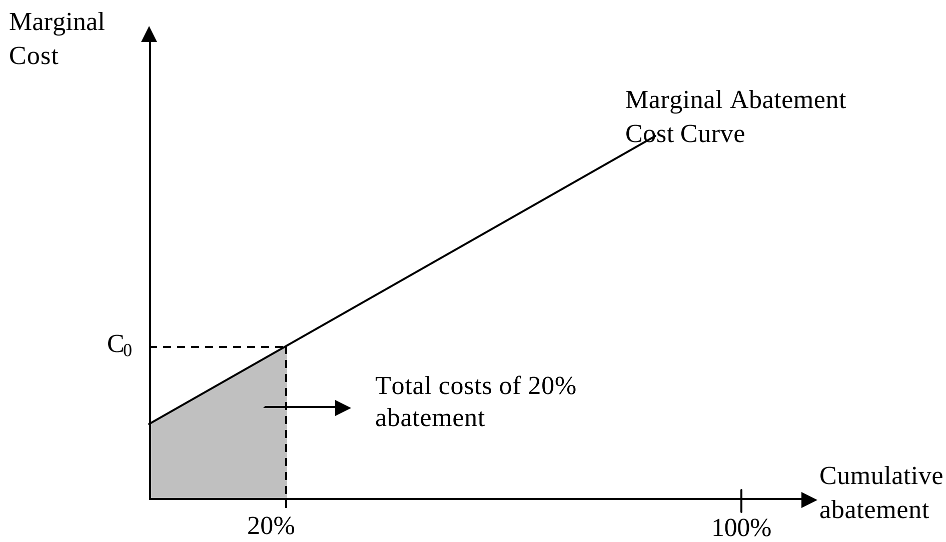
The bottom line is that, given the difficulties of using lower discount rates, there is a strong rationale to strengthen efforts to include environmental considerations into all economic decisions (mainstreaming). This requires the identification of the types of values involved and the use of valuation techniques to measure all environmental values affected by a project, including those values linked to uncertainty (option values) and the existence of the resource.

Economic Costs and Benefits

The underpinnings of BCA can be grasped without much difficulty. It is important to understand what ‘costs’ and ‘benefits’ mean in economic terms. Let’s start from the cost concept. It refers to the necessary expenses to obtain some outcome. Think of an outcome as the improvement of air quality, and its costs being the installation of monitoring stations, the installation of clean fuel engines, and so on.

Graphically, costs are represented by a *marginal cost curve*. Consider the case of air pollution. The word ‘marginal’ means that the cost (measured on the vertical axis) refers to the last unit of abatement achieved. For example, if we are already abating air pollution by 20 percent, then a small increment in air quality will cost C_0, as indicated in the Figure 2.1. The fact that the marginal abatement cost curve is increasing follows from the assumption that cheapest control alternatives are implemented first. The cost curve is the equivalent of the standard supply curve usually found in economics textbooks. In this case we are referring to the ‘supply’ of clean air!

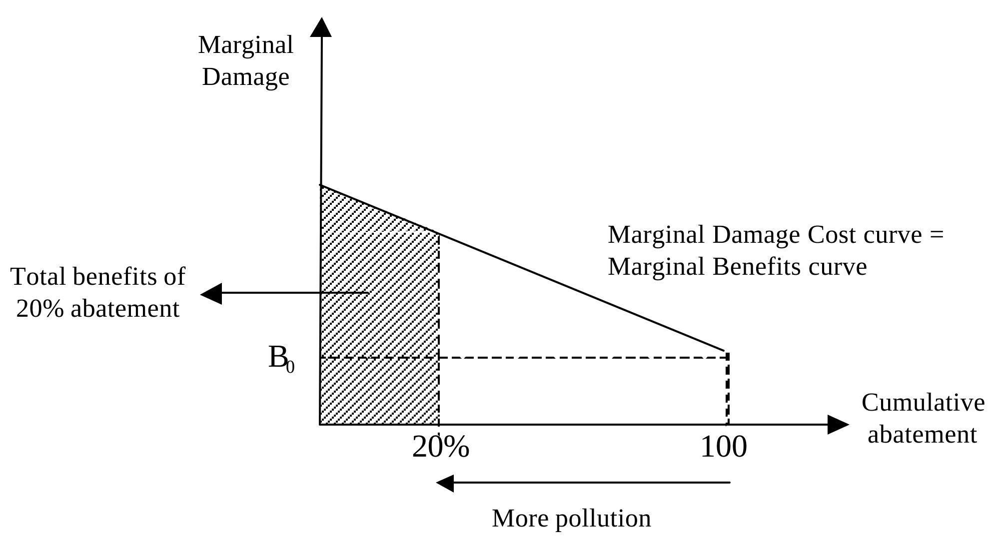
Figure 2.1 Marginal cost of abatement



The marginal abatement cost framework is often used in environmental management, even if not always spelled out graphically. For example, in a cost-effectiveness analysis the cost of implementing alternative management options is usually considered. Here the options available are implicitly being ranked from the cheapest to the more expensive.

Another feature of the marginal abatement cost curve is that the area below the curve is a measure of the *total cost* of any given level of abatement. In Figure 2.2, the shaded area below the curve gives the total cost necessary to reduce air pollution by 20 percent.

Figure 2.2 Marginal benefits

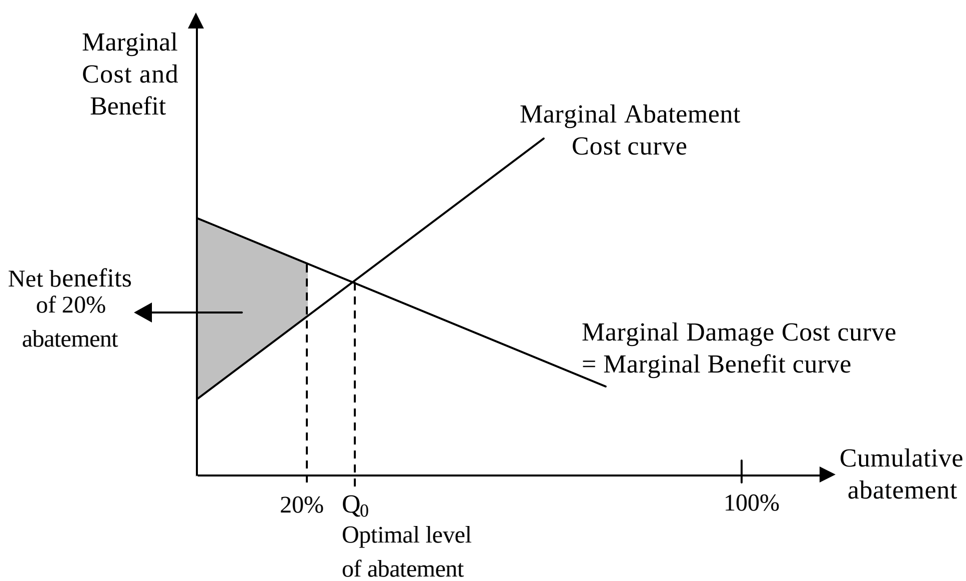


Let's now consider the benefits side. Benefits can be defined as an individual's willingness-to-pay for an environmental improvement or a natural resource. Consider the case of air pollution, again. Lower emissions improve people's quality of life in terms of better health, visibility, and less damage to property etc. People may indeed be willing to pay for better air quality because it would save them other kinds of costs. This is captured by the marginal benefit curve in Figure 2.2. In the pollution case, this is often called marginal damage cost. This duality follows from the fact that better air quality produces “benefits” and worse air quality produces “damage costs”. The reader should be aware that this is in fact the same thing.

Assume that air is 100 percent clean. If air quality goes down by a small amount, then society would be willing to pay a certain amount B_0 (presumably very low) to avoid the resulting damages. If air quality is already very poor, then further increases in pollution can start causing some serious health problems. In this case the willingness to pay to avoid that further increase in pollution may be higher. This is captured by the fact that the marginal benefit is decreasing with the level of abatement. The area below the marginal benefits curve measures the total benefits of reaching a given level of abatement and willingness to pay for it.

We can use the information about costs and benefits to identify an optimal level of pollution abatement. In Figure 2.3 it can be seen that abating pollution by 20 percent would produce total benefits that are higher than the total costs. Graphically, the area below the benefits curve is bigger than the area below the costs curve. Further improvements in air quality increase the net benefits. This is true until abatement reaches Q_0. At that level, any further abatement is no longer worthwhile, since society would not be willing to pay the cost of additional abatement.

Figure 2.3 Comparing costs and benefits



BCA essentially compares costs and benefits and tries to assess whether the benefits of a policy or a project is worth its costs. The representation in Figure 2.3 is useful to understand the link between BCA and environmental valuation. BCA answers to the question: if a policy reduces air pollution by 20 percent, are benefits from the policy higher than the total costs of implementing it? In other words, is the area below the benefits curve bigger than the area below the costs curve? Valuation is the tool that allows to measure in monetary terms the benefits: i.e. the size of the area below the marginal benefit curve.

Measuring Benefits (or Damages)

The benefits from an environmental project are often difficult to identify and measure. Sometimes, environmental goods and services are traded (this is usually the case with commercial natural resources, such as timber, iron ore, and gold). In such cases, prices can be used to infer people’s willingness-to-pay for the resource[ii]. In other cases it may not be so easy. Better air quality is not sold or bought in any market, so no price exists for it. Likewise, there is no explicit trade in landscape beauty. One of the reasons some environmental goods are not traded is that they are public goods meaning that it is not possible, or it is technologically very difficult to charge a price for their consumption.

This manual is intended to provide an introduction to the techniques to measure people's preferences for the environment. Valuation techniques answer questions such as: if markets for air quality existed, how much would society be willing-to-pay to buy air quality? The answer is relevant because it would then justify having to pay, often very high costs, for providing better air quality. Moreover, it would give guidance on how much abatement would be justified, given that a 100 percent clean up might be prohibitively expensive.

Several techniques have been developed that allow the measurement of environmental benefits. A simple diagram can be used to link environmental degradation to valuation techniques. Figure 2.4 focuses on the distinction between those methods that rely on the scientific measurement of an impact (dose-response functions) and those methods that are based on human behavior. The figure should be read as a flow diagram where the starting point is 'Environmental degradation'.

Methods based on dose-response functions

Regardless of the technique used to value environmental amenities, economists usually employ a damage function approach to valuing environmental damages. The dose-response function approach separates the valuation of environmental effects into two parts. First is the estimation of the impacts of the environmental change in quantitative terms (for example, cases of illness avoided, improvements in visibility, or changes in agricultural yield). Second, is the valuation of these changes. This separates the "hard science" of estimating the impacts of environmental degradation on health, ecosystems, and production, from the valuation of these effects. Valuation usually proceeds by multiplying the impact by a price or unit monetary value (such as hourly wage in the case of illness avoided, crop price in the case of changes in yield). A limitation of these methods, is that they do not question how much people are 'willing-to-pay' for avoiding the damage. WTP, or a lower bound of it, is rather inferred by existing prices. The alternative approach—asking people to value environmental damages directly—would require people to understand the epidemiology or atmospheric chemistry linking damage to physical effect.

Methods based on people's behavior

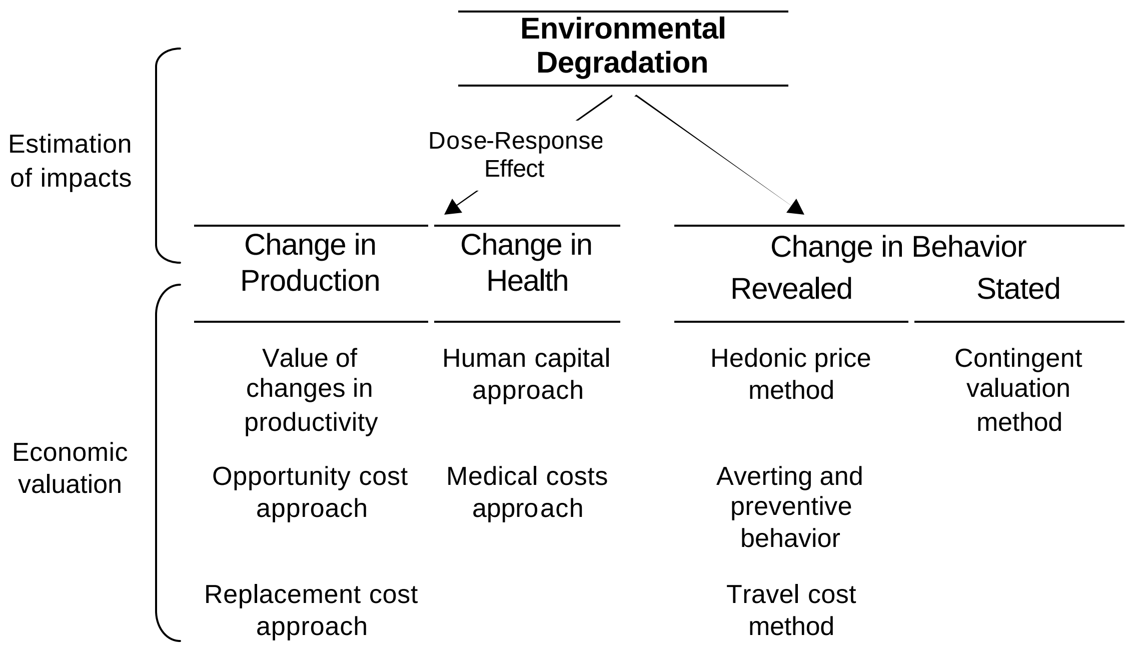
In some occasions, willingness to pay to avoid degradation is inferred directly from people's behavioral reaction to the environmental change, regardless of the existence of an impact, such as a change in health or productivity. For example, water quality changes may not result directly into changes in health. The response in this case can be observed in individuals buying more bottled water for drinking purposes or individuals purchasing houses in 'cleaner' neighborhoods. When environmental degradation is 'revealed' in an observable change in people's behavior, we refer to revealed preferences techniques.

In some cases, environmental preferences are not evident from people's choices. Some categories of values cannot be observed either in the market place nor through some implicit price of related marketed goods. Imagine the value of the 'panda bear': no markets exist to buy or sell panda bears and few people go all the way to China to see one. Still, conservation NGOs have been raising funds for their protection. People are indeed willing-to-pay simply for the existence of an environmental good or service or a natural resource, regardless of being able to ever use or directly enjoy it. The contingent valuation method (CVM) elicits these types of value through the application of surveys.

The CVM can be also used for consumed environmental goods (i.e. water) when no market prices exist and data on observed behavior is difficult to obtain.

Finally notice that revealed and stated preferences methods can be also useful to value environmental degradation's impacts on health and production. For example, a contingent valuation study can ask for people's WTP for a reduction in sick days. We can then link the values obtained to the amount of degradation using the dose-response framework.

Figure 2.4 Choosing a valuation method

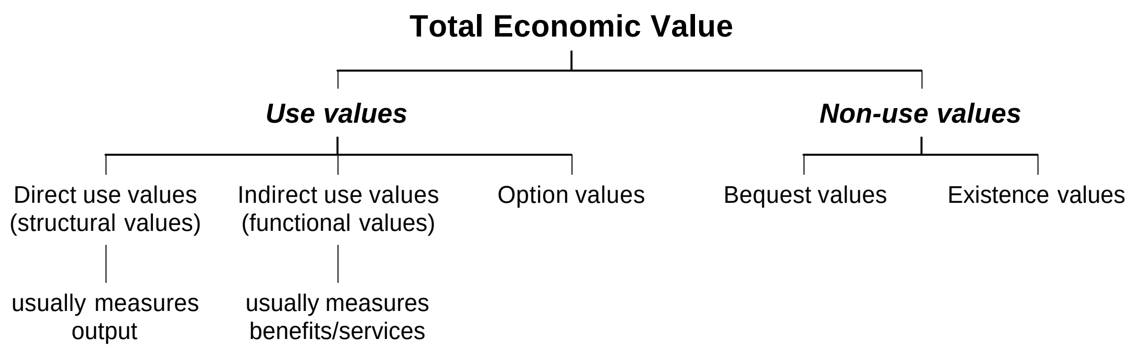


Total Economic Value (TEV)

It is evident that more than one valuation technique can be used to put a monetary value on the same resource. For example, the cost of illness approach captures the health benefits of clean air, while a travel cost method can be used to measure also the recreation value of air quality. Since each method measures different aspects of air quality the estimates will be different.

The growing variety of valuation techniques is a consequence of the fact that the environment can be a source of welfare for different reasons and different individuals. A forest can simultaneously provide timber for loggers, ecosystems services for local communities, water filtration for hydroelectric plants, genetic resources for multinational pharmaceutical companies, and carbon sinks for global CO_2 emissions. The sum of all the types of values associated with a resource is called total economic value (TEV), a term that appeared in the 1980s. There is now a consensus on the categories of environmental values and Figure 2.5 shows their classification.

Figure 2.5 Total economic value



The first important distinction is between use values and non-use values. Use values are those that originate from the society's gains from using, or potentially using, a given environmental resource or its services. Use values include direct, indirect, and option values. Non-use values include bequest and existence values. Figure 2.6 presents an example of the total economic value of a tropical forest.

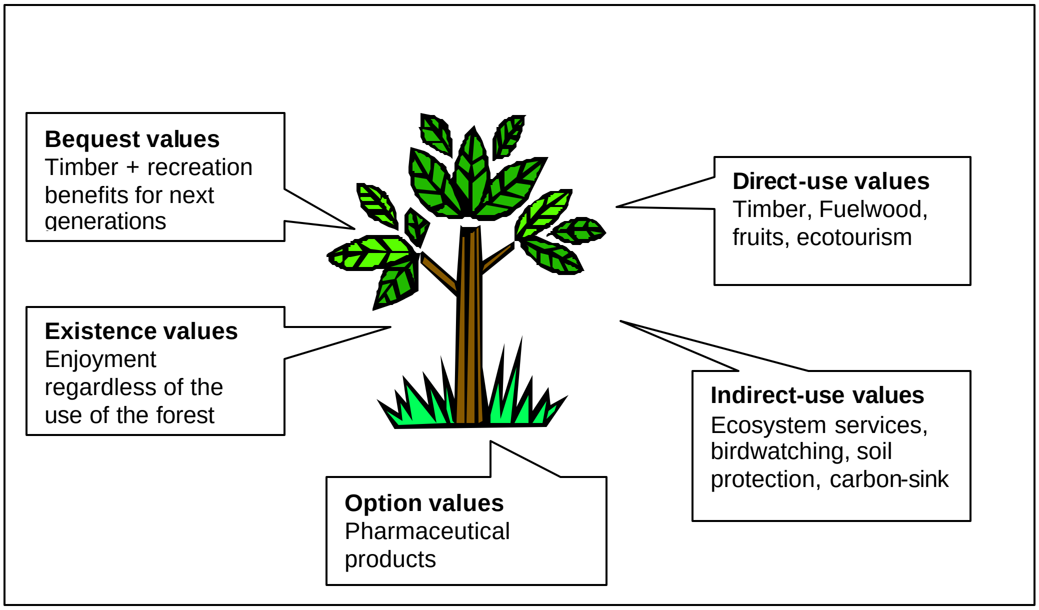
<u>Direct use values</u> derive from the consumptive or non-consumptive *use of the resource*. The individual directly enjoys the resource either by consuming it (i.e., logging the forest to obtain fuel wood or fishing for subsistence) or by gaining enjoyment from the resource stock itself (i.e., recreation value of a park or the scenic vista of a coastal area).

<u>Indirect use values</u> are those resulting from the *use of a resource's services*. For example, a forest provides watershed protection, and the ozone layer protects the Earth from ultraviolet (UV) radiation. The distinction between direct and indirect use values is not always clear.

<u>Option values</u> derive from the *potential future use of a good*, if the need arises. The concept is very popular in finance where options are sold for the right to sell a stock-market commodity at a specified price at a specified time in the future. The value of options derives from the fact that present time information is not perfect. Time will tell us if holding the asset is worthwhile, and keeping that option will make it possible to take advantage of any new information. The concept applies to natural resources as well. For example, the conservation of a natural area is an option, giving us the possibility of transforming the area in the future, or keeping it, according to the new information gathered on the relative value of the natural area.

In 1967, in a very influential essay, John Krutilla identified another category of values, which were to become an important area of research in environmental economics: <u>non-use or passive use values</u>. These values are the manifestation of people's willingness to pay for a resource regardless of their ability to make any use of it now, or in the future. Such values may arise because of altruism towards future generations (bequest value) or because of the simple knowledge that something exists (existence value) even if individuals never plan to use it.

Figure 2.6 Total economic value of a tropical forest



Non-use values pose a special challenge to valuation given that, by definition, existence value need not be revealed in any type of behavior. The contingent valuation method, which directly asks willingness to pay through the use of surveys, is the only way to elicit such values.

3
VALUING CHANGES IN PRODUCTION

Figure 3.1 summarizes the different impacts that can arise from a change in environmental quality and provides suggestions of valuation techniques that are most commonly used to value impacts. This chapter will introduce the productivity approach, which, as its name suggests, values losses in production. The productivity approach is one of the most widely used valuation techniques with an easily understood rationale behind its theory (see Bojo 1995 and Cesar 2000). The technique focuses on environmental resources as an input to the production of goods or services. When an input is degraded, this leads to a reduction in the services provided to production with a resulting loss in profit for the producer. Figure 3.2 provides an example of this relationship. In this case, overgrazing has led to soil erosion. As the grass becomes patchy and the soil is washed away, it reduces the soils capacity to sustain grass on which the animals graze. In turn this reduces the income of the farmer. It is by focusing on this final impact—of reduced farming income—that the productivity approach can be used to value environmental degradation.

Figure 3.1 Choosing a valuation method

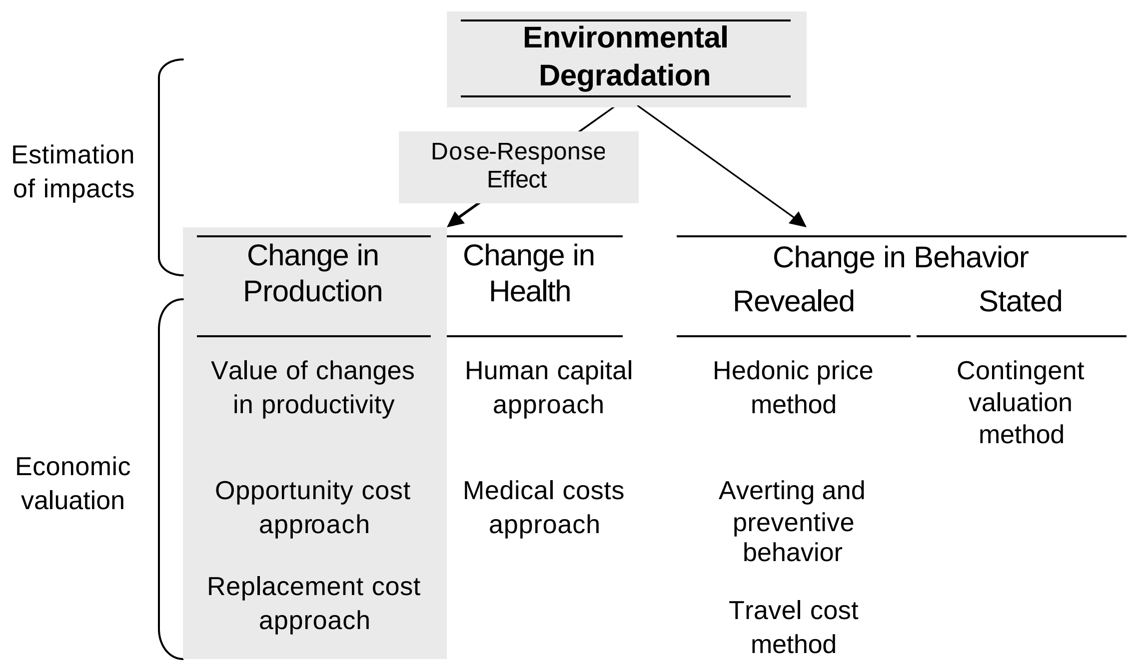


Figure 3.2 Linking environmental degradation to changes in production

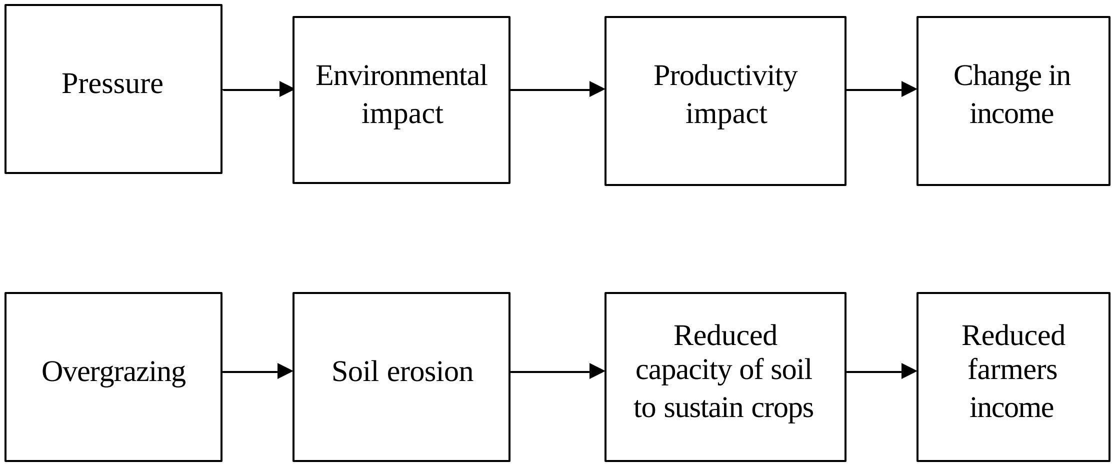


Figure 3.2 can be used to analyze any type of productivity impact. First a pressure (over-grazing) leads to an environmental impact (soil erosion). This in turn leads to a productivity impact (reduced capacity of soil to sustain crops). This alters farmers' income. This framework is commonly used to analyze cause and effect relationships. Another typical example is that of health. For example, increased vehicle use (behavior), leads to air pollution (environmental impact). This in turn results in an increased number of workers with respiratory infections caused by the air pollution (productivity impact). The loss of workdays leads to a loss in wages for the workers.

