HANDBOOK FOR NON-CANCER HEALTH EFFECTS VALUATION

Non-Cancer Health Effects Valuation Subcommittee
of the
EPA Social Science Discussion Group

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Members of Non-Cancer Health Effects Valuation Subcommittee of the Social Science Discussion Group are:

Gary Cole, Chairperson	OPPT
Jan Auerbach	OW
Dan Axelrad	OPEI
Gary Ballard	OSWER
Allan Basala	OAR
Ed Bender	ORD
John Bennett	OW
Matt Clark	OW
Chris Dockins	OPEI
Charles Job	OW
Robert Fegley	ORD
Reid Harvey	OAR
Yvette Hopkins	OSWER
Michele McKeever	OAR
Greg Ondich	ORD
Joe Reinert	OPEI
Brett Snyder	OPEI
Sherry Wise	OPP
Sandy Evalenko	OPP

Analytical and preparatory support was provided by Industrial Economics Incorporated, 2067 Massachusetts Avenue, Cambridge, Massachusetts.

EXECUTIVE SUMMARY

This handbook provides an introductory survey of the theory, techniques, and existing literature pertaining to economic valuation of non-cancer health effects. This handbook is designed to improve the understanding of non-cancer valuation methods and their application among EPA staff involved in preparing and presenting policy analyses; provide a means to facilitate consistency in the use of the existing literature on non-cancer valuation across the Agency; and present a set of "off-the-shelf" approaches and suggestions on the use of these approaches for analyses of environmental health risk reduction. In addition, this handbook presents some of the main challenges, issues, and uncertainties associated with the economic methods commonly used for health effect valuation.

THEORETICAL BASIS OF HEALTH EFFECTS VALUATION

Most often, the reason for estimating economic values of environmental health effects is to compare the economic benefits of a policy to the costs of that policy. In the pollution control context, these cost-benefit analyses, which include regulatory impact analyses required for major rules under Executive Order 12866, may be used to rank regulatory options, to inform decisions that rely on an economic justification, or even to evaluate entire programs.

Proper evaluation of economic efficiency requires accurate measures of benefits and costs. Economists define benefits and costs as dollar equivalents of changes in well-being. In economic theory, an individual's well-being depends on his or her consumption of marketed goods and services, his or her health status, and other characteristics of his or her environment. Typically, dollar equivalents of changes in well-being are measured by willingness-to-pay compensation (WTP) or willingness-to-accept compensation (WTA). WTP for health is the largest amount of money an individual would voluntarily pay to obtain an improvement (or to avoid a decrement) in health. WTA is the smallest amount of money the individual would voluntarily accept as compensation to forego an improvement (or to endure a decrement) in health. This handbook focuses on WTP, mainly because WTP is often less problematic to measure and quantify and, as a result, is the term used most commonly in the economic valuation literature.

Measuring WTP for health presents several problems to the analyst. First, when environmental quality improves, there are several health-related impacts on well-being (e.g., medical costs, indirect costs such as lost wages, pain and suffering). It is easy to overlook one or more of these, resulting in an underestimate of the value of health. A second issue is that the health of one person may affect the well-being of another (e.g., the case of parents ill health affecting their children), suggesting that the focus on each individual's WTP for his own health may be too narrow in some cases. Third, health effects of exposure to environmental contamination may be immediate or delayed, making it important to consider how the timing of health effects influences WTP. Finally, environmental contamination may not cause specific health effects with certainty, but rather may increase the risk of poor health.

PRIMARY METHODS OF MORBIDITY VALUATION

Researchers have used a wide range of approaches to value environmental health effects. Several available methods measure the theoretically preferred value of individual willingness to pay to avoid a health effect, while other methods that provide useful measures of the value of avoided morbidity are less well-grounded in economic theory. Methods also differ in the perspective from which valuation is measured (e.g., before or after the incidence of morbidity), and the degree to which they account for the major elements of willingness to pay.

To develop an understanding of the methods available for estimating environmental morbidity values, it is first important to understand the various components of these values. The loss of social welfare associated with the incidence of one case of a health effect is comprised of four elements: the cost of treatment, the loss of output associated with the reduction in work activity in the labor market, the loss of value of non-market activities, and individual's pain and suffering. When the individual who suffers the disease bears the whole cost burden, the value of environmental morbidity is the individual's maximum WTP to avoid the disease, equal to the monetized value of the four components. In the absence of sick pay, medical insurance, and/or charity, the value of environmental morbidity is the sum of the WTP to avoid the costs borne by the individual and costs borne by third parties (e.g., insurance companies).