Applications of the Productivity Method

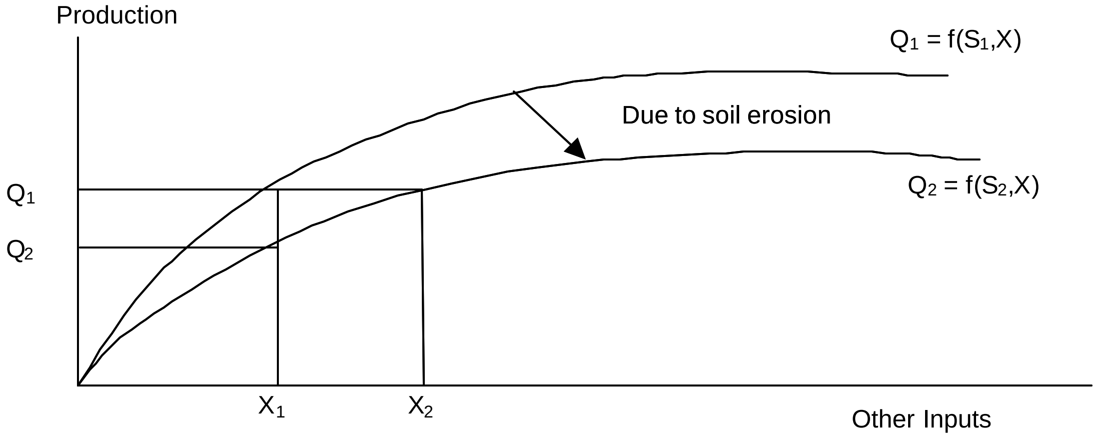
The approach can be used for a wide range of valuation problems. It has been widely used due to its ease of explanation and justification. This can be an important characteristic as will be seen in the following modules as other techniques can be controversial. Below is a limited list of potential scenarios in which the approach may be useful:

- **Soil Erosion**. It can be used to measure the decline in on-site crop yields, and the resulting downstream effects such as blockage of irrigation systems and sedimentation of reservoirs.
- **Air Pollution**. The damage on human health resulting from air pollution and its impact on workdays.
- **Acid Rain**. The resulting damage to trees can be valued using the lost value of production.
- **Pollution of Fisheries**. As waters are polluted, it reduces its capacity to sustain fish stocks. This has an effect on the income of fishermen.
- **Salinity of Croplands**. This results in declining yields and at its most serious eliminates the ability of soil to sustain crops.

Theory Behind the Productivity Approach

When there is a change in an environmental input, this can lead to a change in the quantity produced. For example, in the case of soil erosion there may be an accompanying decline in the volume of crops harvested. However, it may be possible for the farmer to replace the loss of one input (soil) for a substitute input (in this case perhaps fertilizer). Figure 3.3 shows a production function, where production is a function of soil (S), and other inputs (X). As the quality of the soil declines from S_1 to S_2 due to soil erosion, the production function shifts down to Q_2. The farmer faces two options. First, he can do nothing and produce at Q_2 instead of Q_1, using the same level of other inputs. The second option is to keep production at Q_1, by increasing other inputs, such as fertilizer, from X_1 to X_2. In reality, the farmer is likely to respond somewhere in between, by letting production fall a little and increasing inputs somewhere between X_1 to X_2. Either way, the farmer suffers an economic loss in the form of decreased profits. Under the first option he loses the value of lost output. In the second option, the costs of production increase as a result of having to increase other inputs.

Figure 3.3 Graphic representation of production change



This provides us with two measures for valuing the degradation of land: the value of lost output, or the cost of additional resource inputs. Both affect profit.

$$p = PQ - c(Q)$$

Where, π = profit
P = price (which is assumed to be fixed by the market)
Q = production
c = cost of inputs (which depends on the production, Q)

Steps in the Practical Application of the Productivity Approach

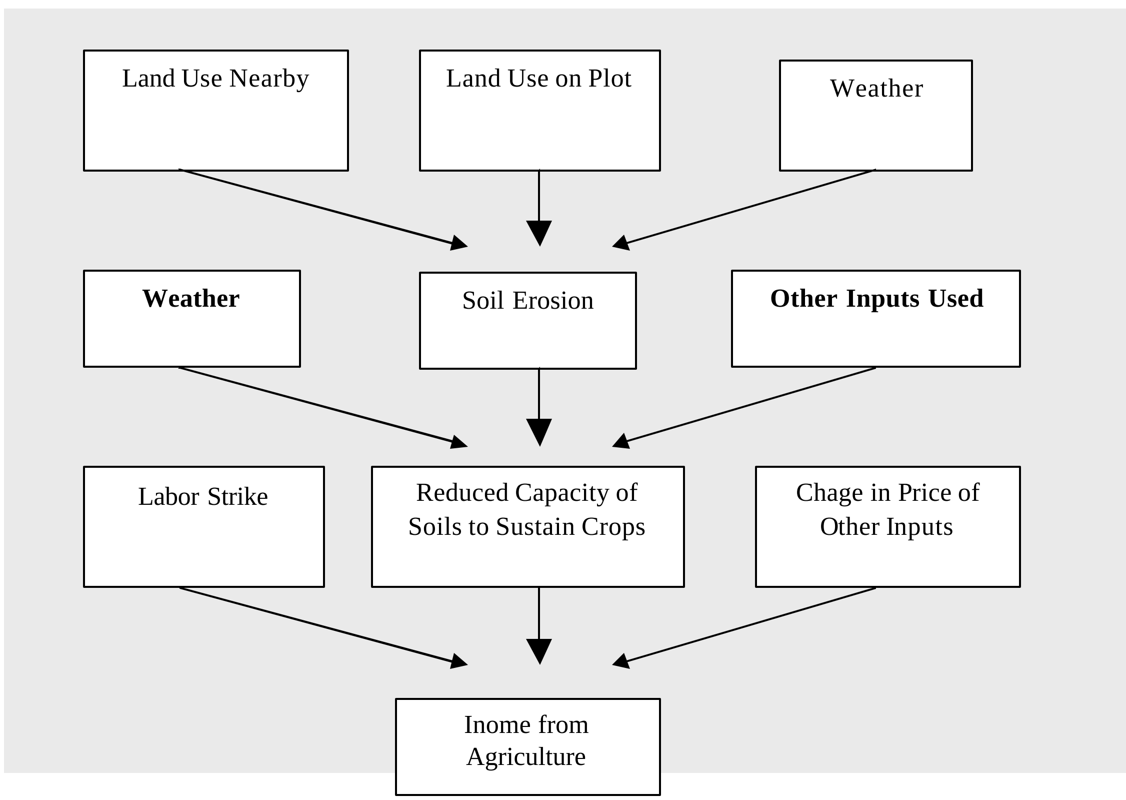
The productivity approach is often very appealing due to its ease of explanation and justification. However, in practice it can be one of the most challenging exercises. Presented below is a summary of the two steps that need to be undertaken, and the issues that accompany them.

Determine the physical impact

Arguably the most significant problem with the productivity approach is determining the physical impact arising solely from the driving force or behavior we are interested in. In this example, we are only interested in valuing the impacts on income from *soil erosion caused by human mismanagement*, but this can be hard to differentiate from other causes.

An example of this complex linkage is that of soil erosion and farming income. Assume that farming incomes are observed to have fallen last year and it is suspected that this is due to overgrazing. However, this link is hard to prove as shown in Figure 3.4. For example, reduced income in agriculture can be due to a multitude of things such as a labor strike, change in the price of inputs, or the capacity of the soil to maintain crops. Even if we can prove it was due to a decline in crop yields, this decline may not have been caused by soil erosion. It may have been caused by a weather event that damaged the crop, or a decline in the number of other inputs used. The final linkage is to show that soil erosion is responsible for the decline in crop yields, as it may have been caused by many other factors, such as increased rain.

Figure 3.4 Linkages between environmental degradation and income in agriculture



What this example shows us is that it can be very difficult to differentiate impacts associated with a particular source. This is due to a series of complex biological relationships and in order to understand them economists rely on scientists. This information can be obtained from a number of different sources:

1. Experimental (using field trials). In this case the cause is deliberately imitated and its effect observed. For example, the decline in crop yields is observed from imitating soil erosion. This approach has the advantage of being in controlled conditions so it is easy to eliminate compounding factors. For example, the weather has a very large influence on crop productivity whereas you may only be interested in measuring that part of the reduction in production that comes from soil erosion. However, frequently these field trials do not take account of the role of the natural resources leading to a lack of quality

studies in the area. In addition, the management of crops in field trials does not represent management practices, which are carried out by the local farmer. It is difficult to extrapolate the findings of the trials as they are in such a controlled environment. In "real" situations, other factors will come into play and these synergies between factors are not accounted for.

2. Statistical (using cross-section, or time series data). This approach attempts to isolate the effect from other effects by using regression techniques. For example, the effects of soil erosion from other effects such as weather. The good thing about this approach is that it looks at real data in a real life situation. However, there are also difficulties with this approach. For example, the data is often only available for a short time horizon. It can be difficult to control for all other factors and this may influence the result. There is also the problem of self-selection.

Once the relationship has been estimated, there is still the second step, which is to value the impacts.

Attaching market values to the losses

One of the benefits of using the productivity approach is that the valuation of impacts is often less controversial than other methods. The rationale behind it is simple and can easily be explained and justified. The most straightforward approach is to use market prices to value the loss in production, or the cost of increased inputs. However, there are several issues that need to be considered.

In some cases, the use of market values can be misleading. Many prices are distorted due to government interventions, such as subsidies, taxes, import protection etc., or due to the presence of a monopoly. When considering the social cost it is necessary to look at the "real" cost to society, i.e. the price excluding the tax, or subsidy. Where possible, prices should be adjusted to reflect their competitive level. This is where a social analysis, such as this, differs from a financial analysis.

In many cases the change in productivity that is being considered is not large enough to change the market price. However, if the changes are large enough, changing market prices can make the analysis more difficult. This would occur if a large proportion of national supply comes from one area that is badly affected by a change in environmental quality. It could also occur if local markets are badly affected and are differentiated from national markets, such as local fish catch. If this is the case, then the market price should be adjusted to reflect the forecasted price in the absence of the environmental change.

One aspect that is often ignored in the analysis is that a change in production may alter costs. For example, if increased salinity reduces yields, there will be a corresponding reduction in harvesting costs. The opposite may happen in the case of a chemical spill killing off a large proportion of the fish population. In this case, costs may go up as it takes more time to catch the same number of fish.

Another issue that may complicate the analysis is that many products are not marketed and this can make it difficult to observe a market price. When this is the case, a number of alternatives can be used, such as valuing the:

- Benefits of the product. For example, medicinal plants could be measured as the benefit of avoiding a health outcome.
- Cost of substitutes. For example, the value of the loss of the availability of firewood could be valued by considering the costs of an alternative.
- Cost of increased labor time. Again in the case of reduced availability of firewood, cost could be valued as that of the increased time taken to collect the same amount of firewood.

The use of market prices generally only reflects use values and does not take account of non-use values such as existence, non-use, and bequest values. In some cases these can be substantial and considerably higher than use-values. Therefore, the productivity approach only provides a lower bound estimate of the opportunity costs foregone.

An Application of the Productivity Approach: Soil Erosion in Morocco

Pagiola and Bendaoud (1995) study the long run effects of soil erosion on wheat production in a semi-arid region of Morocco. It is thought that population growth in this area has led to the expansion of agricultural practices with increasingly lower rainfall and shallower soils. This in turn is thought to lead to erosion and the loss of productivity

The study area lies in the commune of Bouguergouh, in Settat province, along the escarpment that divides the plains of the Lower Chaouia from the plateau of the Upper Chaouia. The region is characterized by low and erratic rainfall. The main agricultural activities in this area include cereal production, and extensive livestock. Karim and the very similar Marzak are the most frequently planted varieties.

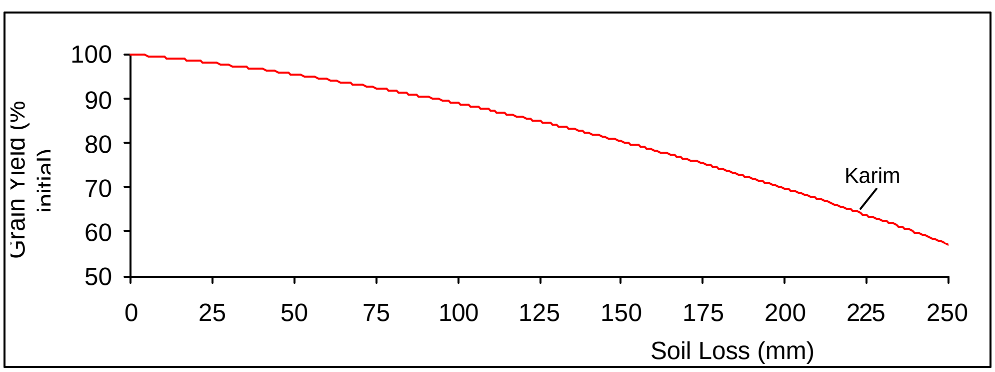
The following describes how the two main steps (determining the physical impacts and attaching values to them) were undertaken and the assumptions that were made in estimating the cost of soil erosion in Bouguergouh. In addition, the results of the study are also presented[iii].

Determine the physical impacts

The first step in this analysis is to estimate the level of soil erosion. As there was no concrete data on erosion rates, a simulation analysis was used. A range of plausible erosion rates was assumed, and the estimates of production trends made for each of these rates.

The analysis then uses a crop growth simulation model to simulate the relationship between soil conditions and wheat production. The model requires information on soil characteristics, climatic conditions, and cultural practices. Data on soil characteristics were obtained by collecting and analyzing the soil. Climatic data was taken from daily observations at a nearby market for the period 1983-1992. Information on cultivating practices was obtained from research by INRA (French Institute for Agronomy Research).

Figure 3.5 Determination of physical impacts: soil loss and grain yield in Morocco



As shown in Figure 3.5, as soil loss increases, the grain yield declines. Soil erosion is cumulative as each year when soil is lost; it is lost forever and will affect production for as long as crops are produced there. This means that a 2mm/year soil loss is equivalent to 20mm of soil over 10 years.

Attach a market value to the losses

Once the impacts of soil erosion on production have been estimated, the next step is to attach a market value to these losses. The socioeconomic data required for the analysis of the value of the losses was obtained from a survey of farmers in the area. Prices for most inputs were observed in the area.

The long-run economic effect of a given erosion rate can be calculated by the net present value of losses due to erosion; that is, the sum of the discounted differences between returns in any given year and initial returns over a specified time period. In the case of soil erosion, the losses continue over time. The true cost of soil erosion is not just the decline in yields from a single year's erosion, but the value of the decline in yields over the entire time horizon that the soil would have been used for agriculture. It is common practice in economics to discount these costs using the present value technique described in chapter 2.

Table 3.1 Economic valuation of agricultural losses from soil erosion in Morocco

	Annual Value*	Present Value (no erosion)*	Present Value (erosion at 5mm per year)*
Revenues	4,740	51,600	49,000
Cost of Inputs (inc. fertilizer, seed, herbicide, labor, harvesting costs)	1,610	17,500	17,500
Returns	3,130	34,100	31,500

*all values are in Moroccan dirhams

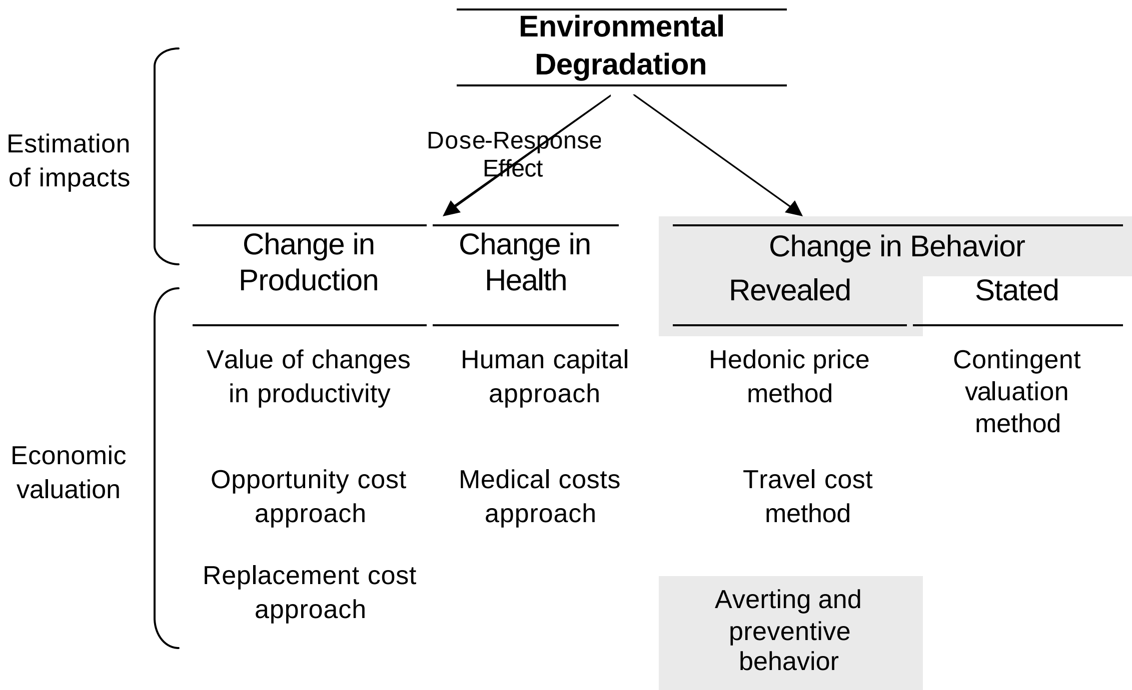
Table 3.1 presents the annual returns to Karim production, using a 50-year time horizon, and 5mm of soil loss per year. This means that in the fiftieth year, 250mm of soil will have been lost. This loss will have reduced initial yields of DH4,740 to DH2,714 in the fiftieth year. The present value (PV) of revenues, discounted at 10 percent, is DH49,000. Assuming that costs are DH1,610 per year and don't decline with declining yields, the PV of costs of production is DH17,500. This gives a PV of net revenues of DH31,500. If there was no soil loss, then yields would not decline annually and would be DH4,740 every year. Again, assuming costs remain constant at DH1,610 per year, the PV of net revenues is DH34,100. The net present value of losses resulting from annual soil loss of 5mm per year on wheat production, using Karim, as an example, is 2,600DH/ha.

4
AVERTING AND MITIGATING BEHAVIOR

The averting and mitigating behavior methods are an example of revealed preferences approach to valuation (see Figure 4.1). This chapter will introduce the topic with an example.

In late 1983, an outbreak of a waterborne disease affected a small county in Pennsylvania, USA.

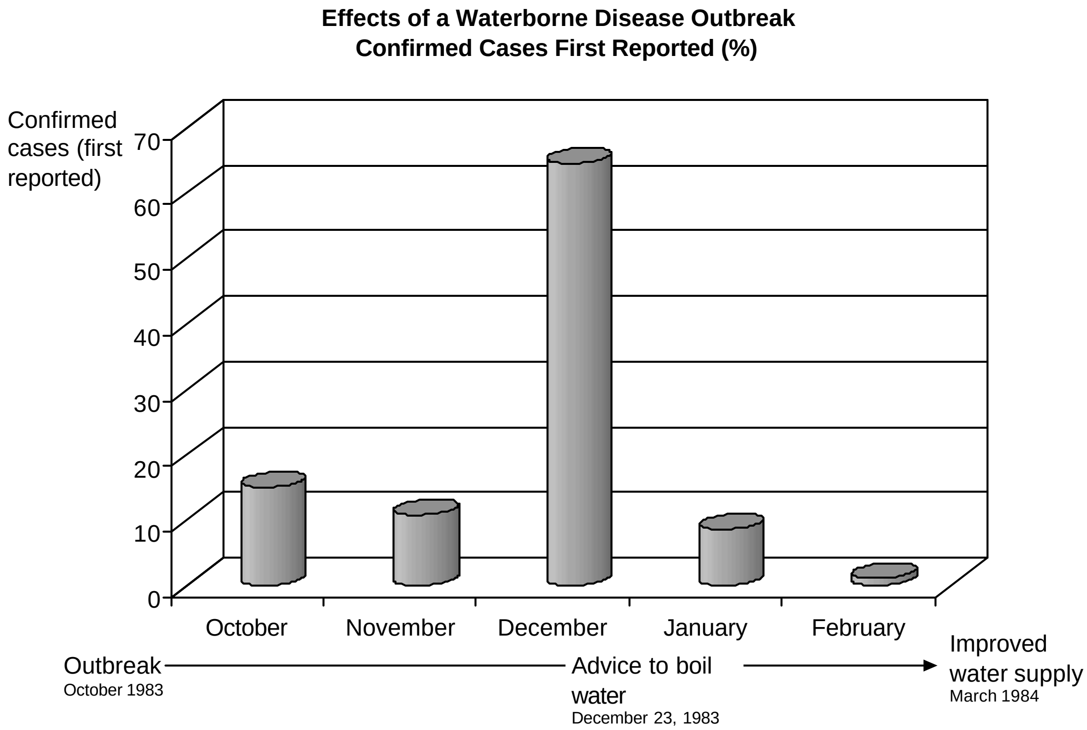
Figure 4.1 Choosing a valuation method



Research conducted on a sample of individuals, revealed that most of the cases of infection took place between October and December, and dropped to almost zero in January and February (see Figure 4.2). A new water supply line providing clean water was completed at the end of March 1994. So, how and why did the number of diseases fall after December, before the pipeline providing clean water was built?

In December 1983, the county authorities had announced the disease outbreak and advised people to boil water until a safe drinking water supply could be provided. After this announcement the population started taking defensive actions to avoid their vulnerability to the disease[iv].

Figure 4.2 Effects of a waterborne disease outbreak



The health literature often measures the cost of illness as the opportunity cost of staying at home sick: i.e. the income lost while ill or injured. Benefits from environmental improvement are then measured as the value of the ill-days avoided. A shortcoming of this approach is that individuals can take preventive or remedial measures that reduce the effects of the environmental degradation. Ignoring the capacity of individuals to mitigate the effects of poor environmental quality could lead to wrong conclusions.

Applications of Averting Behavior Approach

In the example above, the number of cases of waterborne disease can be thought of as a function of the level of pollution and the degree of defensive or mitigating activity. This is shown in equation 1 below.

$$S = S(P,D) \qquad (1)$$

Where:

S: incidence of impact from environmental hazard (i.e. work days lost)
P: level of environmental hazard (i.e. level of water pollution)
D: level of defensive or mitigating behavior (i.e. expenditure on bottled water)

This relationship, linking an impact to its causes and the behavior of the individuals, is known as *household production function*. It can be applied to many different situations. For example, the number of cases of respiratory infections (S) is dependent on the level of air pollution (P) and expenditure of air purifiers (D).

This relationship does not only have to be applied to environmental hazards. It can also apply to an environmental good. For example, the level of enjoyment an individual gets from their leisure time

(S) depends on the natural qualities of a national park (P), and the time spent traveling there (D). Table 4.1 describes some of the common applications of the averting behavior framework.

Table 4.1 Uses of the household production function framework

Environmental factor P	Associated activity D	Final effect S = S(P,D)
Water pollution	Boil water / Buy bottled water	Health
Recreational qualities of a natural resource	Travel and time spent visiting	Recreation
Air pollution	Window cleaning	Clean windows
Air pollution	Use of air purifier	Health
Plant attacked by pests	Integrated pest management	Agricultural yields

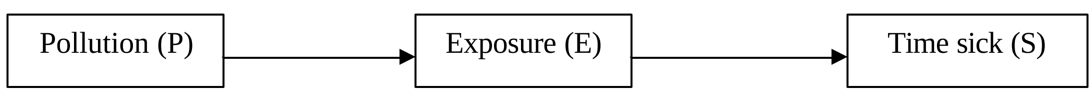
The existence of a ‘household production’ situation can provide important information about the economic value of environmental quality (i.e. air, water and natural resources) by observing the choices individuals make with respect to a related traded commodity (i.e. medicines, bottled water and park visits).

It is however important to keep in mind that the use of the averting behavior method is recommended when (i) people understand the environmental hazards to which they are exposed; (ii) they take action to protect themselves; (iii) the actions taken can be observed and their cost measured.

Theory of Averting Behavior

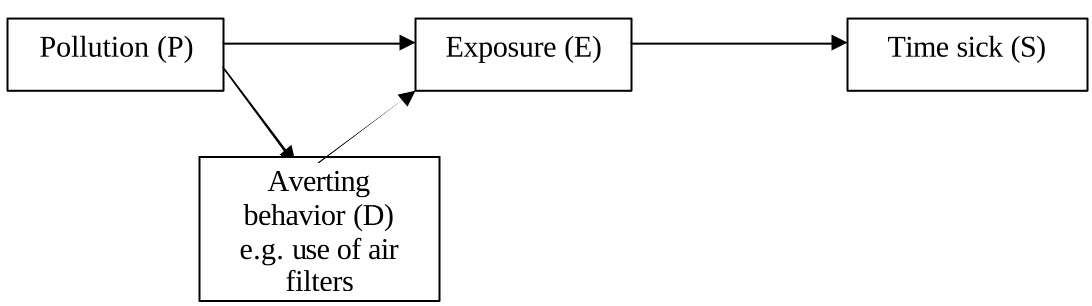
Often the valuation of health impacts from pollution considers only the actual number of cases of sickness as shown in Figure 4.3.

Figure 4.3 Dose-response relationship



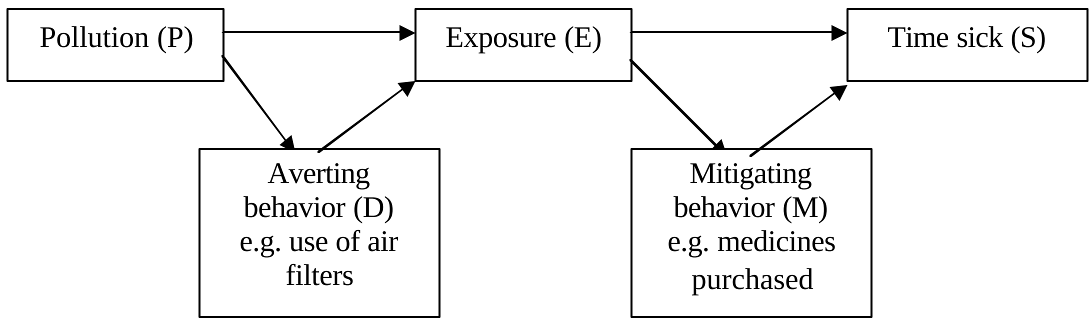
However, when defensive actions are possible, the framework becomes more complex. The researcher must now consider how individuals respond to avoid (increase) exposure to an environmental hazard (or to an environmental good) as shown in Figure 4.4. This is known as **averting** or **defensive behavior**. The effect of pollution is not only sickness, but also the amount of resources spent to avoid it! The valuation should now include not only the value of discomfort of illness and the value of time spent sick, but also the value of defensive behavior.

Figure 4.4 Dose-response relationship with defensive expenditures



However, sometimes defensive behavior will not avoid sick days. This may be because it is too expensive to undertake. For example, an individual may prefer to endure a day of sickness if the defensive behavior costs two weeks wages. It may also be the case that defensive behaviors are not available to completely avoid sickness. Once an individual is sick, they can chose to undertake **mitigating behavior** to reduce the impacts of the sickness or the time spent sick (see Figure 4.5). For example, an individual may get the flu. Without medicine he will be sick for two weeks, but with the medicine he will be sick for one week. The value of this medicine should also be included in the valuation exercise.

Figure 4.5 Dose-response relationship with defensive and mitigating expenditures



The Averting and Mitigating Behavior Method in Practice

For a more throughout review of this valuation method the reader can refer to Freeman (1992), especially chapter 10 “Valuing Longevity and Health”.

The application of this approach to valuation is based on the assumption that individuals recognize the existence of a hazard and take actions to avoid it. The steps to be followed in the analysis are the following:

- Identification of the environmental hazard and the affected population
- Observation of the responses of individuals
- Measurement of the cost of taking actions

Step 1 – Identification of the environmental hazard and population affected

Typical environmental hazards that result in averting and mitigating actions include water pollution (as in the example above), noise from airports or roads, the extent of soil degradation in a rural area, and air pollution. Monitoring equipment is important to measure such variables and check whether certain critical levels are being reached.

It is also important to define the population at risk. This is a delicate aspect of the analysis. The averting behavior approach is based on observed actions and fully relies on data about the affected population. If observations are taken from individuals only marginally affected by the hazard, the analysis will underestimate the values. If observations are taken only from individuals who are significantly affected by the hazard, and this is then applied to all individuals who are marginally affected, then the analysis will overestimate the values. Practical considerations and common sense have to be adopted. In the case of waterborne diseases, the relevant population will be the one in the proximity of the water body and the population downstream. In the case of air pollution, the population can be harder to ascertain, depending on seasonal and climatic conditions among others.

Step 2 – Observation of individuals' actions

There are various ways to collect information on the actions taken by individuals. One can ask all potential victims, when their number is limited. Alternatively, one can choose a representative sample of the affected population and carry out a survey. The survey method needs to be carefully designed in order to avoid common problems such as biased samples, strategic bias, and self-selection.

In addition, consider the case in which out-of-pocket expenses, such as the purchase of medicines, are being paid by the government through the national health system. Would these expenses be recorded by observing averting behavior? The answer is no, but they should be! If individuals are compensated, or do not have to pay for their medical expenditure, these costs will not be reflected in their expenditures. But this does not mean they are not willing to pay for it, just that someone else is paying for it. A researcher will then try to estimate the public expenditure in defensive expenditures and include it in the WTP calculations. If not, estimates should be treated as an underestimate of the true WTP.

Step 3 – Measuring costs of taking actions

As a final step, actions have to be valued in monetary terms. Prices are usually available for environmental substitutes such as bottled water, double glazing, air purifiers and so on. However, the purchase of environmental substitutes may not be perfectly related to the level of the hazard. For example, a certain level of the hazard may be tolerated before taking action. Only when the environmental threat reaches a certain level, will defensive expenditures start.

In every case it is important to understand *why* the individual is taking his chosen course of action and whether this action is enough to avoid the hazard. The analysis is complicated by two things in particular:

- Some goods are only partial substitutes for the environment. For example, air conditioners only partially reduce exposure to hazardous air pollutants. The researcher must be aware that sickness and discomfort may still occur and this should be included in the analysis.
- Some goods provide additional non-environmental benefits. For example, air conditioning also ameliorates the room temperatures making it more pleasant. Also, in the case of bottled water, while it may reduce the risk of contracting a disease it also tastes better. This additional benefit should be taken into account in order to avoid overestimating the benefits.

Example: Valuing the Impacts of a Giardiasis Outbreak

The availability of a clean and safe water supply is often a key concern for people in developing countries. Yet, reducing or eliminating contamination is often very costly and therefore has an opportunity cost that other goods cannot be bought. The decision on whether or not to invest in uncontaminated water can be assisted by economic analysis.

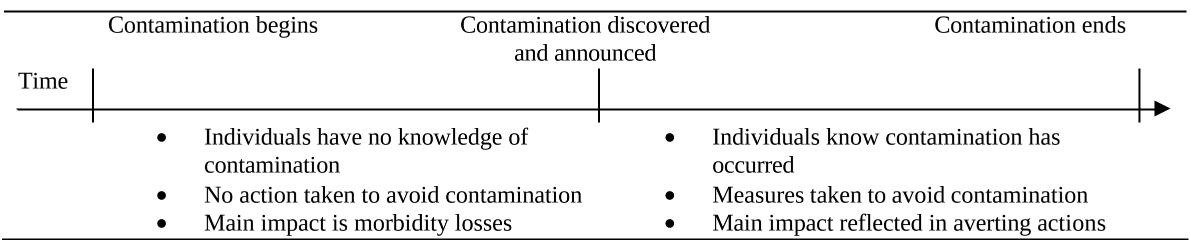
Individuals spend resources on boiling, hauling, and buying water in order to obtain this very necessary resource. Analyzing the decisions of individuals regarding the availability of clean water can provide useful information on the benefits derived from an investment in clean water supply. A comparison of the present and future costs of supply with an estimate of the flow of present and future benefits could ideally be done in order to make a decision.

Techniques to calculate the benefits of clean water exist. This section describes an example in which expenditures in defensive activities constitute an important element of the valuation of waterborne disease losses. The example refers to a giardiasis outbreak that took place in Luzerne County, Pennsylvania (USA) in 1983 (see Harrington *et al*, 1989). In general, an outbreak of a waterborne disease results in two categories of damage:

1. Morbidity and mortality losses – Although seldom fatal, giardiasis can be an unpleasant and temporarily debilitating diarrheal disease. Valuation of morbidity raises difficult issues regarding the valuation of time and direct disutility of illness.
2. Losses associated with the actions taken by individuals to reduce their exposure to environmental contaminants – Averting activities can be observed in a wide variety of situations, but it is particularly important for drinking water contamination, where the availability of close substitutes gives people an option to avoid the illness.

The episode of giardiasis outbreak in Luzerne County, took place between the end of 1983 and 1984. Information that the outbreak had occurred and availability of substitutes for publicly provided water, are key in understanding the effects of the outbreak. Figure 4.6 shows that (i) the outbreak, (ii) the announcement of contamination, and (iii) the end of the contamination episode define two intervals in which individuals have different information and hence behave differently. In the time between the start of the contamination episode and the announcement by the authorities, individuals were not taking any actions to prevent exposure and the effects of the outbreak were essentially an increase in illness, workday losses and hospitalizations. During the second period, when individuals knew contamination had occurred, measures were privately taken to avoid exposure and fewer cases of illness were registered.

Figure 4.6 The giardiasis outbreak in Luzerne County, Pennsylvania



The authors of the study undertake a two-step valuation. In the first step they calculate the first period's damage by valuing the morbidity costs of the outbreak. In the second step, they assume a negligible impact in terms of morbidity in the second interval, and measure the cost of the averting activities undertaken to reduce exposure to the contaminant. In order to estimate losses due to averting actions, fifty telephone interviews were undertaken with households chosen at random from the telephone book.

The valuation exercise required information on:

(i) How much time individuals spent on average to get water; and
(ii) An estimate of the value of time.

The survey showed that individuals chose a variety of strategies to ensure safe drinking water. Households were then classified according to the strategy for obtaining water:

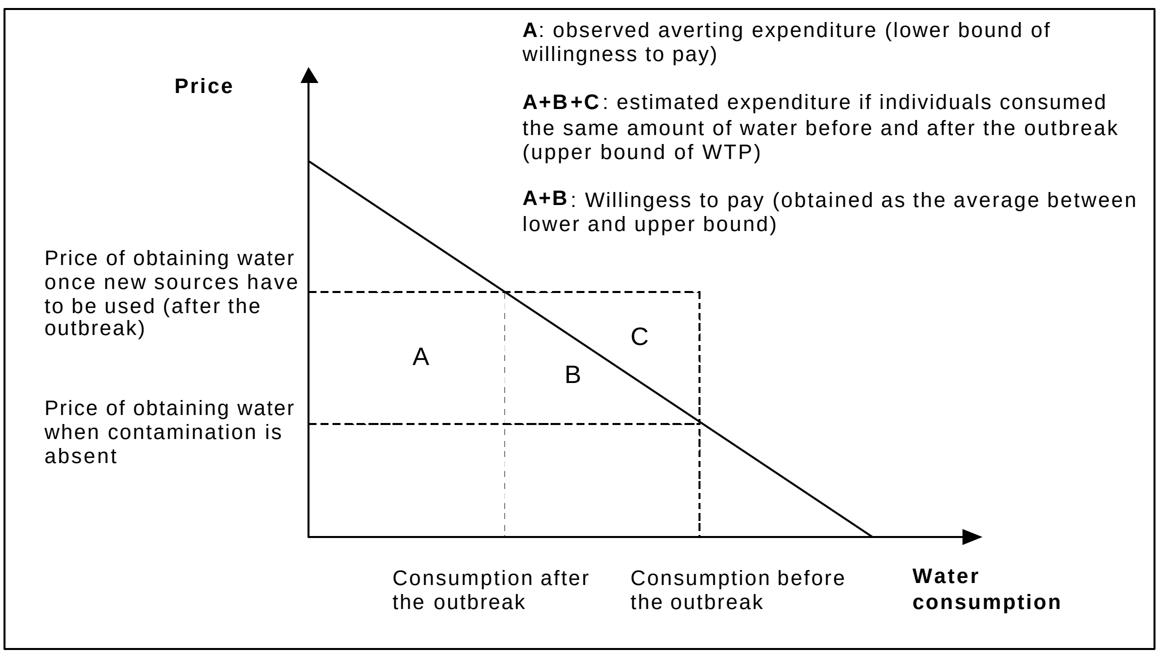
- Haul water (22% of households)
- Boil water (24%)
- Purchase bottled water only (2%)
- Haul and boil water (6%)
- Haul and purchase bottled water (18%)
- Boil and purchase bottled water (18%)
- Haul, boil and purchase bottled water (8%)
- None of the above (2%)

Very few households purchased bottled water only; most of them either hauled or boiled water and purchased bottled water in combination with hauling and boiling. A difficulty arises when averting activities are performed jointly with ordinary activities: i.e. while coming back from work, visiting relatives or friends, and so on. In such cases the valuation of time spent specifically in averting activities is difficult to estimate.

In general, the valuation of time spent obtaining water is a very delicate step in the analysis. In this study, individuals are categorized according to their working status: working adults, homemakers, retirees, disabled, unemployed and students. In the case of working adults, time is valued at the average after-tax wage rate in the outbreak area with confirmed cases of giardiasis. Valuing time for the other categories is more difficult. The authors use three scenarios according to the value of time of homemakers, retirees and disabled, and unemployed and students.

Using data on the method of obtaining water, the time spent collecting water and the value of time, calculations can be made to estimate the averting expenditures. However averting expenditures are not equivalent to willingness to pay, which is the object of valuation. Actual averting expenditures constitute a lower bound for WTP. After the disease outbreak, the cost of obtaining water increased as people had to obtain safe drinking water from alternative sources. As an effect of the higher price individuals reduced their consumption of water[v]. Multiplying the quantity of water originally consumed by the new cost of obtaining water provides an upper bound of WTP. The two measures obtained, are then averaged to obtain a 'best estimate' of the WTP for avoiding water pollution[vi]. See Figure 4.7.

Figure 4.7 Willingness to pay to avoid giardiasis in Luzerne County, Pennsylvania

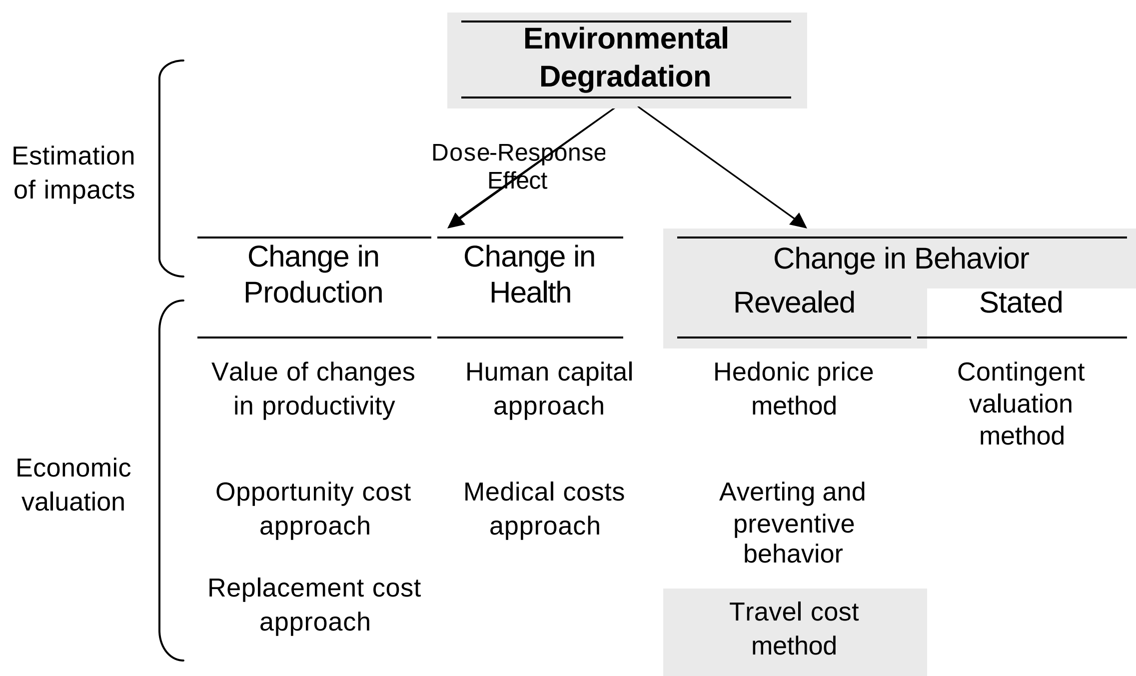


Depending on the hypothesis regarding the value of time for non-working individuals, three different estimates are obtained for the losses due to actions taken by individuals to avoid contaminated water. The study concluded that the losses linked to averting actions ranged from $12.10 to $38.50 millions. Morbidity losses (in the period of time between the beginning of the outbreak and the announcement of the county authorities) ranged from $4.60 to $7.00 million. Summing up the losses from morbidity and averting actions, the total losses of the outbreak ranged from $16.70 to $45.50 million. Ignoring averting expenditures would lead to a serious underestimation of damages.

5
TRAVEL COST METHOD

The underlying assumption of the travel cost method (TCM) is that if an individual is willing to pay (WTP) the cost of visiting a recreational site then he should value that site at least as much as what he paid to visit it. The underpinning of this approach is that the effect of increasing travel cost is considered the same as increasing the price of admission. Since many natural areas have either low or no admission prices, this approach uses travel cost as a proxy for estimating consumer's surplus and extracting it via changes in admission fees. Data is usually collected through surveys in which an individual states the amount of time and money he spent traveling to a park, tourist center, fishing spot, and so on. The travel cost approach is different from the contingent valuation method in that the behavior of subjects is observed in real markets rather than in hypothetical circumstances. The TCM is a 'revealed preferences' approach to valuation (see Figure 5.1). If a person travels to a recreation site that can be entered free of charge, then this person values the site at least as much as the cost of getting there. If there is an admission charge this must be added on to the cost of travel to obtain the willingness to pay for the experience. Since travel cost varies from person to person it is then possible

Figure 5.1 Travel cost method as a revealed preferences approach to valuation



to construct a demand function for recreation.

A Bit of History

In 1947, the US National Parks Service needed to prioritize park areas that would qualify to be declared 'protected'. It then solicited the advice of experts about the value of the country's national parks and methods to elicit such values. Harold Hotelling responded with a very original representation of how the recreational value of a park could be measured, setting the stage for the 'travel cost method'.

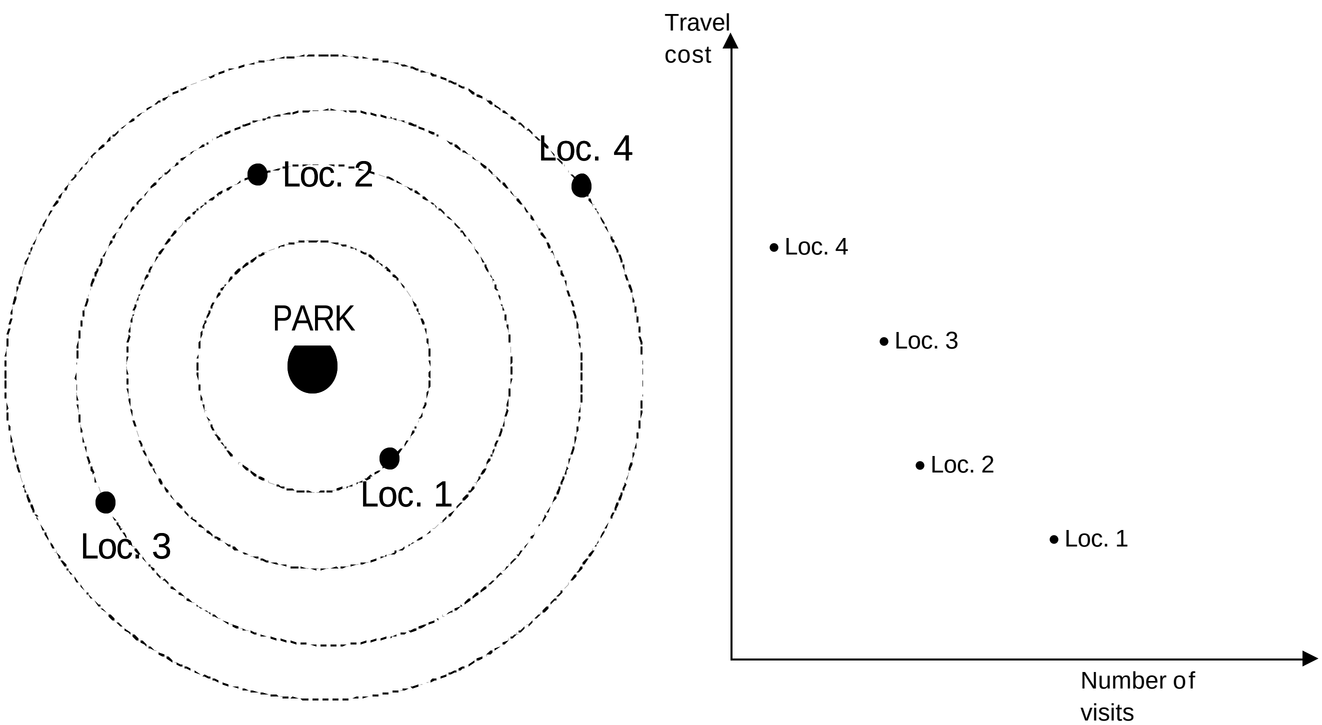
Hotelling's idea is based on the fact that people pay to visit the park, notably the cost of traveling. Since people come from different locations, they incur variable costs for enjoying the park. This information can be linked to the number of visits that people make to obtain a demand curve for recreation (see Figure 5.2)

Hotelling suggested defining concentric zones around the park, so that the cost of traveling from any point of the same zone is constant. For each zone, it is then necessary to accurately measure the cost of traveling, the number of visits to the park in a period (i.e. month or year), and the population of the zone. With this information it is possible to plot a demand curve, where the price is akin to the travel cost and where the level of demand corresponds to the number of visits.