Three methods are used most often to value environmental morbidity. The first is the cost-of-illness (COI) method, which measures the costs incurred as a result of illness, including direct costs such as medical expenses and indirect costs such as foregone earnings. This method directly measures values using observed behavior and is most prevalent in the medical economics literature. The cost-of-illness method does not measure WTP for reduced morbidity. Two other methods are more prevalent in the environmental economics literature. The contingent valuation method (the most commonly used stated preference method) measures respondents' WTP for hypothetical health improvements. The averting behavior method (a revealed preference method) estimates WTP from observed behavioral responses to real situations. This method infers WTP from the cost and effectiveness of actions taken to defend against illness. See Exhibit ES-1 for a summary of the three most common environmental morbidity valuation methods. Several other methods have been used less frequently to value environmental morbidity, including hedonic methods, and several other methods that, similar to the cost-of-illness method, do not measure WTP: risk-risk tradeoffs and health-state indexes. In addition, studies of jury awards are a potentially useful source of data, although they have not been fully evaluated by economists for their usefulness for valuation of health effects.

Exhibit ES-1

EVALUATION OF THREE MOST COMMON METHODS FOR MORBIDITY VALUATION

Method	Approach	Advantages	Disadvantages
Cost-of-illness	Measures direct costs such as medical expenses and indirect costs such as foregone earnings.	Relative ease of application and explanation. Does not require household surveys. May be lower bound on WTP.	Does not measure WTP. Ignores important components of WTP such as pain and suffering.
Contingent Valuation	Surveys elicit WTP for hypothetical changes in health effects.	Flexibility allows application to variety of health effects. If designed properly, allows measurement of complete WTP, including altruism.	Hypothetical nature introduces many sources of potential inaccuracy and imprecision. Method is controversial and often expensive.
Averting Behavior	Infer WTP from costs and effectiveness of actions taken to defend against illness.	WTP estimates based on actual behavior.	Difficult to isolate value of health from other benefits of averting action. Difficult to measure individual perceptions of cost and effectiveness of averting action.

The economic value of health is a sometimes elusive concept that is difficult to quantify precisely. For that reason, it is useful to use more than one technique to estimate the value where possible. In addition, while any of the methods discussed in this handbook may provide a valuation estimate, it is important to evaluate critically the plausibility of an estimate for its reasonableness in a particular application. For example, if the estimated value of avoiding an acute, reversible effect exceeds other reasonable estimates for avoiding long-term, chronic effects, then the acute effect value is probably too large and will be difficult to defend. On the other hand, willingness-to-pay values that are less than cost-of-illness values for the same effect are probably too low, particularly if the effect clearly results in some pain or other impairment of activity.

VALUING NON-CANCER HEALTH EFFECTS USING BENEFITS TRANSFER

Benefits transfer is an alternative to primary research that can be used to develop benefits estimates. In benefits transfer, valuation information on individual WTP from one or more existing studies is used to assess aggregate benefits of a proposed or new policy. The techniques of benefits transfer have been used for many years to evaluate public policy options and to assess natural resource damages. Benefits transfer often is used when insufficient time or money is available to gather the primary data required for a new valuation study.

The benefits transfer technique involves a four step process. The first step is to describe the policy case. In this step, the analyst describes in detail the health effects of the policy, the resulting impacts on economic well-being, and the characteristics of the affected population. The second step is to identify existing, relevant studies. This step generally involves literature searches and discussions with researchers in the field. The third step is to evaluate the suitability of existing studies for benefits transfer. This step concerns assessing the quality and applicability of identified studies. The fourth step is to transfer the benefit estimates.

There are advantages and disadvantages to using the benefits transfer technique compared to primary research. On the one hand, primary research is costly and time-consuming, and in advance of conducting the research there is no guarantee of success. Benefits transfers usually can be conducted much more quickly and at lower cost using studies whose quality can be assessed in advance. Also, when several relevant studies are available, combining them may to some extent mitigate problems or errors specific to any one study. On the other hand, the resulting benefits transfer estimates are unlikely to be as accurate or precise as estimates from primary research tailored specifically to the new policy issue.[1] Previous analyses suggest benefits transfers should be conducted and interpreted with careful consideration of potential sources of inaccuracy or imprecision. An additional problem specific to morbidity valuation is that the number of health effects for which WTP estimates exist is quite limited: there is not much available to transfer.