"Hotelling's response was ignored by the National Parks Service since other respondents had expressed a consensus view that the problem could not be solved […]. Ten years later it resurfaced" through the works of Trice and Wood (1958), Clawson (1959), and Clawson and Knetsch (1966) (reported in Pearce, 2002). There are now hundreds of travel cost studies implemented not only in the US but all around the world. There are two main applications of the method:

1. *Valuation of natural resources* (i.e. parks, beaches) that people visit for recreational purposes
2. *Valuation of the damages from pollution* by observing the change in visitation to a natural area (i.e. damage of an oil spill to a marine park)

Figure 5.2 Hotelling's idea - From the cost of traveling to the demand for recreation

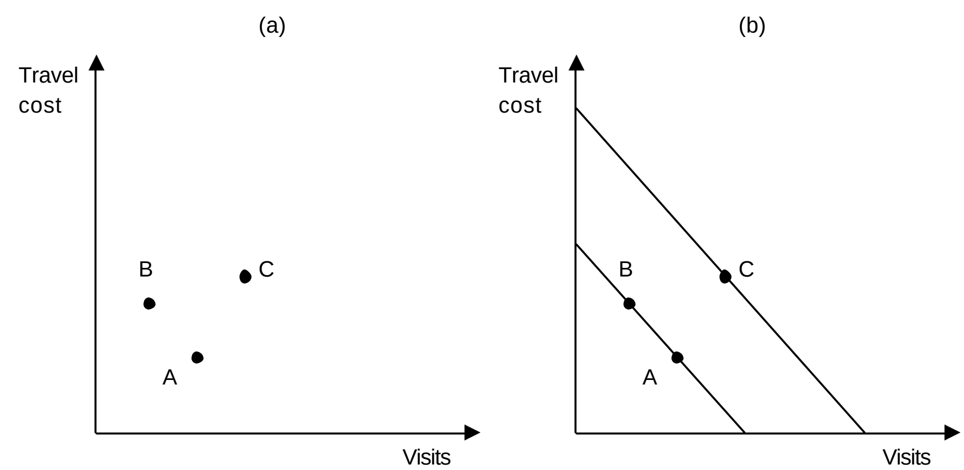


From Theory to Practice

The basic principle of a travel cost is very simple. However, linking the aggregate number of visits and the travel cost might not be enough. It is important to consider also all the variables that influence the visitation rate, other than travel cost. These variables may include income, age, personal interests, and so on. The following example is taken from Pearce et al. (1989).

Assume we observe three individuals traveling to a park from three different locations (see Figure 5.3(a)). Individual A lives closest to the park so her travel cost is relatively low. Individual B lives further away and his observed number of visits is less than those observed for A. The third individual who lives very far away from the park actually undertakes more visits than either A or B. This very typical situation may occur for several reasons. For example, individual C may be wealthier, thus being able to devote more resources to park visits. Or, he may have children that want to go to the park every weekend. There may be several reasons to justify this behavior. What this means, in economic terms, is that individual C has a different demand curve from individuals A and B (see Figure 5.3(b)).

Figure 5.3 Observation of number of visits and travel costs



In order to overcome this problem, we need to define a *trip generating function*[vii] that links the visitation rate to its determinants including the cost of traveling plus any admission fees:

$$\text{VisitationRate}_i = f(\text{TravelCost}_i + \text{AdmissionFee}; \text{Income}_i; \text{No.Children}_i; \ldots) \qquad (1)$$

Notice that the visitation rate and the explanatory variables (on the right hand side of the equation) have a sub-index *i* indicating the unit of observation. According to the observation units used, there are two main approaches to estimation:

1. *Zonal travel cost method* – The area around a park is divided into zones. In this case, the sub-index *i* identifies zones. The visitation rate is obtained as the number of visits from any given zone divided by the population of that zone. The explanatory variables are the average values for the zone: average income, average age, number of fishing licenses, etc.
2. *Individual travel cost method* – In this case the observation units are the individuals (or a sample of them) visiting the park. The visitation rate refers to the number of trips made by any individual in a specified period. The explanatory variables refer to individual characteristics.

Basic Methodology for a Zonal Travel Cost Model

This section explicitly describes the zonal and not the individual travel cost method. Yet, the procedure described below can be easily applied to the individual travel cost method. Just keep in mind that the zonal travel cost method focuses on zones (e.g. cities, neighborhoods, regions) as the object of analysis, while the individual travel cost method focuses on human beings.

Step 1 – Gathering information on travel cost, number of visits and other variables

Questionnaires are used to ask visitors to the recreational sites where they have traveled from. From visitors' responses one can estimate their travel costs and relate this to the number of visits per year.

The 'travel cost' data should include all explicit and implicit costs related to visit a park. It is possible to identify at least the following categories:

- Explicit costs necessary to reach the site, e.g. gasoline and vehicle maintenance relative to a particular trip, train or bus ticket.
- Time cost of travel. The time spent traveling cannot be used for other activities (e.g. work) thus representing an opportunity cost. A common problem is how to value time. Many studies use the wage rate as an approximation.
- Cost of time spent on site. The time necessary to visit the site has also an opportunity cost. This variable is however not necessary under the assumption that all visitors choose visits of the same duration and have the same opportunity cost of time.

Compounding factors should be considered. For example, if the travel to the site is associated with some other beneficial activity, e.g. visiting a relative en route, then the travel cost cannot be totally associated with the park attributes. Ignoring this information can overstate the park's value.

It is important to include any variable that might help account for differences in the behavior of individuals from different cities. Other variables may include age, income, number of fishing licenses etc.

In a typical study, this information might be collected by surveys sent to all—or a random sample of—individuals living in each city.

Step 2 – Estimate the trip generating function

After collecting the relevant data, a trip generating function is estimated. Each zone represents an observational unit. The estimation gives parameters for each of the explanatory variable. The parameters obtained tell us how much a change in the correspondent variable affects the visitation rate.

Step 3 – Derive the demand curve for each zone

Once the trip generating function has been estimated, it is then possible to draw zone-specific individual demand curves, in which the visitation rate depends on a hypothetical entrance fee. Notice that each zone is in principle characterized by a different demand curve. This is because each zone will have different characteristics such as: income, percentage of young people, travel cost, vicinity to alternative sites, and so on.

Step 4 – Derive the 'willingness to pay' for the site

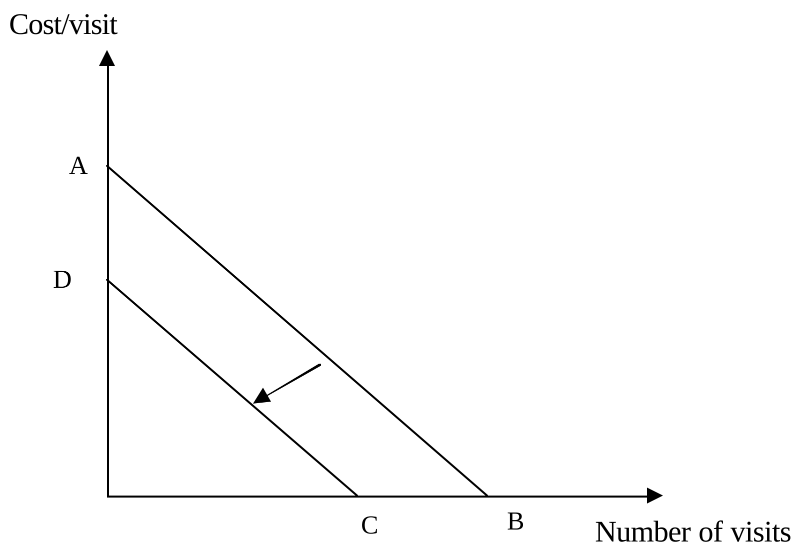
The area below the demand curve is the *consumer surplus* and it is this that we want to measure as it approximates an individual's willingness-to pay for the site. By multiplying the individual's consumer surplus by the population of each zone and summing up across the different zones one finds the aggregate *willingness to pay* for the recreational site.

Measuring Damages from Pollution

The methodology explained above can be used to estimate the damages caused by environmental degradation, such as pollution. Assume that the quality of the water is one of the main attributes of a marine reserve. A change in the park's qualities would result in a change in the observed number of visits to the park. If data regarding the new visitation rate is available, it is possible to calculate the new parameters and obtain a new demand curve for park visits.

In figure 5.4, AB is the curve prior to the change and CD is the curve after the change. The lost benefits are given by the area ABCD, corresponding to the decrease in consumer surplus.

Figure 5.4 Measuring damages from pollution using the travel cost method



Problems Associated with the TCM

When dealing with the travel cost method, there are mostly two sources of problems. One of them is the difficulty of being able to account for hidden costs and benefits, such as the cost of time and the benefits of visiting multiple sites in one visit. Another difficulty arises because the travel cost method may still represent a lower bound of an individual's willingness to pay. Such is the case when a person has moved his residence near a recreation site. In such cases, the travel cost became very low, and underestimates WTP.

Time cost

The underlying assumption of the TCM is that travel costs reflect the recreational value of visiting a site. A simple TCM might assume that the only travel cost is related to gasoline expenses, however time is also valuable to people in that time spent during a long car journey cannot be spent doing anything else. Therefore the value of time should be added to the travel cost as a reflection of the true recreational value, which the visitor gets from visiting a site. Ignoring time costs is generally believed to lead to a significant underestimate of the recreational value that people obtain from visiting a site. No real consensus has yet been achieved on how to estimate a value of time.

Multiple visit journeys

Often individuals visit several sites in a single journey. When administering a TCM questionnaire, how should analysts apportion the visitor's travel costs? During the day the visitor may have incurred high travel costs, however only a portion of these reflect the recreational site in question.

A further complication is that many people enjoy traveling. For them the journey to a recreational site is not a cost and may even be a benefit [viii]. In such cases we should subtract the time benefit of the journey from its travel costs. In such cases a simple TCM may be overestimating the recreational value of sites.

Substitute sites

One visitor may travel 80 km to visit a site which he/she particularly enjoys whereas another who has comparatively little enthusiasm for the site may travel the same distance from another direction simply because there is no other available site near his/her home. Using the simple TCM approach would yield the result that both visitors held the same recreational value for the site, which is clearly incorrect.

House purchase decision and non-paying visitors

It may well be that those who most value the recreational attributes of various sites will choose to buy houses near those sites. In such cases, they will incur relatively low travel costs to visit the sites that they value so highly. In this case the travel cost method will grossly underestimate of the true recreational value of the site. In general, TCM studies often omit visitors who have not incurred travel costs to reach the site (for example, those who have walked from nearby homes). However, this group may well put a very high value on the site.

Case Study: Coastal Water Quality in Davao, Philippines

Davao is the second largest urban area in the Philippines and is located on the island of Mindanao. The urbanized portion of the city is primarily located on the coastal plain alongside the Gulf of Davao. Until 1992, most of the residents of Davao who used local beaches for recreation went to beaches very near the urban area, the most popular of which was Times Beach. However, in early 1992 the city health department found very high levels of fecal coliforms and pathogens in the water and issued a series of warnings to the public about the health risks of swimming at Times Beach. As a result, most people stopped using it for recreation.

A study by Choe et. al. (1996) uses the information on how much people spend on visiting Times Beach to build a demand curve for its recreation services. The ultimate objective of this example is to see how the travel cost method can be used to estimate the welfare loss caused by the pollution of coastal water.

Step 1 – Gathering information on travel cost, number of visits and other variables

As with most travel cost analyses, the basic information for this study was collected through a survey in which respondents were asked about their household's income, age, education level and travel habits. In this specific example, households were also asked about their willingness to pay for a city-wide plan to clean up the rivers and sea to make Times Beach safe again. This information was used to carry out a contingent valuation analysis (see chapter 7). Notice that using more than one valuation method at a time enables a test for what is technically known as *'convergence validity'*, that is, the robustness of valuation results obtained from different valuation methods.

A total of 777 interviews were completed, of which 447 could be used for the travel cost study. Most surveys are very good at gathering personal information, but can be poor sources of information with respect to environmental and location variables. This is due to the difficulties that many individuals face with providing precise estimates of these types of goods. For example, it may be very difficult for an individual to precisely state the total cost of a journey including fuel, vehicle depreciation, and time costs. This type of information must then be obtained from alternative sources. In this case, the travel cost for each household to reach Times Beach was calculated using round-trip transportation costs, calculated using topographic distances from the household's neighborhood to Times Beach, plus the opportunity cost of travel time, which was assumed to be equal to half the household hourly wage rate.

Step 2 – Estimate the trip generating function

The trip generating function used for the study is an additive function of travel cost, household income, household's socioeconomic characteristics (which determine the preferences of a household), and the travel cost to substitute sites.

$$V_i = a_0 + a_1 TC_i + a_2 Y_i + a_3 Edu_i + a_4 Age_i + a_5 TCSub_i + error_i \qquad (2)$$

Where:
V_i = number of visits made to Times Beach each year by household i.
a_0 = intercept
TC_i = travel cost to Times Beach by the household (expressed in pesos per visit)
Y_i = annual household income (expressed in 1,000 pesos)
Edu_i = head of household's education level (years)
Age_i = respondent's age (years)
$TCSub_i$ = travel cost to a substitute site by the household (expressed in pesos per visit)
$error_i$ = error term, which allows for any other factor that has not being included in the trip generating function, but which is expected not to affect the value of the coefficients.

There are a number of statistical methods available to estimate the coefficients of the trip generating functions. In this example, we will use the Ordinary Least Squares method. This method enables us to estimate the coefficients (a_0, …, a_5) that provide the best fit between the data and the assumed theoretical model represented by equation (2). The coefficients obtained from the estimation are key as they provide information on how much a change in each explanatory variable affects the number of visits by a given household.

The results obtained are consistent with common sense (see the estimated parameters in Table 5.1). For example, as household income increases, the number of trips increases. Furthermore, increases in travel costs result in a reduction in the number of visits to Times Beach. For the typical household, a 10 pesos increase in travel costs would cause the household to reduce its visits to Times Beach by one (e.g. from 6 to 5) each year. This can be obtained by multiplying the parameter for travel cost (i.e. a_1 = -0.104) by the change in travel cost (e.g. 10 pesos). The last column of Table 5.1 shows the t-statistics for each parameter. These values provide an indication of the reliability of the coefficients. If the t-statistic is bigger than 1.96 (in absolute values) then the corresponding coefficient has a 95 percent chance of being different from zero. In this example, the coefficients for education and age are not statistically different from zero. A similar trip generating function was estimated using data on visits after the warning on water pollution had been circulated (see Table 5.2).

Table 5.1 Parameters of the trip generating function before the advisory

Variables	Parameter obtained from pre-advisory estimation	t-statistics
Intercept	$a_0 = 9.762$	3.37
Travel cost	$\mathbf{a_1 = -0.104}$	-4.11
Income	$a_2 = 0.026$	1.96
Education	$a_3 = -0.163$	-0.93
Age	$a_4 = -0.027$	-0.58
Substitute	$a_5 = 0.019$	2.92

We now have enough information to calculate the loss in welfare due to water pollution.

Step 3 – Derive the demand curve for each zone

To obtain the household demand curve, we substitute the parameters (a_0, …, a_5) obtained in the estimation process and the values for travel cost, income, education, and substitute sites for each household into the following function:

$$D_i = (a_0 + a_1 TC_i + a_2 Y_i + a_3 Edu_i + a_4 Age_i + a_5 TCSub_i) + a_1 P \qquad (3)$$

The demand curve relates the number of beach visits (D_i) to the cost of visiting the beach (P) for each household. See Figure 5.5 for a typical household H's demand curve.

There are two elements to the demand function. The intercept term (in this case equal to 5.163) is obtained by multiplying each coefficient with the value of the respective variable and summing up the results. The intercept term gives us the maximum number of visits a household would make in one year if there was no extra cost, other than travel cost, associated with going to Times Beach. The slope[ix] (in this case equal to –0.104) tells us how much the number of visits would decline if the cost of going to the beach increased by 1 peso per visit. Furthermore, the demand curve tells us that if there were an entrance fee of more than 49 pesos then nobody would go to Times Beach.

Step 4 – Derive the 'willingness to pay' for the site

The area below the demand curve is the household's consumer surplus derived from a years worth of visits to Times Beach. In this case it amounts to 128 pesos (US$5.12) per household. It is possible to compute a demand curve, and the consumer surplus, for each household. Summing up across households we obtain the total consumer surplus generated by the recreation services of Times Beach. However, if household H is representative of other households in Davao then we can simply multiply the households' willingness to pay by the 100,000 households in Davao to obtain the total consumer surplus for Times Beach. In this case it would amount to 12,800,000 pesos (US$512,000) per year. Table 5.2 presents the parameters for the demand curve before and after the advisory (obtained from the regression) and the values of the variables for a typical household.

Table 5.2 Parameters for the trip generating functions before and after the advisory

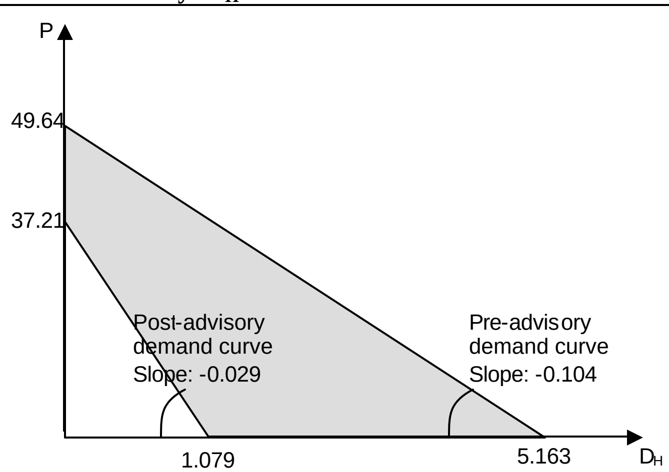
Before the advisory		
Variables	**Parameter values**	**Values of variables for a specific household H**
Intercept	$a_0 = 9.762$	
Travel cost	$\mathbf{a_1 = -0.104}$	50
Income	$a_2 = 0.026$	60
Education	$a_3 = -0.163$	10
Age	$a_4 = -0.027$	42
Substitute	$a_5 = 0.019$	95
After the advisory		
Variables	**Parameter values**	**Values of variables for a specific household H**
Intercept	$a_0 = 4.892$	
Travel cost	$\mathbf{a_1 = -0.029}$	50
Income	$a_2 = 0.019$	60
Education	$a_3 = -0.276$	10
Age	$a_4 = -0.029$	42
Substitute	$a_5 = 0.005$	95

Step 5 – Calculate the welfare loss due to water pollution

We have already mentioned that after 1992 the government warned the public about the health risks of swimming at Times Beach. As a result, most people stopped using it for recreation. Steps 1 – 4 can be repeated to obtain a new post-advisory value for consumer surplus. This post-advisory consumer surplus amounted to approximately 2,000,000 pesos (US$80,000). The total welfare loss caused by lost recreation benefits from Times Beach is the difference between 12,800,000 and 2,000,000 pesos: 10,800,000 pesos (US$432,000). Thus, the average welfare benefit lost due to the pollution in Times Beach was about 10 pesos a month per household. (US$0.40).

Figure 5.5 Household demand curve for beach visits by a typical household in Davao and welfare loss due to water pollution

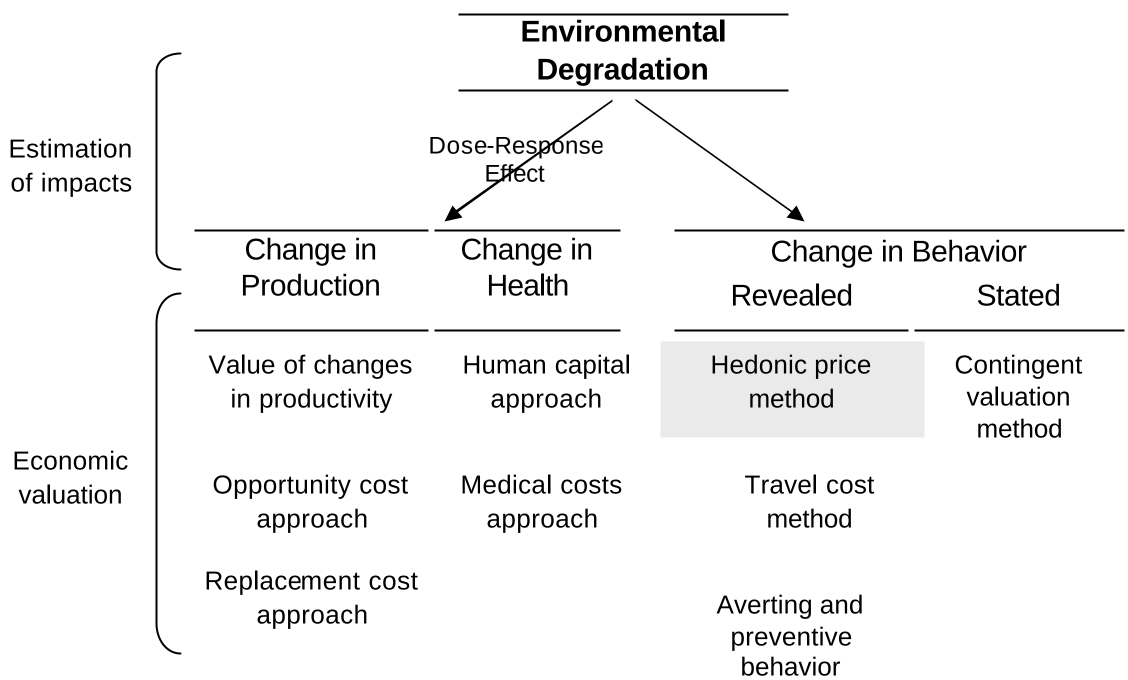
Demand curve:
Before the advisory: $D_H = 5.163 – 0.104P$
After the advisory: $D_H = 1.079 – 0.029P$



6
HEDONIC PRICES METHOD

When buying a good or service, it can be thought of as buying a bundle of characteristics that the good or service is comprised of. For example, when buying a car we are not interested in the car *per se* but in its features such as comfort, speed, power, color, shape, and so on. When renting or buying an apartment we will usually consider its size, number of rooms, neighborhood, distance from commercial centers, and distance from public schools. Consider two apartments that are identical in all respects (such as neighborhood, location, age, etc.), but one is larger than the other. The larger apartment will cost more than the smaller one because it is bigger. If we could hold all other characteristics constant, we could measure the price increase corresponding to increases in size only. In other words we could measure the implicit price of size. The same can be done for environmental aspects, such as the quality of the air around the apartment, or the level of noise.
Hedonic pricing is based on the idea that an individual's decision to buy goods or services is based on this bundle of characteristics. It is a revealed preference method as shown in Figure 6.1. When

Figure 6.1 Choosing a valuation method



environmental quality is one of these characteristics the value people place on it can be inferred from what is paid for the good.

When is the Hedonic Price Method Appropriate?

The hedonic price method is commonly used in the context of property and labor markets. In the first case, the assumption is that environmental quality is an attribute of the real estate and its price reflects people's preferences for environmental quality. In the case of labor markets, the assumption is that health risk is an attribute of a job and the wage rate should then reflect the willingness to be compensated for taking such risks.

The application to labor markets can be difficult, especially in less developed countries, because workers often do not know the true risk of certain jobs. In addition, alternative jobs might not be available and individuals have to accept riskier jobs in spite of lower wages.

This session focuses on housing prices. Important assumptions are: (i) active and well-functioning markets for housing, and (ii) that the individuals' perceived risk is similar to the actual risk. Examples of cases in which hedonic pricing can be useful to make decisions are:

- Changes in local air and water quality, i.e. by phasing out diesel engines.
- Reducing noise pollution from airport and road traffic
- Building a public area (i.e. park, sport ground) with recreational values
- Planning the location of an environmentally hazardous facility
- Evaluating the impact of neighborhood improvement schemes in poorer parts of cities.

All the cases above will affect property values. In the next section we describe how this information can be used to elicit values of environmental costs or benefits.

Valuing Environmental Quality Using the Hedonic Price Method

The hedonic price method essentially consists of estimating a *demand for environmental quality* by observing the value people place on environmental attributes when buying a good or service.

The methodology follows the following steps:

- Specify the hedonic price function
- Data collection
- Estimation of the correlation between environmental quality and market price for good
- Derivation of a demand curve for environmental quality

Step 1 - Specify the hedonic price function

We first need to identify those attributes that are likely to determine the price of housing in the market. It is important to bear in mind that all relevant variables should be included in the analysis as their omission could lead to under or over estimating the value of environmental benefits. However, the inclusion of irrelevant variables could lead to weaker results. There are mainly three groups of elements that can be expected to affect the price[x] (see Figure 6.2):

- Physical characteristics of the property – These are the size of the apartment/house, the number of rooms, the availability of common areas (pool, gym, TV room), elevator, laundry services.
- Neighborhood characteristics – The existence of good public services, such as transport, waste disposal, water connections, can be an important factor in determining the price of a property. In the same way, the level of crime, proximity to commercial areas, local firehouse, school, office or work, can be very important.
- Environmental characteristics – When choosing a location for the apartment/house, individuals will consider the level of air quality, noise, smell and other environmental characteristics.

Figure 6.2 Determinants of housing prices

Price of the apartment determined by:

- Size
- Number of rooms
- Public services available
- Vicinity to job
- Vicinity to commercial area
- Vicinity to schools

And…

- AIR QUALITY
- NOISE
- SMELL

Mathematically:
Price = f (Physical Qualities, Neighborhood Qualities, Environmental Qualities) (1)

This function is referred to as *hedonic price function* or simply *hedonic function*. It relates the price of a property to its attributes, including those attributes that have an effect on an individual's welfare. The word *hedonic* comes from the Greek word for "pleasure". Our objective is indeed to assess the value of "environmental pleasure" – or displeasure.

Step 2 - Data collection

A proper econometric analysis requires a large amount of data. By data we usually mean observations on price and characteristics of different properties in a given period (*cross-section data*). We may also use information on properties over time (*time series)* but this information may be more difficult to gather. Data may be collected using surveys and censuses.

The researcher needs to be sure that the market is well functioning and is not segmented. Moreover, people have to be aware of the differences in environmental variables across neighborhoods. This would guarantee that the property prices reflect the differences in environmental attributes.

Step 3 - Estimate the implicit price of air quality

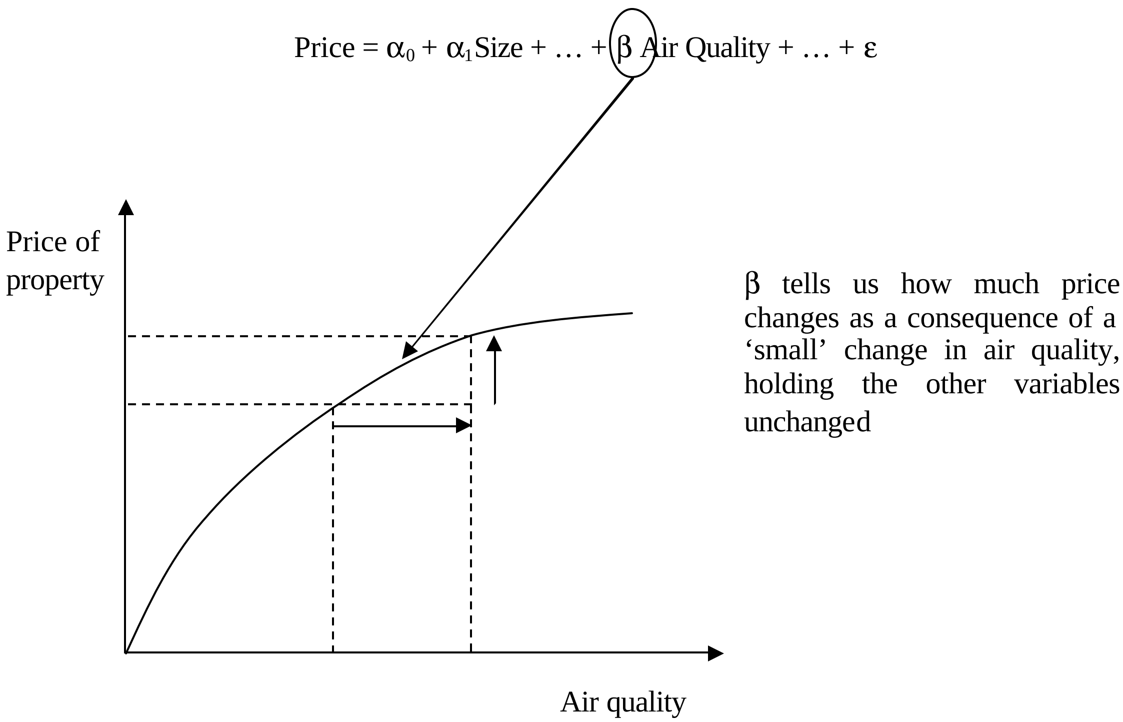
Once physical, neighborhood and environmental variables have been identified, the function relating such variables to the price of the property is estimated. Econometricians usually perform this operation and estimate the parameters that best fit the available data.

Each parameter relates a characteristic of the apartment to its price. Take for example the parameter for 'air quality'. It is basically telling us how a change in air pollution changes the value of property[xi].

Notice that as air quality improves, the price increases, but at a decreasing rate (Figure 6.3). The regression is used to estimate the parameters that better fit the available data.

The function linking air quality to its implicit price (β) is referred to in the literature as an *implicit price function*. This brings us one step closer to estimating the willingness-to-pay for improved air quality.

Figure 6.3 The relationship of property prices and air quality



Step 4 - Derive a demand curve for environmental quality

The observed price of a property is usually the result of an interaction between the supply and demand for properties. However, we are interested in estimating the demand curve for air quality only. In step 3, we obtained an *implicit price for air quality* (β in Figure 6.3). This is an approximation of the welfare effects of improving air quality.

The estimation of a demand curve requires a second regression in which the implicit price for air quality is the dependent variable and the individuals’ characteristics are the explanatory variables. The procedure is explained in the Annex.

Most studies do not take into account the second step in the analysis. This is due to econometric problems such as the ‘identification’ problem, described in Box A1 (see Annex). These shortcomings are difficult to solve without making very restrictive assumptions and without sufficient data on individuals’ characteristics. *The best option to the researcher is to estimate welfare changes directly from the hedonic price function*. For small changes in air quality this is not a concern. In fact the ‘implicit price’ for air quality derived from the hedonic price function is equivalent to the ‘marginal WTP’ in the ‘proximity’ of the initial level of air quality. The following describes a typical case in which changes in air quality are not ‘small’.

Welfare Effects of Large Changes in Environmental Quality

So far, we have dealt with the welfare effects caused by small improvements in air quality. However, governments are often faced with the decision to finance projects that affect a large number of people. The hedonic price principle can be used to value benefits by comparing property values. However, if the project is large enough, the consequent change in supply and demand for properties can alter the conclusions of the hedonic study. Let's see why.

Suppose a large environmental project is expected to improve air quality in an urban area. To start, the effect of the project will be captured by an increase in property values.

Table 6.1 Characteristics of two locations

Area A	Area B
Good air quality	Bad air quality
High price of land: p_A	Low price of land p_B ($<p_A$)

Assume that we have two areas of a city the characteristics of which are listed in Table 6.1. Assume both areas have the same size. The value of land per hectare in area A is higher than in area B (i.e. $P_A>P_B$). This follows from the fact that people will be willing to pay more to live where quality of environment is better. The project will improve the air quality in area B, for example by relocating industrial activities away from residential buildings. As a result, air quality in area B will be as good as in area A.

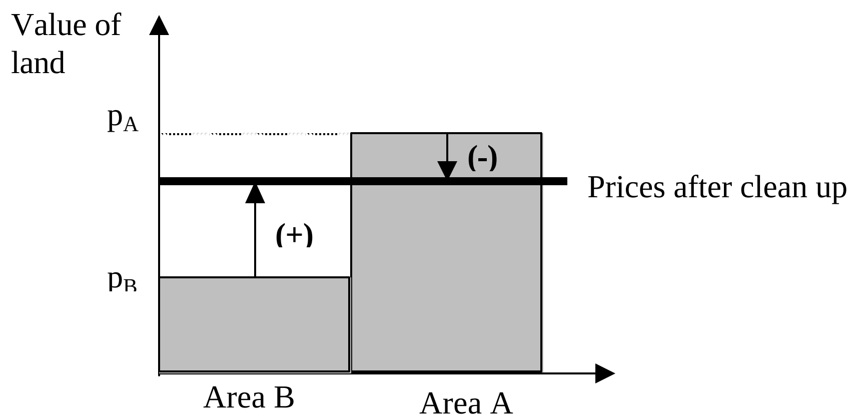
$$\text{Benefits of the project} = (p_A - p_B)\ (\text{Size of area B}) \qquad (2)$$

A crude estimation of the benefits of improving air quality is shown by equation (2). The rationale is that area B will have the same value as area A after the project, because people in area B will be willing to pay what they are currently willing to pay to live in area A. Is this a correct estimate of benefits from improving air quality?

Kanemoto (1988) has shown that the right hand side of the equation (2) puts an upper bound on the value of the project's benefits (it overestimates benefits). This happens because prices will change after the project. As air quality improves in area B, people will start moving into area B and away from area A. This will cause an increase in the prices of land in area B.

Prices in area A, however, will fall because people are now moving away. This population shift will take place until prices in the two areas have reached the same level, P* (see Figure 6.4). The price of land in area B will not reach the level p_A because prices of land in area A have been dropping, due to people moving out. Benefits for area B's residents do not increase as expected. In addition, given that price of land in area A has decreased, there is a reduction in welfare for area A's residents.

Figure 6.4 Change in prices of land for big environmental projects



Example 1: Air Pollution in Los Angeles (USA)

Brookshire et al. (1982) carry out a valuation exercise to estimate the benefits from air quality improvements obtained from the hedonic price method. The study compares the results with those obtained from a contingent valuation. In this section we concentrate on the hedonic price results and show how the estimation was carried out in this real world example.

The study was restricted to households within the Los Angeles metropolitan area using household level data. The primary assumption of the analysis is that variations in household, neighborhood, accessibility and pollution levels are capitalized into home sale prices. The following variables were considered in the study.

Housing prices were obtained from the sales of 634 single family homes, which occurred between January 1977 and March 1978 in the communities used for the survey analysis.

Housing structure variables used were: living area, number of bathrooms, and availability of pool, fireplaces. One common problem in econometrics is multicollinearity. This happens when several explanatory variables are related to one another. Therefore if one variable increases across the sample, the correlated variable systematically increases – or decreases. In this specific case, the authors found collinearity between the “number of rooms”, the “number of bedrooms” and the “living area” variables. For this reason the regression only includes the latter (see Table 6.4).

Neighborhood variables used are: crime rate, school quality, population density, ethnic composition, and public safety expenditures.

Accessibility variables are distance to the beach and distance to employment.

Environmental variables are of course the ones we are most interested in particularly air pollution data. A particular problem exists with respect to the mapping of household specific data with information on air pollution. Air monitoring stations are located throughout the Los Angeles area providing readings on nitrogen dioxide (NO_2) and other pollutants. In order to estimate the level of air pollution for each household, air pollution levels were characterized by three air quality levels as shown in Table 6.2. Improvements from "poor" to "fair", and "fair" to "good" across the region are each associated with about a 30 percent reduction in ambient pollution levels.

Table 6.2Classification of NO_2 levels in Los Angeles (1982)

Air quality	Good	Fair	Poor
NO_2	< 9 pphm	9-11 pphm	> 11 pphm

Table 6.3 presents the results of the regression that estimates the hedonic price function. They find that approximately 90 percent of the variation in home sale price is explained by the variation in the independent variables set. This is shown by the R^2 value at the bottom of the table. Almost all coefficients are statistically different from zero (i.e. they are significant at the 1 percent level). The only exception is the crime rate. They also find that the pollution variable has the expected negative impact on house prices. More pollution implies lower housing prices. Moreover, the analysis showed that the shape of the hedonic price function is concave, as in our representation in Figure 6.3. As the level of pollution decreases, the incremental willingness to pay for better air goes down.

Table 6.3 Estimation of the hedonic price function

The dependent variable is 'Home sale price' (expressed in logarithms)

Independent Variable	NO_2 Equation
Housing Structure Variables	
Sale Date	.018591
	(9.7577)
Age	−.018171
	(−2.3385)
Living Area	.00017568
	(12.126)
Bathrooms	.15602
	(9.609)
Pool	.058063
	(4.6301)
Fireplaces	.099577
	(7.1705)
Neighborhood Variables	
Log (Crime)	−.08381
	(−1.5766)
School Quality	.0019826
	(3.9450)
Ethnic Composition (Percent White)	.027031
	(4.3915)
Housing Density	−.000066926
	(−9.1277)
Public Safety Expenditures	.00026192
	(4.7602)
Accessibility Variables	
Distance to Beach	−.011586
	(−7.8321)
Distance to Employment	−.28514
	(−14.786)
Air Pollution Variables	
log (*TSP*)	
log (NO_2)	−.22407
	(−4.0324)
Constant	2.2325
	(2.9296)
R^2	.89
Sum of Squared Residuals	18.92
Degrees of Freedom	619

[a] *t*-statistics in parentheses.

A 1% increase in NO_2 concentrations causes a 0.22% decrease in home sale price

The next step is to use the change in rental prices to calculate the willingness to pay for lower pollutant concentrations. The model allows two kinds of improvements: (i) from 'poor' to 'fair' and (ii) from 'fair' to 'good'. The corresponding variation in rent specifies the premium an individual household would have to pay to obtain an identical home in the cleaner air region[xii]. Table 6.4 shows the rent differential (i.e. changes in housing prices expressed as US dollars per month) for the different communities surveyed.

Table 6.4 Sale price differentials caused by improvements in air quality

	Property Value Results[a]	
Community (1)	$\overline{\Delta R}$ (Standard Deviation) (2)	Number of Observations (3)
POOR–FAIR		
El Monte	15.44 (2.88)	22
Montebello	30.62 (7.26)	49
La Canada	73.78 (48.25)	51
Sample Population	45.92 (36.69)	122
FAIR–GOOD		
Canoga Park	33.17 (3.88)	22
Huntington Beach	47.26 (10.66)	44
Irvine	48.22 (8.90)	196
Culver City	54.44 (16.09)	64
Encino	128.46 (51.95)	45
Newport Beach	77.02 (41.25)	22
Sample Population	59.09 (34.28)	393

Air quality in Montebello is currently '**poor**' (NO_2> 11 pphm). An air quality improvement to '**fair**' (NO_2 9-11 pphm) would increase welfare by US$30 per month per person.

As an example, consider the Montebello community. It is located in a poor air quality area. If air quality was to increase to fair, the average person would be willing to pay nearly US$30 per month more than that which he is currently paying.

In general, rent differentials ranged from US$15.44 to US$73.78 for an improvement from "poor" to "fair" air quality and US$33.17 to US$128.46 for an improvement from "fair" to "good" air quality.

Example 2: Wages and Environmental Risks to Health

The analysis of hedonic housing markets exploits the fact that environmental amenities are an attribute of residential properties and thus affect its price. This analysis assumes that the 'value' of the environmental amenity is embodied in the housing market. This assumption is however true only if citizens do not migrate among cities. If we include in the analysis the fact that workers can move to other (cleaner) cities then we have to allow for the fact that environmental quality is not only reflected in the housing market but also in the job markets by means of higher salaries. Intuitively, the value people attach to urban amenities should be reflected in the higher wages they require to live in less desirable cities. A seminal work in the 'wage-amenity studies' literature is the work by Roback (1982). It shows that the "value of the amenity is reflected in both the wage and the rent gradient. The precise decomposition depends on the influence of the amenity on production and the strength of consumer preferences"[xiii]. The assumption of cities with 'closed borders', where no migration is possible, can be a good approximation of reality in the short term. If one considers a longer period, then the effects on wages should be taken into account.

Another case in which changes in wages provide very important information is with respect to health risks. The assumption is that workers will accept riskier jobs if they are offered higher salaries. By riskier jobs we mean cases in which the activity performed involves the use of hazardous substances or in general exposes the worker to a higher probability of dying. Generally, the analysis is structured in the same way as in the hedonic prices model. Salary is a function of several variables among which: (i) the job characteristics (such as distance from home and size of the company) and (ii) the risk of dying. The econometric estimation is then as follows:

$$\text{Wage}_i = \alpha_0 + \alpha_1 \text{ Job Characteristics} + \alpha_2 \text{ Risk of death} + \ldots + \text{Error term}$$

In this case we are particularly interested in the parameter α_2. It tells us how the wage rate changes with changes in the risk of death. The slope of the wage-risk function is called *Value of a Statistical Life.*

Notice that we are not talking about the 'value of a life'. It is rather the value of the benefits of avoiding risk to die. We are constantly exposed to risk (driving the car, taking a plane, eating in a restaurant) but it would be absurd to think of reducing the probability of dying from such activities to zero. In real life we are constantly making trade offs between money and health risks. For example, buying a more expensive car with lower accident fatality rates. The hedonic wage equations capture this behavior. Suppose that currently the risk of dying in a job is 1 in 25,000. Imagine that if the risk increased to 1 in 20,000 and all other characteristics stay constant the wage rate increased by US$50. In such a case, the slope of the hedonic function is:

$$VSL = a_2 = \frac{US\$50}{\left(\frac{1}{20000} - \frac{1}{25000}\right)} = US\$5{,}000{,}000$$

Consider a firm with 100,000 employees. Suppose that the job risk increases by 1 in 100,000, for example because of the poor air quality due to gases originating from the production process. Then the chances are that one of the employees will die performing his activities. The hedonic wage calculation shows that workers will need US$5,000,000 in extra wages to be willing to take the risk.

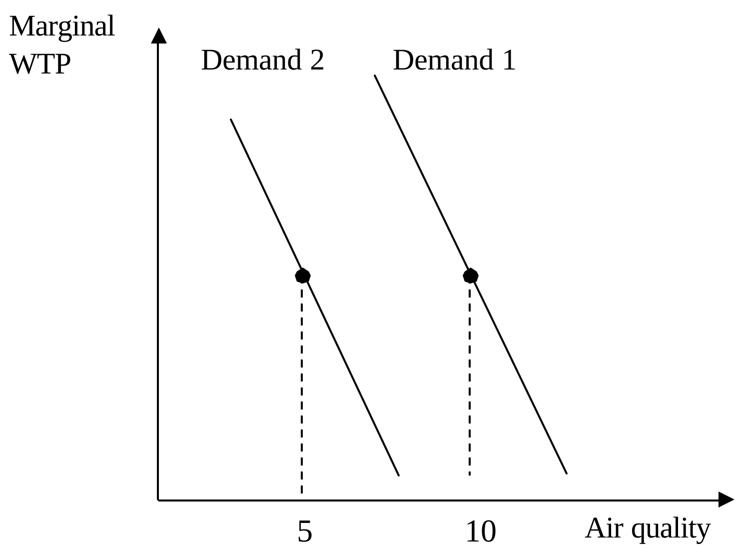
Why is this information useful? Suppose that the firm's management is deciding whether to invest in improved security measures. The option on the table is to improve the air filtration mechanism. Improved air filtration is estimated to cost US$4,000,000—a big investment, given that the company could use the money for other purposes. This will reduce the risk of dying by 1 in 100,000 for each of the 100,000 workers. The hedonic-wage analysis gives us important information in this case: workers are willing to forego US$5,000,000 in wages for the reduction in risk of dying made possible by the new filters. From the economic perspective, the investment would be more than justified.

A more detailed analysis of the 'Value of a Statistical Life' is presented in chapters 8 and 9.

Annex 6.1

To understand how willingness to pay for environmental quality and hedonic prices relate to each other we need to work backwards. Let's assume that two individuals have similar preferences. The only difference between the two is their income. It is plausible that people with higher incomes demand better air quality than poorer people. In other words willingness to pay for air quality increases with income. The demand curves for air quality for the two individuals are represented in Figure A6.1. The demand curve for air quality allows us to calculate the amount of money an individual is willing to trade for a change in the level of air quality, while keeping his utility constant.

Figure A6.1 Demand for air quality



Individual 1 is more likely to choose to live in a neighborhood with better air quality (and higher rents) than individual 2. The next step is to understand how the demand curve relates to the hedonic function. Imagine that we surveyed the two individuals and gathered the following information:

Table A6.1 Individual 1 vs. individual 2

	Individual 1	Individual 2
Neighborhood	A	B
Air quality Index	10	5
Price of property (US$ thou)	200	150
Beta	100	110
Income (weekly US$)	1,000	600
Household size (people)	4	3

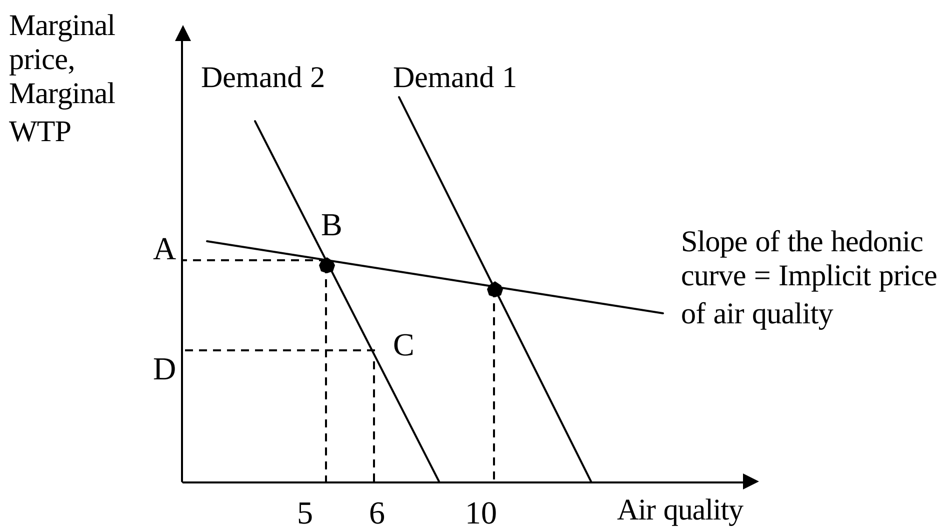
Individual 1 lives in neighborhood A which is characterized by higher air quality. Moreover, individual 1 has certain characteristics such as income (US$1,000) and size of household (4) that would presumably affect his preferences for air quality. The characteristics of the individuals and the level of air quality in which they choose to live determine their marginal willingness to pay for air quality. But, can we obtain a value for marginal willingness to pay (i.e. the amount individuals are willing to pay for a 'small' increase in air quality)?

The answer is yes. This is exactly the information we obtained from estimating the hedonic function. In other words the slope of the hedonic function at a given level of air quality, which we will call *marginal price of air quality*, is equivalent to a specific individual *marginal willingness to* pay for that same level of air quality along the demand curve of the individual (see Figure A6.2)

The equilibrium condition in the hedonic model (for any given level *j* of environmental quality) is given by equation A1.

(Marginal price of air quality)$_j$ = (Individual i's marginal willingness to pay)$_j$ (A1).

Figure A6.2 Implicit price and willingness to pay for air quality



The rest of the analysis is again a task for econometricians. By estimating the relationship between marginal willingness to pay (the β)[xiv] and the characteristics of the individuals, we obtain an expression for the demand curve for willingness to pay for air quality.

Assume the local government is planning to increase air quality from 5 to 6. The change in individual 2's welfare will be the increased area below her demand curve (area ABCD). The social welfare change can be obtained from summing up the consumer surpluses increases for all affected individuals.

Box A6.1 The identification problem in hedonic price studies

In his seminal 1974 article, Rosen describes the two stages hedonic price method we have presented above. In the same paper the author warns of the '*garden variety identification problem*' linked to the second-stage estimation of the demand for environmental amenities. Brown and Rosen (1982) describe the identification problem thoroughly. The basic intuition of the problem comes from the fact that the data that is used to estimate the hedonic price function, and hence the implicit price of the environmental amenity, is the same that is used to estimate the individual marginal willingness to pay. But the marginal willingness to pay is, by construction of the hedonic method, equal to the implicit price of air quality. The result is that the parameters obtained in the second-stage are the same as the parameters obtained for the implicit price for environmental quality.

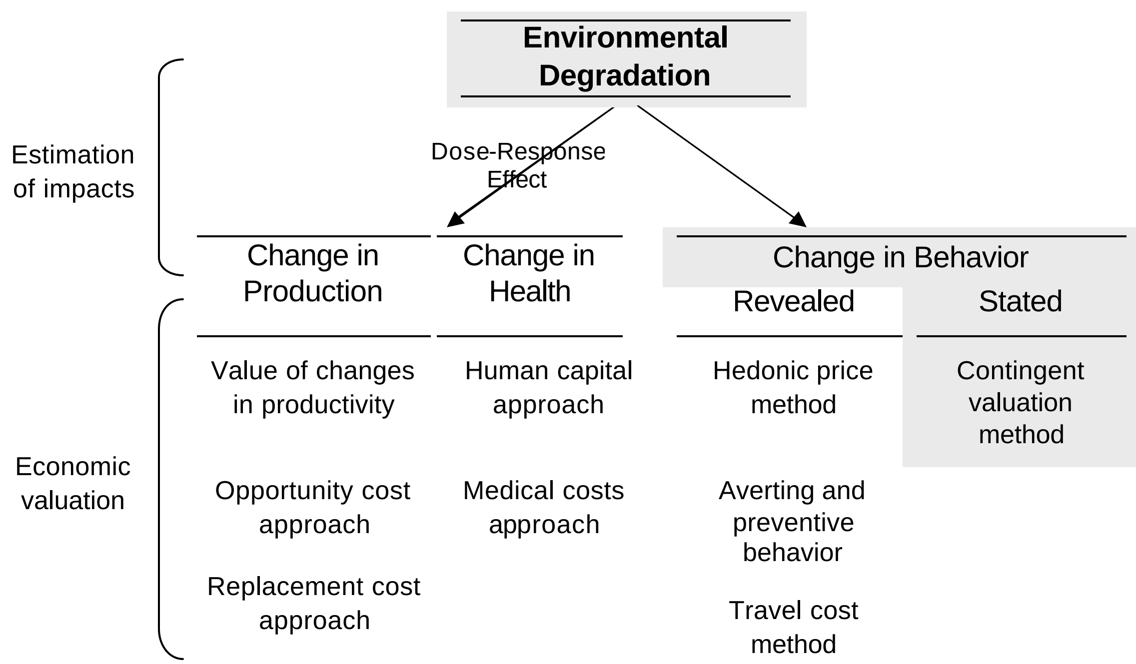
Brown and Rosen (1982) point out that a way to avoid the problem is to impose some *a priori* functional restrictions on the hedonic price function. In this way, estimation of the first equation and of the second equation would be based on different functional forms. The success of the trick would be however as good as the quality of the restrictions imposed on the hedonic price function. Another way to go around the problem is to use data from different markets. If consumers in different markets have identical preferences but face different hedonic price functions, then the implicit price in the first-stage estimate will vary independently of individual characteristics included in the second-stage regression.