Not surprisingly, the two major issues involved in benefits transfer concern (1) the *quality* of existing studies, and (2) their *applicability* to the new policy situation. Applicability refers to the match between the *study case,* or the situation examined in the original study, and the *policy case*, or the situation relevant to the new policy. Key elements of this match include the correspondence between the "commodity," or health effect, valued in the study case and the health effect of the policy; and the similarity between the population examined in the study case and the population affected by the policy. As discussed in this handbook, the value of avoiding a health effect depends on characteristics of the effect, such as severity and duration, as well as on characteristics of the

[1]See Chapter 4, Deciding Whether to Conduct a Benefits Transfer, for further discussion of this topic.

population affected, such as income or baseline health status. Ideally, the analyst would prefer that the health effects and populations considered in the study and policy cases be quite similar. Secondarily, the analyst would prefer a defensible method to adjust for important differences.

ISSUES IN APPLYING THE VALUATION LITERATURE

Valuation of health effects is generally of interest when an estimate of the reduction in risk of that effect can be established. Understanding the health science basis for the effect and properly applying the relevant economic literature is not always straightforward. For example, values for individual health effects are not always available, or existing dose-response relationships may address slightly different health effects than the economics literature.

There are many reasons to exercise caution in the application of economic values for health effects. Three situations are commonly encountered in application of economic values. In the first situation, WTP values are not available. Often, a cost-of-illness measure can be developed relatively easily, but the pain and suffering component is not captured, and the pain and suffering component can be a major factor in valuation of some chronic effects. Although everyone would no doubt agree that some illnesses hurt more than others, there is no accepted scale to measure the quantity of pain or suffering. This immeasurability complicates valuation, but monetization of pain and suffering would remain difficult and controversial even if the amount pain could be quantified. This handbook evaluates alternative strategies for monetizing pain and suffering, including benefits-transfers based on existing information on the economic value of avoided pain and suffering and primary research to monetize pain and suffering directly.

In the second situation, existing WTP values are poorly matched to the effect of concern -- this can lead to issues of double-counting and increased uncertainty in benefits transfers. There are several important factors associated with the transfer of existing economic values for use in policy analyses that could cause the aggregate benefits estimate to differ from the "true" value. In most cases, simplistic assumptions about the additivity of the values for component parts of health effects can lead to an upward bias in the aggregate value. For example, WTP to avoid two days of a symptom may not equal two times the WTP to avoid one day of a symptom. In addition, WTP to avoid a cough and headache may not equal WTP to avoid these two symptoms separately. On the other hand, WTP estimates may understate the true value. In general, the details of a specific benefits transfer govern the direction of bias. In a few cases, available literature supports an adjustment to economic values to correct for these errors. In all cases, however, benefits analysts need to be aware of the potential influence of these factors on the overall benefits estimates, collect information from the relevant health effects and economics literature that are being considered as the basis for benefits estimation, and carefully consider the uncertainties in valuation for individual health effects of concern.

In the third situation, the health effect itself is poorly characterized in the relevant health science literature. In this situation, there are steps that an analyst can take to frame the potential value of non-cancer risks associated with a specific contaminant exposure. First, one can identify the

critical and prevalent non-cancer effects for a contaminant using health effects data published in EPA's Integrated Risk Information System (IRIS). In some cases, IRIS will contain enough information to develop a general description of the nature of the specific effects. If needed, additional information can be obtained by reviewing the health effects studies cited in IRIS. It may be possible to develop a unit valuation for the effects depending on how clearly they are defined. Such a valuation may be based on cost of illness data, primary research, or the transfer of willingness-to-pay data. Finally, by looking at the population that is subject to doses at or above the RfD, as estimated by risk analysts, one can estimate the number of people at risk of contracting the effects. Thus, even without an estimate of the probability that people exposed at this level will contract the effect, arraying the available information in this manner provides helpful insight into the potential value of avoiding the effects. Furthermore, this type of analysis can suggest whether additional investigation of the health effects data (e.g., dose-response data) is warranted. Typically, risk analysts conduct each of these steps, but it can be useful for economic analysts to have a basic understanding of the underlying risk analysis to best present available information to decision- makers.

COLLECTING INFORMATION TO SUPPORT NON-CANCER HEALTH EFFECTS ANALYSES

In addition to providing the reader with a basic understanding of the theory and methods of non-cancer health effects valuation, as well as some insight into the major issues that could be encountered in health effects analyses, this handbook provides information that will help the reader get started on a non-cancer health effects benefits analysis. Several information sources are available for use by risk assessors to characterize the types of health effects that are associated with prevention of contaminant exposures. A basic knowledge of the methods of risk assessment and the underlying studies that characterize health effects is helpful to the economist or benefits analyst in conducting non-cancer health effects analyses. In addition, several useful sources of information on existing economic studies of non-cancer health effects, including references to several documents EPA has developed, can facilitate a literature review. Finally, health benefits approaches used in other Federal agencies and departments may provide helpful information to design strategies for valuation.