In the real world, researchers are often bound to use limited resources and data on several markets is not always available. What is the best option left for the researcher? The answer is that, given data limitations, it is better to estimate the hedonic price function only. For small changes in environmental quality, the hedonic price function gives the marginal willingness to pay information we need (as noted earlier in the session). But for a larger project, the derivative of the hedonic price function no longer measures the value of the amenity change. But Kanemoto (1988) showed that the hedonic price function can help defining an upper bound for the welfare change

7
CONTINGENT VALUATION METHOD

In the market-place, individuals tend to have clear information on which to base their valuation and choices. The product tends to be visible, its characteristics are generally well known, and it has a market price. Economists can elicit the value that individuals place on a good or service by observing purchasing behavior. Most valuation techniques are based on observing people's behavior to "reveal" the value they place on it. However, in some cases there are simply no market proxies to observe. In such circumstances, it is possible to ask a sample of people what they would be willing-to-pay (WTP). In this situation, economists rely on people to "state" their preferences. This method is known as the contingent valuation method (CVM) and is the main approach for eliciting values of changes in behavior using stated preferences as shown in Figure 7.1.

Figure 7.1 The contingent valuation method



The Contingent Valuation Method

The CVM enables economic values to be estimated for a wide range of commodities not traded in markets. This method uses survey techniques to establish the value of goods and services that are not exchanged in markets and therefore have no prices associated with them. The CVM involves asking a randomly chosen sample of people what they are WTP for a clearly defined change in the provision of a good or service, or to prevent a change. It can also be used to elicit what people are willing-to-accept (WTA) to forgo a change or tolerate a change. The most commonly applied approach in the CVM is to interview people and ask them what they are WTP towards the preservation of that asset. Analysts can then calculate the average WTP of respondents and multiply this by the total number of people who enjoy the environmental site or asset in question to obtain an estimate of the total value which people have for the asset.

An interesting advantage of the CVM approach is that it can be used to elicit values of resources that people will never personally utilize or visit. Take Antarctica as an example: a natural reserve individuals are WTP to preserve, but would not in general like, or be able, to visit. In other words CVM can be used to elicit non-use values.

Steps for Designing a Contingent Valuation Study

The main stages in the application of the contingent valuation method are summarized in Figure 7.2. Each stage in discussed in more detail below.

1 - Setting up the hypothetical market

The first step is to set up a hypothetical market for the environmental service in question. The following issues should be considered when setting up the hypothetical scenario. The valuation scenario should be well defined, fully explaining the good in question and the nature of the change. This may be done with the use of images such as photographs or illustrations.

The institution responsible for providing the good must also be identifiable and believed to be capable of providing it. This helps the respondent visualize how the good will be provided in practice.

It should also be made clear how the payment will be made. Commonly used payment methods include taxes, fees, price changes, or donations.

An example of a well-defined scenario is given below:
"The old civic building in the city center is a unique example of architecture from its period (1600s). Over the past 10 years it has fallen into disrepair (show photograph of before and after). Without intervention it will deteriorate further and in five years will fall down. The local government will have to spend money if it is to restore the building to its state ten years ago. These extra funds will be generated by raising income tax."

2 - Obtaining bids

Bids can be elicited using several survey techniques: face-to-face interviewing, telephone interviewing, or mail. Telephone interviews are probably the least preferred method since conveying information about the good may be difficult over the telephone, partly due to a limited attention time span. Mail surveys are frequently used, but suffer from potential non-response bias and low response rates. Face-to-face interviews with well-trained interviewers offer the greatest scope for detailed questions and answers.

The purpose of the survey is to elicit an individuals maximum WTP in order to have the environmental improvement go ahead (or their maximum WTP to prevent a deterioration in environmental quality occurring). Alternatively, the scenario may be phrased so that a minimum WTA to go without the improvement or to put up with the deterioration is appropriate.

Follow-up questions such as "Do you think the environmental service would improve the quality of life in your community?", should be administered in order to understand the motives behind each respondent. This can help eliminate protest or invalid responses.

3 - The results of the analysis

Once the data has been collected, the difficult work of making sense of it begins. The wealth of information collected can be used in different ways and for a variety of purposes. The possible outputs we can obtain from a CVM study are presented below.

Average WTP or WTA

Once bids (WTP or WTA) have been gathered, an average bid can be calculated. Average WTP or WTA can be used to have a quick assessment of the value a resources has for a particular population.

"Protest" bids are usually omitted from the calculation. Protest bids are zero bids given for reasons other than a zero value being placed on the resource in question. For example, a respondent may refuse any amount of compensation for loss of a unique environmental resource such as the Grand Canyon, as they believe it is the government's responsibility to protect it, or simply that they do not wish to take part in the survey. A decision must also be taken over how to identify and treat outliers. The follow-up questions can help with this.

Average bids are easily calculated if an open-ended value approach has been used. If a closed-ended referendum approach has been used, i.e. Yes/No answers, then econometric techniques can be used to calculate the probability of "yes" answers to each suggested amount.

Bid curves

A bid curve can be estimated using econometric regressions. WTP/WTA amounts are used as the dependent variable and information on variables such as income, age and education, which has been collected during the survey, is used as explanatory variables.

A typical regression will look like the following:

$$WTP_i = f\,(I_i, E_i, A_i)$$

Where 'i' indexes respondents.

Bid curves open the possibility of predicting WTP amounts given changes in the independent variables. For example, "What would be the effect of higher wages on the WTP for the provision of water services?"

Aggregated data

Aggregation refers to the process whereby the average bid is converted to a population level value figure. Decisions over aggregation revolve around three issues:

- First is the choice of the relevant population. The aim is to identify either (a) all those whose utility will be significantly affected by the action, or (b) all those within a relevant political boundary who will be affected by the action. This group might be the local population, the regional population, or the population of the country.
- Second is the issue of moving from the sample mean to a mean for the total population. Several alternatives have been proposed. If the sample mean is truly representative of the total population then the sample mean could be multiplied by the number of households in the population.
- Third is the choice of the time period over which benefits should be aggregated. This will depend on the setting within which the CVM exercise is being performed. If the present value of environmental benefits flows over time is of interest, then benefits are normally discounted.

4 - Evaluating the CVM exercise

This entails an appraisal of how successful the application of CVM has been. Did the survey result in a high proportion of protest bids? Is there evidence that respondents understood the hypothetical market? How much experience did respondents have of the good in question? If asking respondents living in a calm rich residential area about their willingness to tolerate a new quarry in their neighborhood resulted in high number of protest bids, then the CVM application would not be considered successful. Similarly, suppose that respondents state their WTP preserve the panda bear in China. This may lack credibility if these respondents are not familiar with this animal.

The quality of a CVM study heavily depends on the quality of its underlying process, i.e. the preparation and administration of the survey. In 1993, based on the existing experiences, a panel of experts published a set of guidelines that would allow the use of CVM in court cases for damage compensation. The guidelines (known as the NOAA guidelines) still constitute a milestone in the CVM short history and are described in Box 7.1.

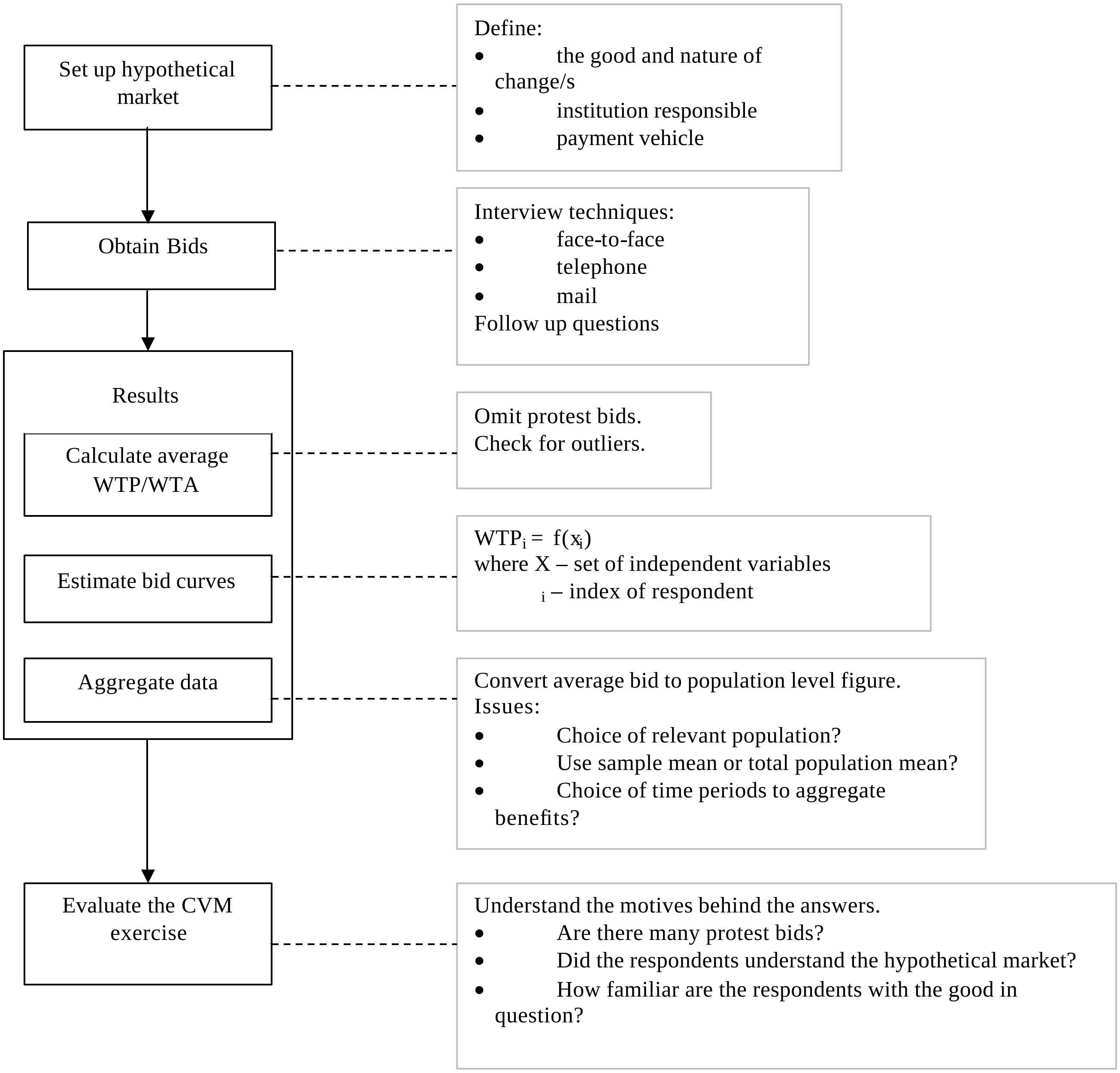
Box 7.1 Recommendations from the NOAA Panel

Due to the large number of issues and considerations regarding the contingent valuation technique, there is an ongoing debate surrounding its credibility. In the late 1980s questions began to arise about its usability in the legal system to estimate damages. Following the Exxon Valdez soil spill in 1989, the Oil Pollution Act of 1990 was implemented. Under that new law the Department of Commerce of the USA, acting through the National Oceanic and Atmospheric Administration (NOAA), was asked about its opinion on whether CVM is capable of providing estimates of non-use or existence values that are reliable enough to be used in natural resource damage assessments. The panel established a set of guidelines to which it felt future applications of CV should follow. These guidelines were numerous, but the seven most important are summarized below.

1. Applications of the CVM should rely on personal interviews rather than telephone surveys where possible, and on telephone surveys in preference to mail surveys.
2. Application of CVM should elicit WTP rather than WTA when possible. The reason is that WTA questions may cause a strategic behavior in the respondent, who may have an incentive to overstate its true value.
3. Applications of the CVM should utilize the referendum format; that is, the respondents should be asked how they would vote if faced with a program that would produce some kind of environmental benefit in exchange for higher taxes or product prices. The panel reasoned that because individuals are often asked to make such choices in the real world, their answers would be more likely to reflect actual valuations than if confronted with, say, open-ended questions eliciting maximum WTP for the program.
4. Applications of CVM must begin with a scenario that accurately and understandably describes the expected effects of the program.
5. Applications of CVM must contain reminders to respondents that a WTP for the program or policy in question would reduce the amount they would have available to spend on other things.
6. Applications of the CVM method must include reminders to respondents of the substitutes for the “commodity” in question. For example, if respondents are being asked how they would vote on a measure to protect the wilderness area, they should be reminded of the other areas that already exist or are being created independent of the one in question.
7. Applications of the CVM should include one or more follow up questions to ensure that respondents understood the choice they were being asked to make and to discover the reasons for their answer.

The NOAA guidelines were criticized as they were believed to make carrying out a CVM too expensive. This was especially thought to be the case with in-person interviews. The guidelines were created within the context of large legal lawsuit settlements, so it was felt that high quality CVMs were necessary. There is no standard approach to CVM, but the NOAA guidelines provide a framework for good practice.

Figure 7.2 Flow chart of designing a contingent valuation study.



Case Study: the Environmental and Financial Sustainability of the Machu Picchu Sanctuary

Established in 1981, and declared a "world heritage" site by UNESCO in 1983, the historic sanctuary of Machu Picchu covers an area of 32 thousands hectares in the Department of Cusco, Peru. The sanctuary includes the 'ciudadela', a 14th century Inca city located on the top of a mountain at 2,500 meters above sea level. Every year, nearly 300,000 tourists visit the 'ciudadela', making it one of the greatest tourist attractions in South America. Despite the number of visits, the revenues derived from the entrance fees have been low. This has been the effect of a tourism policy that aims to maximize the number of tourists thus capturing revenues through lodging, transport and souvenirs. However, in the future this policy option may not be sustainable as the carrying capacity of the site may be exceeded.

This case study uses contingent valuation to elicit visitors' willingness to pay. This can be used to analyze the feasibility of a price system that is capable of maximizing revenues for the site administration while allowing demand to be controlled. The example is based on a paper by T. Hett *et al* (2003) and EFTEC (1999).

The original study was requested by the Finnish Forests and Parks Service in the context of a technical assistance program for Machu Picchu. A total of 1,014 visitors were interviewed in 15 sites around Cusco, the gateway of tourists coming to and from Machu Picchu. Tourists were divided in two groups: (1) those who only visited the 'ciudadela' and (2) those traveling to the 'ciudadela' via the 'Inca trail', a walking route that leads to the city of Machu Picchu, following (at least partly) the old Inca roadway. Here we will concentrate on the results of the first group of interviews.

1 - Setting up the hypothetical market

At the time of the survey, a US$10 entrance fee was being charged to tourists visiting the 'ciudadela'. Thus, the initial steps to the analysis were made easy by the fact that a market for the recreation services of Machu Picchu already existed. Surveyed visitors needed not be induced to imagine a situation in which a price was charged for accessing the site. The aim of the survey was however to ask them to imagine a situation in which a higher price would be charged.

2 - Obtaining bids

Two different procedures were used to obtain the bids. The first group of respondents were asked about their willingness to pay through a referendum type of question. They were asked to imagine that while they were planning their trip they were informed that the price had been increased from the current price of US$10 to US$20. They were asked whether they would still be willing to visit the site at the new price. A second group of respondents were asked to mark their maximum willingness to pay on a 'payment card', like the one depicted in Figure 7.3. Both methods allow average willingness to pay and bid curves to be estimated. Using a variety of split-sample experiments allows us to better understand how respondents may be reacting to the CV scenario and the elicitation procedure (Whittington, 2002). We will focus here on the results from the second type of elicitation method: the payment card.

Figure 7.3 Payment card for assessing the maximum willingness to pay to visit the city of Machu Picchu

The maximum amount that you are prepared to pay to access the city of Machu Picchu (in US$)

10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
110
120
130
140
150
160
170
180
190
200
225
250
300

Any other amount: ……………..

Please do not state that you are willing to pay an amount if you think you that:

- You cannot pay
- Your money could be better spent on other things
- If you are uncertain

3 - The results of the analysis

Using the results from the payment cards, it is possible to obtain a value for the maximum willingness to pay of tourists by calculating the average of the responses. Table 7.1 shows the results. The respondents have been grouped into Peruvians and foreigners. One of the objectives of the study was in fact to analyze the proposal for a differentiated entrance fee that would allow maximizing revenues. Notice that the value of average WTP is US$26 for the Peruvians, US$47 for the foreigners and US$40 for the whole group. These results seem to be biased upwards by the existence of some respondents with very high willingness to pay (more than US$100)[xv]. A way to control for this problem is to show the median WTP. As Table 7.1 shows, overall median WTP is US$30, ten units less than the average.

Table 7.1 Maximum willingness to pay for visiting the city of Machu Picchu

	Average WTP (US$)	Median WTP (US$)	% of respondents WTP more than the current fee (US$10)
All respondents	40	30	82
Peruvian tourists	26	20	66
Foreign tourists	47	30	91

The questionnaire also elicited information on the socioeconomic characteristics of respondents, the purpose of their visit, their attitude towards the management of the site, and their perception of proposed changes. This information can be used to observe the relationship between individual characteristics and maximum WTP.

$$\log WTP_i = a_0 + a_1 Sex_i + a_2 Age_i + a_3 Education_i + a_4 Income_i + a_5 Nationality_i + \ldots + error_i \qquad (1)$$

To do so, a regression was performed using the Ordinary Least Squares method. This method allows estimating the coefficients (a_0, …, $a_{5,\ldots}$) that provide the best fit between the data and the assumed theoretical model represented by equation (1). The coefficients obtained from the estimation are key as they provide information on how much a change in each explanatory variable affects the maximum WTP. Table 7.2 shows the regression results. A measure of the overall fit of the theoretical model (1) to the survey data is provided by the R^2 value. A low R^2 value is typical of contingent valuation studies[xvi]. For example, the survey results highlight the fact that, all else constant, visitors with a post-graduate degree are WTP more than those without. Being Peruvian on the other hand, implies a lower willingness to pay compared to being a foreign visitor – the coefficient is negative.

Table 7.2 Bid function for the visits to the city of Machu Picchu – Regression results

Variable	Coefficient
Logarithm of WTP	Dependent variable
Constant	3.15
Male	0.07
Education	0.25
Income	0.00
Peruvian	-0.67
…	
R^2=0.25	
N=531	

4 - Estimating demand and maximizing revenues from the site's entrance fee

These results could have strong policy implications. If we assume that the sample is representative of the almost 300,000 tourists that visit the 'ciudadela' annually, it is possible to estimate demand curves for foreigners and Peruvians. These are represented in Figure 7.4. The lower curve represents the demand for visits by Peruvian tourists and the higher curve is for foreigners. The different positions reflect the influence of different socio-economic characteristics, attitudes and perceptions by the two different groups.

Currently, a US$10 fee is charged to both Peruvian and foreign tourists. If the price was raised, the number of visits would decline, as indicated by the downward slope of the demand curve. However, the total revenues obtained (price times the number of visits) would initially increase and then decline above beyond a certain fee level. From the point of view of the government it would be useful to know what level the fees should be set at in order to maximize revenues. The study calculates these levels and the results are summarized in Table 7.3.

Figure 7.4 Demand curve for visits to the city of Machu Picchu (Peruvians and foreign tourists)

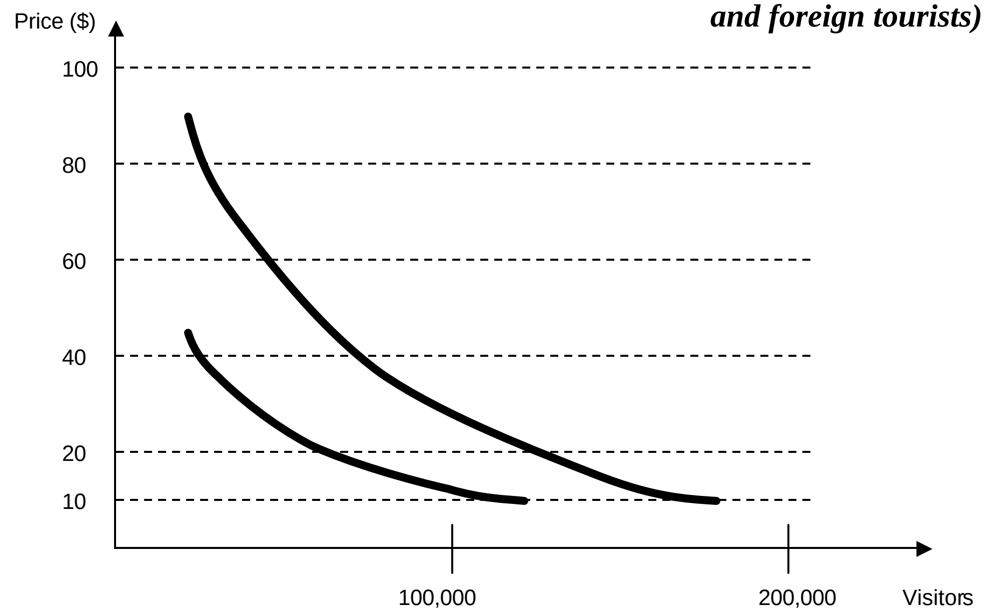


Table 7.3 Policy implications of the survey

Type of policy	Visitors (thousands)		Price (US$)		Total revenues (US$ millions)
	Peruvians	Foreigners	Peruvians	Foreigners	
Current price	94	174	10	10	0.81
Maximize revenues without price differentiation	17	98	37	37	2.21
Maximize revenues with price differentiation	44	93	23	44	2.68

Under the current pricing scheme, a total of 268,000 paying tourists visit Machu Picchu and the total revenues are estimated in US$810,000. If the entrance fee were raised to US$37, the total revenues would go up to US$2,210,000 – more than twice the current revenues. This would of course result in a drop in the number of tourists, especially Peruvians, whose lower income and perception of the site as a public good imply a lower WTP. Differentiating prices (US$23 for Peruvians and US$44 for foreigners) would generate the highest revenues and would result in a higher number of Peruvians visiting the site than that under the undifferentiated price option.

It is in the end the government who decides on which price policy to adopt. The objective of the government may not necessarily be to maximize the revenues and may be influenced by other considerations such as equity. However, the results from the CVM provide a powerful information tool for decision makers and scientists.

Annex 7.1 Advantages and Disadvantages of Different Questionnaire's Formats

Open-ended	**Advantages**	**Disadvantages**
What is the maximum amount you are WTP as an addition to your water bill to implement the previously described clean-up program in the river Nile?	Straightforward. Does not provide respondents with cues about what the value of the change might be. Informative as maximum WTP can be identified for each respondent. Requires relatively straightforward statistical techniques.	It leads to large non-response rates, protest answers, zero's and outliers. This is because it may be difficult for respondents to come up with WTP "out of the blue".
Bidding Game	**Advantages**	**Disadvantages**
Are you WTP an additional $10 on your water bill to implement the previously described clean-up program in the river Nile? If yes, interviewer keeps increasing the bid until the respondent says no. If no, interviewer keeps decreasing the bid until the respondent says yes.	May facilitate respondents thought processes and encourage them to consider their responses carefully.	Anchoring bias may exist, that is the respondent is influenced by the starting point. Leads to a large number of outliers due to positive but insincere responses. Cannot be used in mailing surveys and other self-completed questionnaires.
Single-bound referendum	**Advantages**	**Disadvantages**
Are you WTP an additional $10 (price is varied randomly across the sample) on your water bill to implement the previously described clean-up program in the river Nile?	Simplifies thought process as similar to a real life situation where a product has a single price. Minimizes non-responses and outliers. Endorsed by the NOAA panel.	Empirical studies reveal it elicits larger WTP values than open-ended questions. Some degree of positive, yet insincere, responses. Provides less information. Starting point bias.
Double-bounded referendum	**Advantages**	**Disadvantages**
Are you WTP an additional $10 (price is varied randomly across the sample) on your water bill to implement the previously described clean-up program in the river Nile? If no, would you pay $5? If yes, would you pay $10?	Receives more information than the single bound as know WTP is between certain number.	Limitations of single-bound apply.
Payment card elicitation	**Advantages**	**Disadvantages**
Which of the amounts listed below are you WTP as an additional to your water bill to implement the previously described clean-up program in the river Nile? 0 0.5 1 2 5 7.5 10 12.5 15 20 40 50 75 100 150 200, or >200	Provides a context to the bids, while avoiding starting point bias. Number of outliers is reduced.	Vulnerable to biases relating to the range on numbers on the card. Cannot be used in telephone interviews

Reproduced from DTLR (2002) *Economic Valuation with Stated Preference Techniques:Summary Guide*

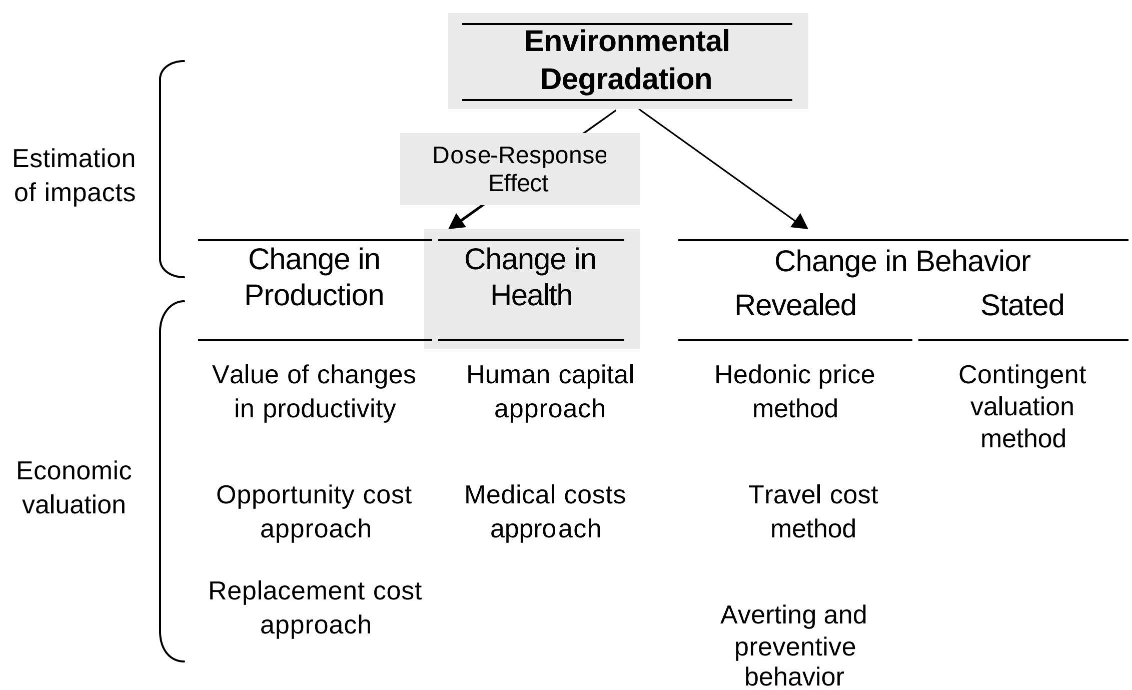
8
QUANTIFYING HEALTH EFFECTS

A special application of environmental economics is the valuation of human health damages due to environmental degradation. We conclude our review of environmental valuation techniques with a snapshot of their application to health damages in chapter 9. However, before valuing damages we need to correctly identify the cause-effect relationships between environmental degradation and health changes.

This chapter outlines the methods that are commonly used to quantify environmental health impacts (see Figure 8.1). Environmental health refers to those impacts of human health, including disease, injury, death and quality of life that are determined by physical, biological, social, and psychological factors. Physical factors include inadequate sanitation, water, drainage, waste removal, lack of housing, and household energy. Behavioral factors include poor personal hygiene, sexual behavior, alcoholism, and tobacco smoking. Globally significant environmental risks include:

- Poor or inadequate water supply
- Inadequate sanitation and waste disposal
- Indoor and outdoor air pollution
- Malaria
- Agro-industrial chemicals and waste (including occupational hazards)

Figure 8.1 Choosing a valuation method

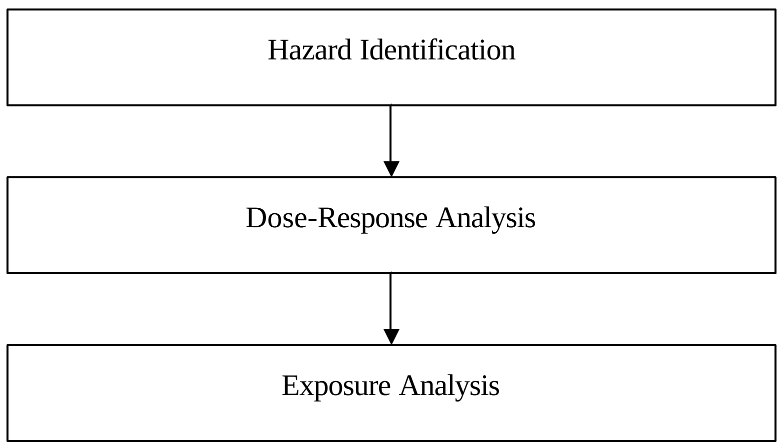


This chapter starts with a review of the empirical approaches available to estimate health impacts. It then goes on to address some of the practical issues associated with the calculation. As original studies cannot always be undertaken to estimate the number of cases of mortality and morbidity, the final section explores how results from existing studies can be used to estimate health risks in other sites using benefit (or benefit-function) transfer.

Steps in the Quantification of Health Effects

Translating the level or change of an environmental pollutant into the number of cases of ill-health or premature mortality is the first step to valuing health effects. In addition, it can be useful in its own right for at least two reasons. First, is to describe the burden of disease. For example, there may be concerns that the level of air pollution in a city is causing sickness and premature mortality. Quantification of these impacts helps give an indication of how serious these impacts are. It also enables comparisons to be made between health hazards thus helping highlight priority areas. A second benefit of quantifying health impacts is to quantify the benefits of a change in the level of a hazard. For example, to describe the health benefits of a program that will reduce air pollution by 10 percent.

Figure 8.2 Steps in quantitative assessment



There are three main steps to quantifying health effects as shown in Figure 8.2. First is to identify a hazard (i.e. particulate matter concentrations). Once a hazard has been identified, the second step is to estimate what the impact of this hazard is on health (i.e. asthma cases). This is measured by a dose (or concentration) response coefficient. The third step is to estimate which people in the population are exposed to the hazard.

Following each of these steps in order may not be a viable approach in all situations. For example, in the case of indoor air pollution the level of exposure is very much dependent on the time spent indoors, whether appropriate vents are fitted, and time spent close to the stove. These issues make it difficult to accurately measure individual exposure (see Ezzati and Kammen, 2001). In this case, the approach has more often been to apportion a certain percentage of observed respiratory infections to indoor air pollution. A similar problem is encountered when trying to estimate the health burden from unsafe drinking water as exposure levels are dependent on a multitude of factors including storage and whether the water is boiled before consumption.

By contrast, the estimation of health effects arising from outdoor air pollution is a well-documented area. Available studies utilize the approach above and provide a good example of the issues and constraints that a researcher will face when trying to quantify health impacts. The rest of this section largely focuses on the example of outdoor air pollution although the issues raised are often applicable to other hazards.

Empirical Approaches to Estimating Health Impacts

There are three main methods of enquiry available to assess health effects:

- Animal toxicological studies: the controlled experiments of animals in exposure chambers
- Human clinical studies: the controlled experiments of humans in exposure chambers
- Epidemiological studies: the study of humans in real-world situations

Each approach has its advantages and limitations, a summary of which is illustrated in Table 8.1. The most compelling approach will depend on the characteristics of the hazard being examined. It is arguable that epidemiological studies are used most commonly in estimating health impacts – particularly in the case of outdoor air pollution. Epidemiological studies of mortality and morbidity fall into two categories. Time series studies measure the impact of short-term (or acute) exposures on mortality rates. Long-term exposure studies use variations in air pollution levels across locations to measure the effects of long-term exposures on health. These two approaches are described in more detail below.

Table 8.1 Empirical approaches to estimating health impacts

Animal Toxicological Studies	
Advantages	*Disadvantages*
1. Useful to determine if pollutant is toxic. 2. Can help determine potential biological mechanisms and pathways.	1. Need to extrapolate from animal species to humans. 2. Animals often given very high dose to elicit a response. Need to extrapolate over lower doses. 3. Limited sub-samples. Maybe animal being studied is just sickly. 4. Usually only consider acute exposures. 5. Replication of exact pollutant mix may be difficult to replicate.
Human Clinical Studies	
Advantages	*Disadvantages*
1. Allow high precision in specific dose and response. 2. Don't need to extrapolate from animal species to humans. 3. Help determine whether an effect is likely to occur from a given exposure.	1. Limited sample size. 2. Can only observe acute exposures. 3. Difficult to replicate entire mix of ambient pollutants.
Epidemiology Studies	
Advantages	*Disadvantages*
1. Real world situation. 2. No need to extrapolate over doses or species. 3. Typically less expensive to undertake. 4. Can study a wide range of health outcomes. 5. Can examine a wide range of pollutants and mixes by looking at different seasons.	1. Degree of imprecision in measurement of exposure and response. 2. Difficult to separate effects from other hazards. 3. Difficult to ascertain mechanism of the effect. 4. A statistically significant effect does not prove causality.

Acute exposure studies use information from a given region or area over a certain period of time. Such studies are also known as time series or episodic studies. The following information is needed: (1) observed daily mortality rates (or, morbidity rates such as observed hospital admissions), (2) daily variations in air pollution, (3) other variables that may affect the relationship between (1) and (2), such as weather conditions, seasonal factors and other characteristics that can change over time. These are known as "compounding" factors. The final objective of these studies is to compute the parameters of a dose-response relationship between air pollution and mortality (or morbidity). Box

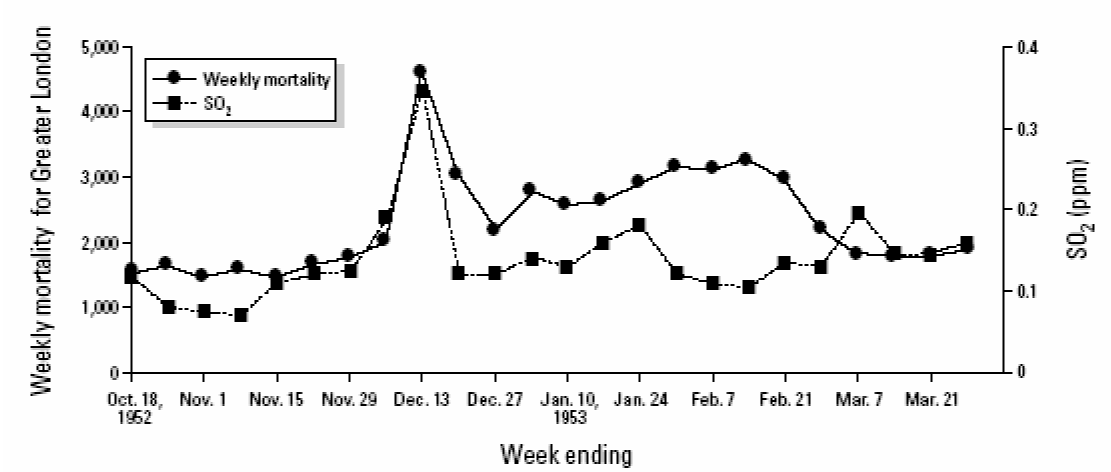
8.1 presents an example of a time series study and Table 8.2 presents an example of the dose-response coefficients estimated for outdoor air pollution for premature mortality and respiratory hospital admissions.

Time-series studies have the advantage of reducing problems associated with confounding or omitted variables (i.e. factors that affect the mortality or morbidity rate but that are very difficult to account for). For example, population characteristics such as diet, smoking habits, age, occupational exposure, and so on, do not change over the study period. Therefore, they do not have to be controlled for in the analysis as they are assumed to be constant.

Box 8.1 Time series data: measuring the acute change in mortality

From 5 December to 9 December 1952 a heavy, motionless layer of smoky, dusty fumes from the region's million or more coal stoves and local factories settled in the London basin. During this period and for several months afterwards elevated mortality rates were observed. A visual examination of the figure below suggests a correlation between sulfur dioxide (SO_2) concentrations and mortality rates. Although the exact number of deaths attributable to the smog is contested, this episode is widely regarded as the catalyst of air pollution epidemiology. While a visual analysis already suggests that there is a relationship between SO_2 and mortality, statistical analysis can confirm and quantify this.

Approximate weekly mortality and SO2 concentrations for Greater London, 1952–1953.



Source: Bell, M., and D. Davis (2001).

A disadvantage of time-series studies is that they capture only the impact of short-term peaks in exposure and do not capture the impact of cumulative exposure. A frequent concern when interpreting the impact of short-term exposures on mortality is that the people affected by short-term exposures may be vulnerable and sick anyway and may have died in the next few days or weeks from other causes. The question then arises as to whether these prevented deaths of people who had a short while to live should be weighted the same as otherwise healthy individuals who have years of expected life years remaining.

Table 8.2 Example of dose-response coefficients for outdoor air pollution (PM10)

Health Effect	**PM_{10}**
Mortality (% change in all-cause mortality rate)	0.084
Respiratory hospital admissions (per 100,000 adults)	1.2

Reproduced from Lvovsky and others (2000)

Chronic exposure studies systematically collect information from different areas and often for a number of points in time. The aim is to estimate the impact of longer-term exposure on health. There are two types of studies: *cross-sectional* and *prospective cohort studies*. Cross-sectional studies analyze mortality rates at various locations at a single period in time to determine if there is a statistical correlation with average air pollutant levels. Attempts are made to control for confounding factors that might be correlated with air pollution levels (such as diet, migration, and so on); however, concerns persist about whether these studies have adequately controlled for such factors.

Prospective cohort studies follow a selected sample of population over time in each location. These studies differ from cross-sectional studies as they use individual-level data so that other health risk factors can be better characterized. Specifically, prospective studies are able to control for mortality risks associated with differences in body mass, occupational exposures, smoking (present and past), alcohol use, age, and gender. This improves the robustness and statistical significance of associations between exposure to a hazard and mortality. In principle, these studies pick up both acute and chronic effects.

Table 8.3 summarizes the main categories of studies that measure the impacts of air pollution with their advantage and disadvantages.

Table 8.3 Categories of studies measuring health impacts of pollution

Type of Study	**Observations taken over time**	**Obs. taken from different locations**	**Characteristics**
Time-series studies	YES	NO	▪ Avoid problems with confounders and omitted variables ▪ Require assumptions when extrapolating to other locations ▪ Only capture short term peaks in exposure ▪ Relatively cheap to undertake
Cross-section studies	NO	YES	▪ Require controlling for confounding factors ▪ Only capture long term effects of pollution ▪ Relatively cheap to undertake
Prospective cohort studies	YES	YES	▪ Require controlling for confounding factors ▪ Capture both short and long term effects of pollution ▪ Expensive to undertake

Aggregation of study results

An important question is whether the effects of short term and long term exposures can be aggregated when estimating the damages. A related question is whether it is appropriate to add the impacts of different hazards. In the case of premature mortality it is not appropriate to add together deaths associated with a given pollutant (e.g., particulate matter (PM)) based on a time-series study with deaths from the same pollutant calculated using a prospective cohort study, as the latter study should capture both effects. It is however, appropriate to add together premature deaths avoided due to long-term exposure to PM (from a prospective cohort study) and premature deaths avoided due to short-term exposure to ozone (from a time series study), as long as each study controlled for both pollutants.

Calculating Health Impacts in Practice

Once a hazard has been identified, and its dose-response coefficient and exposure level estimated, it is possible to quantify the health impacts. The formula for estimating this is given by equations 1 and 2 below. The choice of formula will depend on the form of the dose-response coefficient. In the case of premature mortality, the dose-response coefficient is often expressed as a percentage change in the baseline mortality rate per unit increase in the pollutant (thus the coefficient is multiplied by a constant term equal to 0.01). In this case the standard equation for estimating premature mortality is shown by equation 1. Dose-response coefficients for morbidity are more often expressed as an overall change in heath effects associated with a change in pollution concentration. In this case the additional cases of health impact ‘i’ from pollutant ‘j’ are calculated using equation 2. An example of how this is done in practice is given in Box 8.2.

(1) $M = B * (0.01 * b_j) * A_j * P * E$

(2) $H_i = d_{ij} * A_j * P * E$

Where:
M is the number of additional cases of premature mortality
H_i is the additional cases of health impact ‘i’
B is the baseline mortality rate
P is the population at risk
E is the exposure rate of the population at risk
A_j is the concentration of pollutant j.
d_{ij} is the morbidity dose-response coefficient
b_j is the mortality dose-response coefficient

Issues of Benefit Transfer

The ideal way to measure health impacts resulting from exposure to a hazard is to undertake a local study to establish the dose-response relationship. However, in reality the time and cost of such studies often makes this option implausible. In this case, studies from other locations have to be used instead. The issues and considerations relating to the transfer of information from other locations and periods are discussed in this section.

Box 8.2 Calculating health impacts: an example of the impacts of air pollution in Cairo

An example of how health impacts from air pollution were estimated in "*Cost Assessment of Environmental Degradation in Egypt*" (World Bank, 2002) for Egypt is presented below. No study using local data that statistically links urban air pollution and health has been carried out in Egypt. Therefore findings from international studies were applied to the situation in Cairo. This is known as benefit transfer, which is discussed in the next section. They found that nearly 19,000 people die prematurely each year in Greater Cairo, and 64,100 cases of chronic bronchitis as well as other health impacts.

M = B * (0.01 * b) * A * P * E

M	additional cases of premature mortality	19,000
B	baseline mortality rate	7 per 1,000 population
b	mortality dose-response coefficient	0.084
A	concentration of pollutant	270µg/m^3
P	population at risk	14,900,000 people
E	exposure rate of the population at risk	0.8

H = d * A * P * E

H	additional cases of health impact	64,100
d	morbidity dose-response coefficient	3.06 per 100,000 adult population
A	concentration of pollutant	270µg/m^3
P	population at risk	9,700,000 adults
E	exposure rate of the population at risk	0.8

The data source of the key parameters is the World Bank's World Development Indicators, 2000. The data on the level of PM_{10} was taken from local monitoring stations.

Study design and methodology: desirable characteristics

The first step in quantifying health effects from air pollution exposure using transferred results is to decide which results to transfer. Desirable characteristics of a study are presented below.

- Studies should be based on robust data. For example, in the case of air pollution, data should be based on continuous monitoring of the relevant pollutants. This is because air pollution levels are likely to differ throughout the day (due to changes in temperature and activity levels) and also throughout the year (due to seasonal variations).
- Studies should recognize and attempt to minimize confounding and omitted variables. For example, studies that focus on PM must also control for the other pollutants. Confounding factors can also occur if a factor is correlated with both air pollution and the health outcome, such as weather extremes or seasonality. In a time-series study, controls for the effects of seasonality and weather should be examined. In a cross-sectional study personal characteristics that may affect the health outcome must be controlled for.
- Studies should undertake a reasonably complete analysis of the data. Such analysis should include a careful exploration of the primary hypothesis (e.g., that fine particles are associated with lung cancer mortality) and preferably an examination of the robustness and sensitivity of the results to alternative functional forms, specifications, and influential data points.

Minimize the differences between scenario characteristics

- The disease-specific mortality profile of the country of interest should be similar to the one of the country where the original study was conducted. In some cases the distribution of deaths by cause may differ significantly. In such cases, dose-response functions for disease specific mortality may be better. However, there are some problems with this method. First, air pollution may cause premature death via many routes, such as respiratory failure and cardiovascular mortality. Generating estimates for total mortality ensures that all mortality cases are included. The use of disease specific mortality is also complicated by limited access to disease-specific mortality data and deficiencies in the death reporting system. Note that when total mortality functions are used, differences in population characteristics, such as age structure, nutritional and overall health status, and smoking rates will not lead to bias as these factors will be reflected in the crude mortality rate.

- The age pattern of deaths should be similar in the two cases. The age profile of those affected by a hazard may be very different in developing countries than in industrial countries. For example, in the case of air pollution, the highest incidence was observed in people age 65 and older in Philadelphia (Schwartz and Dockery, 1992), and in Delhi peak effects were reported in the 15-44 age group (Cropper and others, 1997). This implies that more life was lost as a result of death associated with air pollution in India. This has important implications for valuation which is discussed in the next module.
- Attention should be paid to the mix of pollutants. Air pollution is a very good example of how this may be an issue. The air pollutant $PM_{2.5}$ (particulate matter less than 2.5 microns per cubic meter) is a component of Total Suspended Particulates (TSP). The composition of TSP in terms of how much is $PM_{2.5}$ will vary across location. For example, cities with high levels of road or wind-blown dust are likely to have a lower ratio of $PM_{2.5}$ to TSP than cities where the main contributor to TSP is from vehicle emissions. Older studies are usually based on TSP as this was the only data that was available. With the evolution of new monitoring technology, there is increasing data on $PM_{2.5}$. Recent studies have suggested that it is the presence of the smaller particulates that is responsible for health damages. Therefore, while TSP may be a good proxy for $PM_{2.5}$ in a given location, transferring the dose-responses based on TSP data may be misleading where particulate composition may be different. Studies based on smaller particulate measures (such as $PM_{2.5}$ or PM_{10}) are preferred for this reason.
- Results from industrialized countries should be carefully extrapolated to developing countries. Often an analyst must extrapolate the results of an epidemiological study outside of the range of pollution levels observed in the study. This problem often arises when studies from the U.S. and Europe are applied to developing countries. Should one assume that the effects of air pollution observed at (relatively) low levels of pollution in the U.S. are greater than, less than, or equal to, the effects that would be observed in more polluted environments? The answer is not clear. In addition there may be minimum thresholds below which no health affect is observed, and/or maximum thresholds beyond which no additional health affect is observed. Therefore extrapolating to extreme levels – low or high – may be misleading.

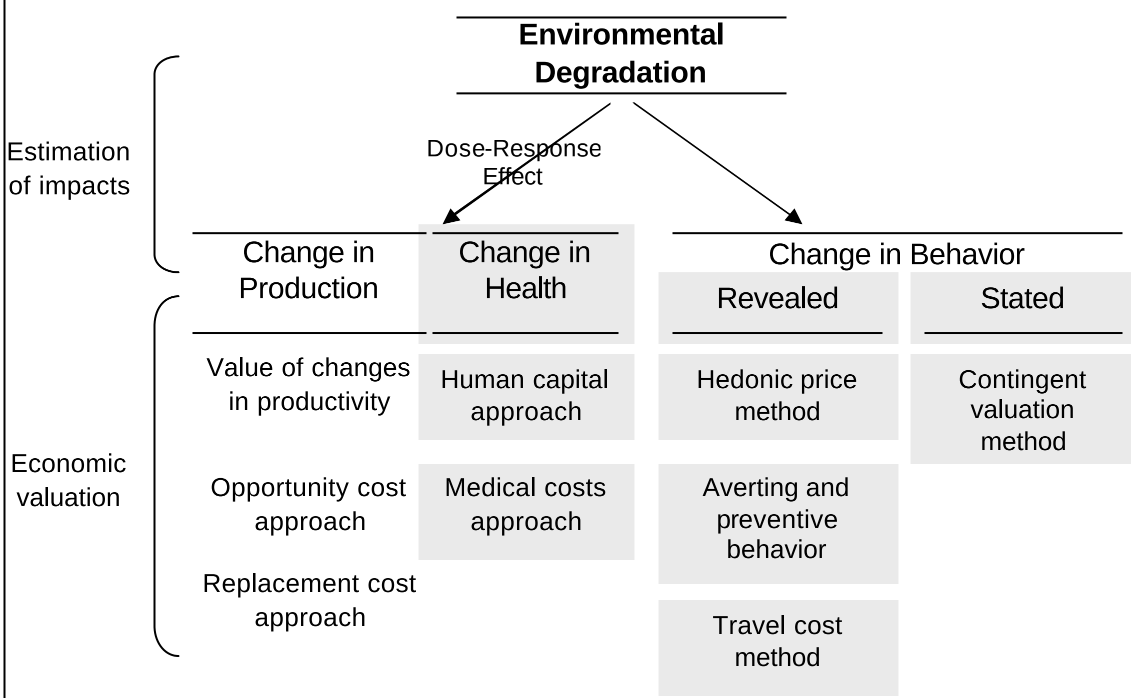
9
VALUING HEALTH EFFECTS

The previous chapter presented methodologies to quantify the number of cases of mortality and morbidity arising from exposure to a hazard. While this can be extremely informative, putting a monetary value on these health effects has additional worth. Valuation permits mortality and morbidity to be expressed in a single unit of measurement—that of money. This can be useful when more than one health outcome is being measured (see Box 9.1). In addition, valuation allows health effects to be compared with costs, permitting comparison across policy options, and simply providing a sense of the magnitude of the total health benefits associated with a particular policy.