APPENDICES

Information supplemental the main text is provided in three appendices. Appendix A provides a comprehensive annotated bibliography of articles relevant to non-cancer health valuation. The abstracts provide a concise description of each article and are organized into the following categories:

- Valuation Theory and Methods
- General Applications
- Commonly Applied Methods of Averting Behavior, Contingent Valuation, and/or Cost-of-Illness Methods
- Benefits Transfer
- Valuation of Mortality Risk

- Regulatory Support Documents

Appendix B includes a detailed literature review of studies addressing the "pain and suffering" component of non-cancer health effect valuation. Appendix C includes six case studies of non-cancer valuation for specific health effects. The case studies address effects that are likely to be of continuing interest to EPA analysts in future policy development. The six effects are: lung function; reproductive effects associated with endocrine disruption; developmental effects associated with endocrine disruption; childhood asthma; childhood lead poisoning; and kidney function. For most of these effects, valuation is not straightforward — the case studies are designed to be illustrative of the types of strategies that can be used to characterize the benefits of avoiding these types of effects.

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INTRODUCTION CHAPTER 1

This document provides an introductory survey of the theory, techniques, and existing literature pertaining to economic valuation of non-cancer health effects. The goals of this handbook are as follows:

- Improve the understanding of non-cancer valuation methods and their application among EPA staff involved in preparing and presenting policy analyses;
- Provide a means to facilitate consistency in the use of the existing literature on non-cancer valuation across the Agency; and
- Present a set of "off-the-shelf" approaches from the existing literature and suggestions on the use of these approaches for application in analyses of environmental health risk reduction.

Several steps were taken to ensure that the information contained in this handbook is helpful to a diverse audience and applicable for a wide variety of uses. First, the exposition is geared toward a non-technical audience and is deliberately kept brief. Readers with little or no familiarity with environmental and health economics should be able to comprehend and interpret the information presented. Second, major uncertainties and limitations associated with the commonly used methods and the existing literature are carefully explained. Consideration and appropriate presentation of uncertainties is critical in conducting valuation analyses. Third, the handbook includes an extensive annotated bibliography as well as several suggestions for further reading focusing on those areas where valuation could prove particularly difficult or controversial.

The remainder of the document consists of five chapters and three appendices. Chapter 2 covers the economic theory of valuation for reductions in human health risk. Chapter 3 summarizes the major primary research techniques that are commonly used for health risk valuation. Chapter 4 covers methods for applying existing primary research through a process known as "benefits transfer." Chapter 5 explores several issues in the application of these values in benefits analyses and suggests strategies for addressing these issues.

These four chapters are designed to provide an introduction to the methods commonly used for economic valuation of non-cancer health effects, as well as some of the main challenges, issues, and uncertainties associated with these methods. The focus of these chapters and this handbook is on valuation techniques to estimate health-related benefits. However, it is important to acknowledge that within the Agency, non-quantifiable effects also provide important information in the benefits analysis. While this handbook does not specifically discuss methods for reflecting these types of effects in benefits analysis, a thorough economic assessment of non-cancer health effects should include a description of these qualitative benefits.

Chapter 6 provides information to help the benefits analyst get started. The chapter provides references to a wide range of existing health and economic literature. This chapter should provide the reader with an understanding of the types of health effects that have been addressed in previous health and economic research, the results of that research (including specific references to previous applications of the results in EPA-sponsored work), and the gaps in coverage of relevant health effects that remain. An annotated bibliography is included as Appendix A. Appendix B includes a detailed literature review of studies addressing the "pain and suffering" component of non-cancer health effect valuation.

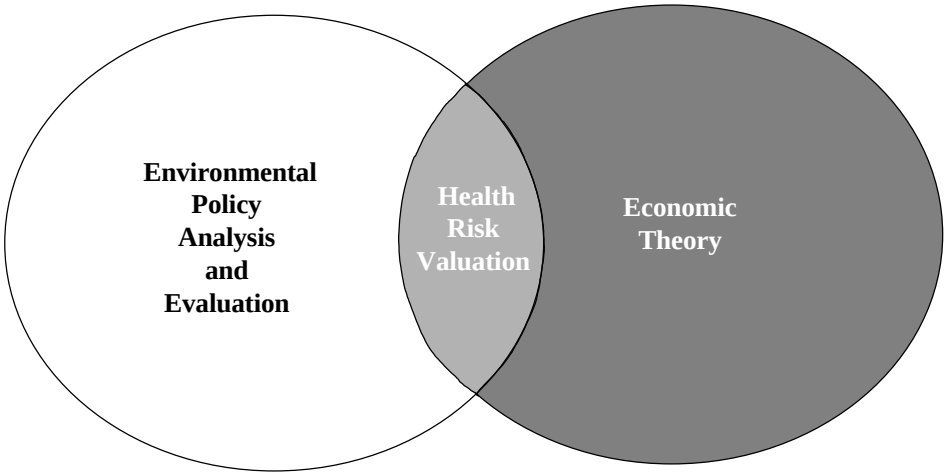
Appendix C includes six case studies of non-cancer valuation for specific health effects. The case studies address effects that are likely to be of continuing interest to EPA analysts in future policy development. The six effects are: lung function; reproductive effects associated with endocrine disruption; developmental effects associated with endocrine disruption; childhood asthma; childhood lead poisoning; and kidney function. For most of these effects, valuation is not straightforward — the case studies are designed to be illustrative of the types of strategies that can be used to characterize the benefits of avoiding these types of effects.

This handbook should provide a useful starting point for developing economic benefit assessments of policies that mitigate non-cancer human health effects, and will hopefully facilitate efforts among EPA program offices to improve the consistency, quality, and comprehensiveness of policy analyses. Many of the techniques and approaches discussed in this handbook apply to any adverse health effect, however, the focus of this handbook is on non-cancer health effects. Two important categories of effects excluded from this handbook are fatal and cancer risks. While most EPA program offices have developed strategies for valuation of these types of effects (see the recently updated Agency Guidelines, USEPA, 1999), this handbook is meant to fill a perceived gap in developing strategies for benefits analysis involving non-cancer health effects.

THEORETICAL BASIS OF HEALTH EFFECTS VALUATION CHAPTER 2

This chapter surveys the economic theory which supports non-cancer and other human health effects valuation. The chapter has four main sections: (1) An overview of the context in which economic valuation enters policy analysis; (2) An explanation of valuation theory outlining the assumptions and reasoning behind the measurement of economic value, and discussing valuation of market goods; (3) An introduction to health effects valuation highlighting special issues arising when applying the theory to human health; and (4) A summary reviewing key points and providing a guide to further reading.

Exhibit 2-1



As illustrated in Exhibit 2-1 above, this handbook reviews topics that arise in the intersection of environmental policy analysis and economic theory that are relevant to health risk valuation. The document does not fully explore either environmental policy analysis or economic theory. For more information on environmental policy and the use of applied economics at EPA, see EPA's Guidelines for Preparing Economic Analysis (US EPA, 2000a).

ECONOMIC VALUATION AND POLICY ANALYSIS

To survey the theory of health effects valuation, it is useful first to consider how economic value estimates can inform policy decisions. Most often, the reason for estimating economic values of environmental health effects is to compare the economic benefits of a policy to the costs of that policy. In the pollution control context, these cost-benefit analyses, which include regulatory impact analyses required for major rules under Executive Order 12866, may be used to rank regulatory options, to inform decisions that rely on an economic justification, or even to evaluate entire programs.

Benefit-cost analysis examines public policy actions in terms of the impact on the well-being of society as a whole. In theory, a policy action should strive to maximize the economic well-being of all affected people at a minimum, while at the same time strive to maximize the net gains from public policy. A properly conducted benefit-cost analysis considers the wide range of impacts a regulation may have on society as a whole. These impacts include: requiring some actors to incur costs for compliance with the regulation; conferring benefits on other actors (for example, in the form of reduced health risk); changing individuals' wealth by redistributing resources (that is, changes in equity); causing society to incur costs for administering the regulation. While this approach may not always result in an *optimal* level of regulation (i.e., it achieves the best possible outcome at the lowest cost), a properly conducted benefit-cost analysis that considers all societal costs and benefits of the action implies that benefits could be redistributed so that no one is harmed. Those people bearing the costs can, in principle at least, be compensated fully with the net benefit remaining (*surplus* of benefits over costs). Further redistribution of the surplus would allow everyone to gain from the policy. If societal costs exceed societal benefits, on the other hand, there is no way to implement the policy without harming someone.

For example, suppose a policy would require installation and operation of pollution control equipment costing firms $1 million, while reducing asthma attacks among nearby residents. In addition, suppose that the law requires that firms operate their plants in a manner that prevents such health effects from occurring. If each of three thousand asthmatics would be willing to accept no less than $1,000 in compensation for incurring the health decrement (or forego the improvement), then the total economic benefit of the policy equals $1,000 times 3,000 persons or $3 million. Because the benefits exceed the costs by a wide margin, provided the costs of administering the policy (the *transactions costs*) are less than $2 million, society is better off with the policy than it would be without. If the policy were not adopted, liability law might allow the asthmatics to demand a total of $3 million in compensation from the firms for harm done by the pollution, although the legal costs

of such an action, with many polluters and many asthmatics involved, could be excessive. With the policy, however, the asthmatics can be made equally well off through the installation of pollution control equipment costing only $1 million, plus the administrative costs to be borne by society.