Valuation exercises are based on the measurement of people's willingness to pay (WTP) to avoid illness. There are many reasons why people value not getting sick. These include the desire to avoid:

- time lost associated with illness
- medical costs
- avertive expenditures
- discomfort associated with illness

Figure 9.1 Valuation methods for health damages



Box 9.1 Benefits associated with two hypothetical air pollution reduction policies

	Policy A		*Policy B*	
	Premature Mortality	Chronic Bronchitis	Premature Mortality	Chronic Bronchitis
Risk Reduction	1 in 10,000	1 in 5,000	1 in 12,000	1 in 3,000
Cases avoided in a large city (pop 70 mn)	720	1,440	600	2,400

Policy A produces a larger change in mortality risk compared to Policy B but a smaller change in the risk of chronic bronchitis. Without expressing the change in risk for the two health outcomes in a common metric, it is difficult to tell which policy produces greater health benefits.

There are several approaches available to value the impact of health risks as shown in Figure 9.1. The valuation of health damages was originally based on the calculation of the financial costs caused by death or illness. The human capital approach would then calculate the present value of forgone earnings due to death or incapacity. In the case of morbidity, the cost of medication and wages lost was used, known as the Cost-of-Illness approach. This estimates the change in costs incurred as a result of a change in the incidence of a particular illness.

More recently, economists started adopting estimates of willingness to pay (WTP) to value health damages. The main distinction between the "financial cost" methods of valuation and the WTP method resides in the fact that the former only represents a lower bound of what a person would be available to give up to avoid illness. The WTP approach, in theory, is able to capture all values that an individual associates with avoiding a change in risk of mortality or morbidity although it is also not without its limitations.

A summary of what each of these approaches is able to measure is presented in Table 9.1. The rest of this chapter explains each of these methods in turn while presenting their relative merits and constraints. Finally a discussion of an alternative to valuation is presented: that of cost-effectiveness analysis.

Table 9.1 Valuation methods and what they value

	Human Capital Approach	**Cost of Illness**	**Willingness-to-Pay**		
			Revealed		**Stated**
			Hedonic Pricing	**Averting Behavior**	**Contingent Valuation**
Lost wages	✓	✓	✓	✓	✓
Medical costs		✓	✓	✓	✓
Productivity losses	✓				
Avertive expenditures		✓	✓	✓	✓
Lost leisure time			✓	✓	✓
Pain & discomfort			✓	✓	✓

Valuation Methods

Valuing mortality with the human capital approach

The first studies that attempted to attach a monetary value to *mortality* focused on lost productivity and lifetime earnings. Value estimates are obtained by calculating the present discounted value of an individual's lifetime earnings. The attraction of this approach is its ease of definition and calculation. Some obvious problems with this approach include the lack of applicability to unemployed individuals, children, and the elderly, and the use of interpolated "earnings" for housewives derived from average wage levels for housekeepers. Some have argued that there is a conceptual issue with this method, in that most people value safety not out of concern for preserving current and future income levels, but rather primarily because they have an aversion to pain and suffering and death. While the human capital approach may be acceptable in a wrongful death suit when the goal is to compensate a person's heirs after the death has occurred, it is not the theoretically correct approach to value an ex-ante reduction in health risk for all people in an exposed population.

Valuing morbidity through the cost of illness approach

The cost of illness (COI) method estimates the change in costs incurred as a result of a change in the incidence of a particular *illness*. Both direct costs (e.g. cost of doctor visits, treatment costs, etc.) and indirect costs (e.g. loss of wages) are included in the estimation. In cases where some of the costs are borne by medical insurance, COI measures will not be limited to a patient's "out-of-pocket" expenses but should include the additional costs borne by the insurance company or the treatment facility to capture the social benefits of the reduced risk.

The COI approach is used widely in the environmental economics literature when WTP estimates are not available, in part because of its ease of application and the abundance of useable information. However, it is important to note that it is *not* a measure of WTP for two basic reasons. First, COI reflects additional costs incurred *after* the illness has occurred whereas WTP measures reflect the value an individual places on a risk change *before* the health risk lottery resolves itself. Second, COI does not capture the additional amount an individual would be willing to spend to avoid the pain and suffering associated with the illness or the costs associated with averting behaviors. In spite of these limitations, COI is sometimes considered to be a lower-bound estimate of WTP.

Willingness to pay (revealed and stated approaches)

Economists define willingness-to-pay (WTP) in this context as the amount an individual is willing *and able* to pay for a reduction in the risk of death or the risk of experiencing illness. In the case of mortality, WTP estimates can be used to estimate the Value of a Statistical Life (VOSL) which is explained more fully in Box 9.2. While some may argue that the value of human life is beyond measure, in truth, individuals engage in risk-benefit trade-offs everyday. Certainly, we observe individuals engaging in risky behavior on a daily basis – choosing to drive at unsafe speeds rather than obeying speed limits, or crossing the street in the middle of a road rather than at a pedestrian crossing, or choosing to smoke rather than abstain, etc. Presumably, they make the decision to engage in risky behavior because they get some benefit from the behavior – perhaps experiencing the thrill of high-speed driving, getting to their destination more quickly, or enjoying the act of smoking. On the other hand, we also observe individuals devoting *some* of their resources to reducing risk, through the purchase of smoke detectors or seeking medical attention. Rarely do we see individuals devoting *all* of their resources to prolonging their lives and warding off disease. This suggests that individuals do make tradeoffs between benefits and health risk and that we can exploit these tradeoffs to arrive at a measure of value for assessing the benefits of small changes in health risk. This risk-resource tradeoff is what we capture with WTP estimates. To be explicit, WTP measures the amount an individual is willing to pay to reduce his *chance* of experiencing a particular health outcome.

Box 9.2 The value of a statistical life

The WTP approach can be controversial especially in the context of mortality risks. In the case of mortality, willingness-to-pay is used to elicit what is known as the Value of a Statistical Life (VOSL). The VOSL does *not* capture the value of an identifiable person but rather the value of a small change in the *chance* of dying. That is, it does not ask individuals how much they are willing to pay to save their own life (or any other specific person's life) with certainty: presumably individuals could be willing to pay everything they have to avoid their own death or the death of a loved one. Rather, it captures an individual's willingness to pay for a small change in his own probability of dying.

As discussed in chapter 8, the first stage of assessing health benefits associated with a pollution exposure reduction is quantifying the expected health outcomes. In the case of our air pollution example in Box 9.1, for instance, a total of 720 premature deaths will be avoided (or 720 lives saved) should Policy A be implemented. These are *statistical* lives saved i.e. we do not know who the 720 people are whose lives will be saved. The reduction in the probability (or risk) of dying as a result of Policy A is 1 in 10,000 annually. This means that for every person exposed to air pollution in the example, the risk of dying is reduced by 1 in 10,000 each year. For every 10,000 people exposed to the air pollution in a given year, one life will be "saved" on average. This "saved" life is what is called a statistical life. By eliciting what individuals are WTP on average for the reduced risk, researchers can estimate the VOSL. The value of a statistical life can be calculated using the following equation:

$$VSL = WTP * \frac{1}{\qquad} \qquad (9.1)$$

There are several options available for estimating WTP for health risk reductions. These can be broadly categorized into revealed preference and stated preference approaches. Revealed preference approaches make use of observed income-risk tradeoffs to estimate WTP and stated preference approaches use direct questioning techniques to elicit WTP. Among the *revealed* preference approaches, hedonic wage analyses are the most common followed by averting behavior studies. *Stated preference* approaches are also used to value mortality risk reductions, with the contingent valuation method being the most widely used to date. Each of these methods is described in more detail below.

Revealed preferences

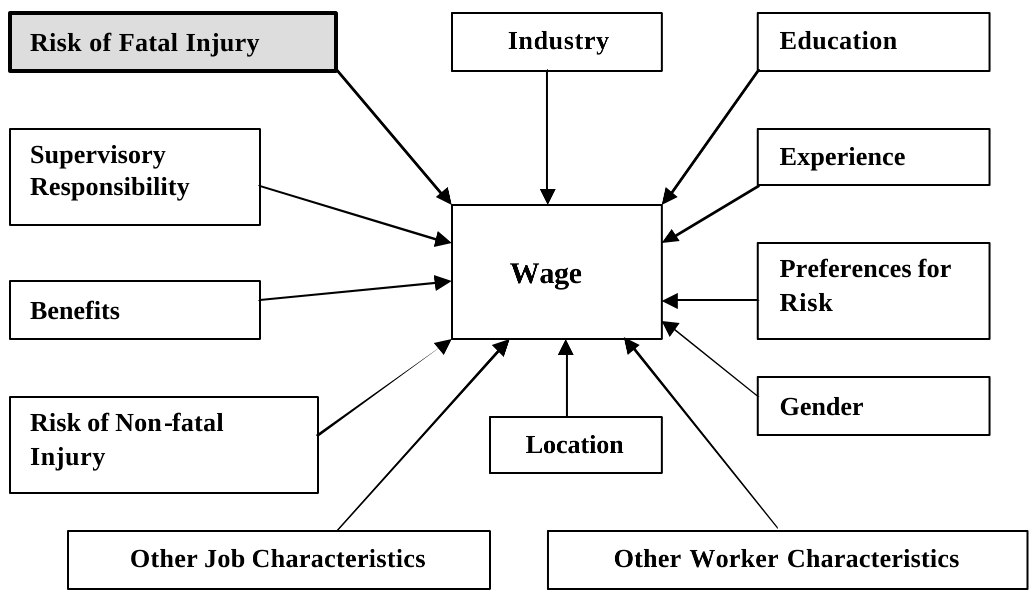
Hedonic wage studies

Hedonic wage studies are an example of the more general Hedonic Price Method, described in chapter 6. Hedonic wage studies, also known as compensating wage studies, or wage-risk studies, are based on the premise that individuals will be compensated for taking on more risk in the work place. That is, individuals employed in jobs with higher risk of injury or death will be paid more than those employed in lower risk jobs, all else equal.

Consider, for example, the case of two companies with similar job vacancies. The jobs are identical in every way except that the job with Company A involves working with potential carcinogens, whereas the job with company B does not. If the companies initially offer the same wage, all workers will try to move to the safer job with company B. This will cause company B to lower wages due to the large supply of workers and/or company A to raise wages in order to attract workers.

Of course, occupations can vary substantially from one company to the next, let alone from one industry to the next, and in fact can be characterized by a number of attributes, including occupational risk, benefits, supervisory responsibility, job security, to name but a few (see Box 9.3). All of these attributes can influence the wage offered to the worker. In addition, worker characteristics, such as education, experience, and gender, as well as industry and location may also influence the wage. A hedonic wage analysis attempts to disentangle the effects on wage of the various job and worker characteristics to isolate the effects of the on-the-job risk on the wage rate. The resulting estimate of the wage "premium" represents the market equilibrium price of a marginal increase in risk for all of the workers included in the study. This is the amount the worker accepts for taking on the increase in risk. For small changes in risk, it should be equal to the amount he would pay for a reduction in risk of the same size.

Box 9.3 Factors that determine wage



A number of different job and worker characteristics influence wages. The purpose of a hedonic wage study is to isolate the effect of the risk of fatal injury on wages while controlling for all of the other factors.

Empirical estimates of the value of statistical life based on hedonic wage-risk studies are numerous in the economics literature in part because of the relative ease in which these models can be applied. Risk data for the labor market are often published and publicly available. Worker characteristics, often collected during surveys, are also relatively easy to find. VOSL estimates derived from studies conducted in the U.S. and other developed countries generally range from $0.6 million to $13.5 million in 1990 USD (Viscusi, 1993). Several studies have also recently been conducted in developing countries such as India (Shanmugam 2001), Hong Kong (Siebert and Wei, 1998), Taiwan (Liu, Hammitt and Liu, 1997), and South Korea (Kim and Fishback, 1999) with estimates ranging from $135,000 to $3.1 million (1990 USD).

While hedonic wage estimates of VOSL are widely available and widely used in benefit cost analyses, they do have several shortcomings when used to value mortality risk reductions in other contexts such as non-work related environmental exposures. First, the nature of the risks is likely to be different. Because mortality risks faced by workers in the job market tend to be accidental in nature, they are relatively immediate compared to risks of environmentally related deaths that may have a significant latency period. Furthermore, occupational risks are more voluntarily in nature and there is evidence that people are WTP more to avoid involuntary risks – such as those often arising from environmental hazards (Slovik, P., 1993).

Second, age and gender distributions of the workers included in labor market studies generally do not match those of populations exposed to ambient pollution. Hedonic studies focus primarily on male workers with an average age of 40 years, whereas ambient air pollution affects both genders and people of all ages. As an example of this problem, consider the U.S. where the typical retirement age is 65 years. Mortality benefits associated with air pollution reduction between 1990 and 2010 as reported by the EPA are expected to accrue primarily to individuals aged 65 and over (see Box 9.4). If, in fact, WTP varies with age, VOSL estimates derived from hedonic wage studies may not be appropriate for estimating benefits due to air pollution reductions.

Third, hedonic wage studies assume perfect labor markets and therefore that workers have perfect information regarding the risks they face. The workers' perceived risk is assumed to be equal to actual risk. This assumption may not hold in reality. However, in spite of these shortcomings, hedonic wage-risk studies remain the most common source of VOSL estimates in the USA.

Averting behavior studies

Box 9.4 Distribution of avoided premature mortalities, 2010, due to 1990 Clean Air Act amendments

Pollutant	***Age Group***	***Remaining Life Expectancy***	***Cases Avoided***
$PM_{2.5}$	Under 65	25	5,060
	65-74	14	5,520
	75-84	9	6,900
	>84	6	5,520

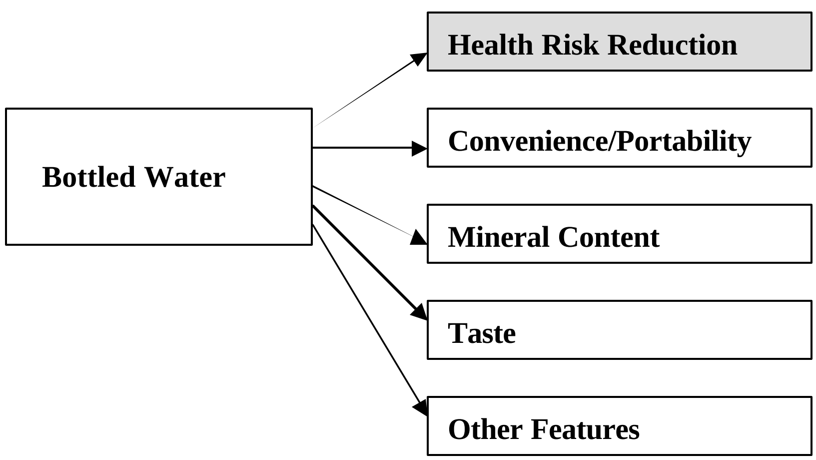
Source: USEPA, *The Benefits and Costs of the Clean Air Act, 1990 to 2010*, report prepared for Congress, November 1999.

The table above shows the age distribution of the expected mortality benefits associated with reductions in ambient levels of particulate pollution in the U.S. resulting from the Clean Air Act. A total of 23,000 statistical lives are expected to be "saved" between 1990 and 2010 with over 75 percent occurring at ages 65 years and over. The most appropriate WTP estimates for use in the valuation exercise to estimate the mortality benefits would reflect the age distribution of the affected population. Because hedonic wage estimates are derived from labor market studies of working-aged individuals, they imperfectly reflect the preferences of the population affected by the pollution reduction in this case.

Another approach to estimating WTP for reduced mortality risk is averting behavior analysis (see chapter 4 for more detail on this approach). This approach is based on the premise that individuals will take protective action as long as they perceive the benefits to be greater than the costs. By observing the cost of the averting behavior or good, and its effectiveness at offsetting the effects of the pollution exposure, one can estimate willingness to pay for the risk reduction. Unfortunately, isolating the effectiveness of the averting behavior/good on the health outcome is often difficult. Although there are numerous activities and products that reduce exposure to pollution and/or ameliorate the detrimental effects of exposure once they occur, many of these activities/goods either have no measurable price or produce joint products.

Consider as an example the case of bottled water (see Box 9.5). Individuals may purchase bottled water to avoid exposure to pollutants in an area with contaminated ground water. However, the bottled water may produce benefits in addition to the reduction in risk, including convenience, better taste, etc. Similarly, air conditioning units may be used to reduce exposure to harmful air pollutants, but in addition, increase comfort on a hot day.

Box 9.5 Potential reasons to purchase bottled water and averting behavior



Individuals may purchase bottled water for many reasons. The goal of the averting behavior study is to attempt to isolate the portion associated with the health risk reduction. Since it is often difficult to apportion the amount of the purchase price to the benefits received, it may be difficult to estimate WTP using this approach.

Stated preference approaches: contingent valuation method

Stated preference approaches attempt to measure WTP through surveys that question respondents directly about their preferences. A number of stated preference techniques are available, including contingent ranking, conjoint analysis and contingent valuation. To date the most popular stated preference technique for health risk valuation has been the contingent valuation method covered in chapter 7 and discussed in more detail below.

Given the difficulties posed by the valuation methods discussed above, it seems that the contingent valuation method may provide a good alternative for valuing mortality risk reductions. Rather than using imperfect data to derive estimates of WTP for reduced risk of environmental health outcomes, tailor survey questions may be able to elicit the WTP value directly from respondents. However, before such approaches can be used, it must be demonstrated that the change in risk can be conveyed to respondents in a meaningful way and that the respondents understand the choice with which they are being presented.

Existing contingent valuation studies of mortality risks generally suffer from two problems: (1) respondents are generally not accustomed to thinking about how much they value a small change in risk and (2) the risk changes with which respondents are presented are often expressed in units unfamiliar to them (e.g., a 1-in-10,000 change in the risk of dying). In a recent review of mortality risk studies in the U.S.A, Hammitt and Graham (1999) show that respondents have difficulty discerning between small risks of different magnitudes. Approximately, 32 percent of respondents did not know that 5/100,000 was a smaller number than 1/10,000. Sometimes, visual aids can be used to circumvent this problem, e.g. asking respondents to darken squares on a sheet of graph paper to help them visualize the risk change or alternatively to place risks on a risk ladder.

Even when care is taken to communicate the size of small risk changes, people often do not distinguish between the magnitude of these changes. Evidence of this can be found in the fact that, in many surveys, people's WTP for reductions in risk of death do not increase with the size of the risk reduction. In a survey of WTP for reductions in risk of death in the context of highway safety (Jones-Lee, Hammerton and Philips 1985), no statistically significant difference was found in the amounts people were willing to pay for a 1 in 100,000 reduction in risk of death during a bus trip and a 7 in 100,000 reduction. Presumably, both numbers were perceived as "small."

Even if people are able to understand the magnitude of a risk change, it may be difficult for them to place a dollar value on it. This is because people are unaccustomed to purchasing quantitative risk reductions. There are two problems here. People are often aware of the risk factors associated with a given cause of death and may actually engage in risk averting or risk reducing behavior; however, they are unlikely to know the magnitude of the risk reductions resulting from these behaviors. For example, people will state that they wear seat belts to reduce risk of injury and death in an auto accident, but it is difficult for them to quantify the benefits of wearing a seat belt. Secondly, as in the seat belt example, many of the activities people engage in to reduce their risk of death do not have a monetary cost associated with them. This is true of most behavioral changes (diet, smoking, exercise). While they may have to invest time to carry out the specific activity, there is often no additional financial cost associated with it.

Cost-effectiveness analysis

Cost-effectiveness analysis is a policy evaluation tool sometimes employed as an alternative to (or as a supplement to) benefit-cost analysis. Widely applied in the public health and medical fields, it is being considered increasingly in environmental economics to assess health benefits. Economists generally prefer benefit-cost analysis to cost-effectiveness analysis, but recognize the potential usefulness of the latter especially when WTP measures are lacking.

In cost-effectiveness analysis, rather than expressing the benefits and costs in a common monetary unit for comparison, the analyst compares the cost per unit of "health" saved. When there are mortality and morbidity impacts, health outcomes can be expressed in the same (non-monetary) units using health state utility metrics. A number of health state utility metrics exist, including Healthy

Year Equivalents, Health Utility Indices, and Quality Adjusted Life Years, but the most widely used in a global setting is the Disability Adjusted Life Year (DALY).

In summary the use of technique to decide whether a policy is worthy of implementation can vary. Generally, the use of benefit-cost analysis is a more complete method where the costs of the project can be directly compared to the benefits. However, in some cases the cost-effectiveness analysis may be more useful. An example of this is the 1990 Clean Air Act that was implemented in the USA. The benefits from the Act between 1970-1990 were estimated to be $16,000 per family of 4 in 1990. This was for every family just facing a small risk and was viewed by some as an unrealistically high estimate. Would your family pay $16,000 every year to avoid air pollution? Probably not. But if cost effectiveness was used, it could have been showed that the cost per life saved of Clean Air Act was $125,000. As VSL estimates are usually considerably higher than this (over half million dollars), it could be concluded that it was worth going ahead with the project and that the necessity to be precise with the benefits estimation would have been removed, as the benefits clearly exceeded the costs.

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Notes

[i] For a more detailed treatment refer to Pearce et al. (1989)

[ii] BCA should take into account the existence of price distortions, though. When doing an economic analysis, prices used should reflect the opportunity cost of the good or service. For example, if a good is subsidized, then its 'true' price is the market price + the value of the subsidy.

[iii] To simplify the presentation only the results from the slope area are presented, although the study divided the area into three basic bio-physical regions distinguished by slope and soil types: plateau, slope, and valley.

[iv] This example is taken from Harrington, Krupnick and Spofford (1989). This article is a good illustration of the application of the averting behavior approach to water contamination.

[v] The telephone survey revealed that 53% of individuals substituted a portion of their drinking water with other liquids; moreover 15% of individuals increased dining out.

[vi] This is done under the assumption that the 'demand curve' for water is linear. The average between the upper and lower bound corresponds to the 'consumer surplus' lost as a consequence of water pollution.

[vii] The trip generating function is used to trace out the demand curve for visits. A variety of functional forms for the trip generating function can be found in the literature. The choice of functional form is important, as changing the functional form can produce large changes in consumers' surplus estimates from a given data set.

[viii] Imagine a panoramic route with breathtaking landscape necessary to reach a park.

[ix] The careful reader may have noticed that the slope of the demand curve is equivalent to the coefficient of the 'travel cost' variable in the trip generating function. This is not a coincidence. The travel cost method is based on the assumption that the effect of increasing travel cost is considered the same as increasing the price of admission. This approach uses travel cost as a proxy for an imaginary admission fee (or price) to calculate consumer's surplus.

[x] This classification is not intended to be exhaustive. Each particular case would require expertise in determining what the relevant variables are. Econometric analysis can help to differentiate those relevant variables in explaining the price of a property from the irrelevant ones.

[xi] The 'β' here is the partial derivative of 'price' with respect to 'air quality': it expresses the change in 'price' as a consequence of a marginal change in 'air quality'. Graphically, this is represented as the 'slope' of the hedonic function along the 'air quality' dimension in any given point.

[xii] The numbers shown in the following table are derived by evaluating the hedonic housing expression, given the household's characteristics, for a pollution change from poor to fair or fair to good as the case may be. The resulting sale price differential is then converted to an equivalent monthly payment through the annualization procedure and divided by twelve.

[xiii] In other words, when estimating the value of changes in environmental quality, the researcher has to keep in mind this double effect on (i) housing and (ii) wages. In mathematical terms, the marginal value of an amenity change is the sum of the partial derivatives of the hedonic wage function and the hedonic property value function with respect to the amenity.

[xiv] This, by assumption, is equivalent to the marginal price of air quality, estimated in the first part of the analysis.

[xv] Observations that contain values very different from the rest of the group are called 'outliers' as they typically lay far from the hypothetical line joining the points in a scatter diagram.

[xvi] The R^2 can take a value between 0 and 1. In contingent valuation studies, this value is usually well below 1. This is due to wide variations between maximum willingness to pay bids – even between individuals that have very similar characteristics.