On the other hand, if the asthmatics would be willing to accept only $100 each in compensation for incurring the health decrement (or forego the improvement), implying total benefits of the policy of $0.3 million, enacting a requirement for pollution control equipment would require society to spend at least $1 million to provide health benefits of $0.3 million to the beneficiaries; this clearly would not be an economically efficient use of resources. In this case, it might be better to require direct compensation of affected individuals by the polluting companies. Alternatively, if transactions costs for setting up a direct compensation mechanism are too high, it may be appropriate to simply tolerate the inefficiency by either under- or over-regulating the market.

This simple example illustrates five key issues arising in the use of health valuation techniques and benefit-cost analysis to evaluate policies affecting health:

- First, economists measure the value of better health as the amount of money an individual is willing to accept to incur a health decrement (or forego the improvement), summed over all affected individuals, when the polluter is responsible for compensation. If the public is judged responsible for paying the firm not to pollute, the value of better health is the amount of money an individual is willing to pay to obtain a health improvement (or avoid a decrement), summed over all affected individuals.

- Second, each individual is assumed to be the best judge of the economic value of his own health. As a result, some attempt to determine what an asthmatic himself is willing to accept to endure worse health (or to pay for better health) is preferable to the assignment of a monetary value by an external observer. Both this and the first issue assume that this amount reflects the value he puts on his own health. While it is possible that this value may include benefits for others (i.e., altruistic benefits), in most cases economists associate values only with the individual himself.

- Third, a cost-benefit framework evaluates economic efficiency without considering who should pay for a policy. Determining whether the asthmatics, the polluting firms, or some third party should pay for pollution control is a separate question that is usually determined by the legal rights of the affected parties. The example above follows the "polluter-pays" philosophy, but in many cases the governing statutes may not require polluters to completely eliminate all health risks attributable to their actions.

- Fourth, benefits and costs are by definition gains and losses relative to some point of reference, and the reference point must be specified in advance. Policy analysts should realize that the choice of a reference point affects the

measurement of benefits and costs. Using the above example, suppose researchers are analyzing a policy designed to reduce asthma attacks by 50 percent from current levels in a given city. In addition, assume the geography of the city is such that residents of two areas of the city currently experience different levels of asthma. If residents of Area 1 currently incur more asthma attacks than those of Area 2, all else equal, the policy option may have a greater value at Area 1 than Area 2. In some cases, an analysis of the incremental, or *marginal*, effects such as this may indicate a great disparity in value due to different reference points.

- Fifth, once the issue of who is to compensate whom is decided and the reference point chosen, benefit-cost analysis implicitly accepts the corresponding distribution of health, income and economic well-being as an adequate basis for judging public policy. A detailed analysis can show how costs and benefits are distributed by income, health status or other population characteristics, but these characteristics are generally not considered in computing total net benefits. Concerns about fairness and equality, while often an important consideration in the policy-making process, are most often considered outside of the cost-benefit framework.

These issues are not always straightforward to address. This volume, designed to provide insights into non-cancer health risk valuation, cannot resolve many of these issues. For example, establishing a baseline from which to measure benefits is often very complicated. EPA's Regulatory Policy Council is currently developing guidance for analysts on this topic (see US EPA, 2000a). Nonetheless, later chapters of this report suggest strategies for addressing these issues in particular valuation contexts and provide examples, through case study analysis, of how analysts have addressed these issues in the past.

In general, valuation of health benefits can be effectively used to illustrate the benefits of a policy using the same metric typically used to measure costs (that is, in dollars). Economic valuation can therefore be a useful input to policy decisions. At the same time, it is helpful to acknowledge the limitations of economic valuation and the cost-benefit framework, and recognize that considerations of the impacts of a policy choice beyond economic efficiency are also relevant to the decision-making process (e.g., equity and intergenerational concerns, and political, ethical and legal issues).

THEORY OF ECONOMIC VALUATION

Proper evaluation of economic efficiency requires accurate measures of benefits and costs. Economists define benefits and costs as dollar equivalents of changes in well-being. In economic theory, an individual's well-being (also called welfare or utility) depends on his or her consumption of marketed goods and services, his or her health status, and other characteristics of his or her environment.

Typically, dollar equivalents of changes in well-being are measured by willingness-to-pay compensation or willingness-to-accept compensation. Willingness-to-pay compensation (WTP) for health is the largest amount of money an individual would voluntarily pay to obtain an improvement (or to avoid a decrement) in health. The person feels that paying this sum in exchange for better health gives the same degree of well-being as keeping the money and living without the health improvement. In this sense, WTP represents the individual's own assessment of the dollar value of better health.

Willingness-to-accept compensation (WTA) is the smallest amount of money the individual would voluntarily accept as compensation to forego an improvement (or to endure a decrement) in health. The person feels that accepting this sum in exchange for living without the health improvement gives the same degree of well-being as not receiving the money but having better health. As in the case of WTP, WTA also represents the individual's own assessment of the dollar value of better health.

Both WTP and WTA are measures of dollar equivalents of changes in well-being, but they are not identical. The two measures differ because they take different reference points to evaluate the change in well-being. WTP measures what the person would pay to obtain better health, while WTA measures what he would require to forego better health. A person's willingness to pay cannot exceed his income; WTA has no upper bound but is at least as large as WTP. The difference between the two measures is likely to be small, and the choice between them inconsequential, for small changes in health. But there may be large differences for large changes in health. In economic theory, the choice between the two measures amounts to an arbitrary choice of reference point to evaluate the change in well-being. In practice, most studies take an individual's current health status as the reference point, and estimate WTP to obtain improved health. In practice however, the choice of using WTP or WTA is a question of property rights. Carson and Mitchell (1993) discuss this issue in more detail. WTP is used when it is determined that the public should pay the firm not to pollute the public resource, and WTA is used when it is determined that the firm should pay the public to be allowed to pollute the public resource. WTP is often less problematic to measure and quantify and, as a result, is the term used most commonly in the economic valuation literature. For

ease of exposition, we use the term "willingness-to-pay" (or WTP) throughout this handbook to refer to the underlying economic principles behind both WTA and WTP.[2]

Determinants of Willingness to Pay

Broadly speaking, WTP depends on two factors: preferences and opportunities. Preferences represent a person's desires, wants or needs, or his perception of how health, marketed goods and services, and other features of his environment affect his well-being. Opportunities describe the means available to satisfy preferences, such as income and time.

The basic role of preferences in determining WTP is straightforward. If one individual has a strong desire for physical fitness while another does not, and the two have similar opportunities, the first person will be willing to pay more for a health club membership. Economists take preferences as given and make no judgment about whether one person has better preferences; each is assumed to be the best judge of his or her own well-being. In addition, it should be acknowledged that preferences may change over time. Older WTP studies may become outdated due to changes in preferences or opportunities for substitute goods.

While taking a person's preferences as given, economists assume that individuals' preferences have several specific properties. In addition to assuming that an individual's preferences are well-defined (i.e., a person is aware of his preferences and acts appropriately to satisfy them), the three most important properties for estimating WTP are substitution, nonsatiation, and convexity. Substitution implies a willingness to make trade-offs: a larger amount of one good compensates for a smaller amount of another, even if one of the goods is health. The substitution principle is critical for measuring WTP, because it implies that health and income can be substituted for one another while maintaining a constant degree of well-being. Examples of income traded for health include the purchase and use of smoke detectors or bicycle helmets. In addition, substantial evidence indicates that people make trade-offs between health and money or other goods. For example, many reasonably well-informed people eat high-fat diets or have other poor health habits, apparently trading future health risk for present enjoyment of certain foods or lifestyles. Some people take jobs entailing a higher risk of death or injury in exchange for higher wages, while others do not use seat belts because of the required time or inconvenience. Economists believe choices like these reveal a willingness to substitute good health for money or other goods.

A second and less controversial assumption about preferences is nonsatiation: more (of a good thing) is preferred to less. Nonsatiation implies that WTP for better health is positive (technically, nonnegative). Third, economists may assume preferences are "convex," which implies

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[2] Because current law may confer property rights to the environment on those exposed to environmental contamination, research continues on better ways to measure WTA for improvements in environmental quality. EPA is currently among the sponsors of this research.

that, all else equal, WTP for additional increments of health may decline as health improves. For example, in this case, individuals in poor health are expected to be willing to pay more for improved health than are similar but healthier people for the equivalent health increment. In some cases it might not be clear how WTP is associated with additional increments of health. For example an individual's WTP to avoid five days of a particular symptom (e.g., a headache) might be greater or less than the WTP to avoid this symptom in five separate instances.[3]

Income and wealth are major determinants of opportunities that affect WTP. Health is a "normal good," that is, WTP for better health rises with income. Besides income, the price and availability of a related good may affect opportunities. For example, if an employer subsidizes an on-site health and recreation facility, employees would be willing to pay less for memberships in other health clubs.

Differences in opportunities or preferences between individuals may also be related to age, gender, schooling, pre-existing health impairments, or other personal characteristics. Individual variation in preferences or opportunities causes WTP to differ between individuals, and policy analysis may require an accounting of these differences. In many policy contexts, however, distinguishing the WTP estimate of, for example, a low-income group and a high-income group is controversial.

Measuring Willingness to Pay: Market Goods

Economists assume that people behave as if to obtain the greatest possible well-being, subject to available opportunities. It follows that in many cases, if opportunities are held constant, actual behavior reveals preferences. This principle, known as "revealed preference," is most useful when measuring WTP for goods traded in markets, but it also has application to valuing health.

If a person seeks the greatest possible well-being subject to available opportunities, that person will buy a unit of a good as long as his or her willingness to pay is at least as great as the cost of obtaining the good (i.e., the utility from consuming is at least as great as the reduction in opportunity from spending money on the good). Two cases in which this principle is applied may be distinguished. The first occurs if WTP declines smoothly as additional units of a good are purchased. A person then buys additional units until WTP equals the price. To illustrate, suppose a nonfat, pasteurized egg product sells for $2 per 16-ounce carton. If Person A and Person B each buy the product, each will buy it until her WTP for the last carton equals $2. If Person A has a higher income, or greater concern for cholesterol or food-borne illness, she may buy more of the product than Person B, but her WTP for the last unit will be $2, just equal to that of Person B. Anyone else buying the nonfat egg product at the same price also values the last carton purchased at $2, regardless of income, health status, or differences in preferences. Conversely, anyone who does not buy the product values it less than $2.

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[3]In Chapter 5 we discuss issues which may arise in attempting to match economic values to health effects evaluated in the health science literature.

The WTP for 50 cartons, however, does not equal $100, or the expenditure required to buy 50 cartons. Instead, the expenditure is a lower bound on WTP for anyone who purchases 50 cartons, because WTP exceeds price for all but the last unit purchased. The excess of WTP over price for the first 49 cartons is called "consumer's surplus." Also, not everyone buying the product would have the same WTP for 50 cartons; Person A's WTP would exceed Person B's owing to her higher income or greater health concerns.

The second application of revealed preference applies when WTP declines discontinuously, or "jumps down," for an additional unit of a good. For example, Person C may be willing to pay $1000 for installation of an air purifying unit in his central air-conditioning system, but he is not willing to pay anything for a second unit. If a unit costs $400, Person C will purchase it, but his WTP exceeds the market price by $600, the amount of his consumer's surplus. Similarly, Person D would purchase a unit if his WTP is $500 (his consumer's surplus is $100), but Person C and Person D do not have the same WTP. In this case, the market price serves as a lower bound to WTP for buyers and an upper bound to WTP for non-buyers.

These examples illustrate several points about WTP measurement. First, market behavior reveals information about WTP for goods traded in markets. Second, if WTP declines smoothly with additional consumption of a good, then everyone buying the good values an additional unit at the market price. If this price is the same to all, then all purchasers have the same WTP for the last unit purchased, regardless of their income, health status, or preferences. Third, total expenditure provides only a lower bound, not an exact value, for the WTP for large changes in the amount consumed, and all purchasers do not have the same WTP for a large change. As a result, it is usually more difficult to estimate WTP for a large, or *nonmarginal*, change in consumption than for a small, or *marginal*, change. A similar outcome occurs when WTP falls discontinuously: the market price provides only a lower bound on the value of one unit, and WTP need not be the same for all purchasers.

Measuring Willingness to Pay: Nonmarket Goods

Unlike membership in a health club, nonfat egg products, or air purifying units, health itself cannot be purchased in a market: it is a *nonmarket* good. Although the economic theory of preferences and value applies to nonmarket as well as to market goods, measuring WTP for a nonmarket good is more difficult. Economists have relied extensively on markets for information about economic value, because actual behavior in markets reveals preferences and also reflects constrained opportunities. Valuing a nonmarket good requires finding an alternate source of information.

Economists have applied two general approaches to measure WTP for nonmarket goods such as health or environmental quality. One approach is called *revealed preference*, because it continues to adhere to the revealed preference principle of inferring WTP from observations of actual behavior. The revealed preference approach generally involves linking the nonmarket good of interest to a related good which is traded in a market. For example, if two acetaminophen tablets relieve one

headache and provide no other benefit, anyone buying acetaminophen must value the last headache relieved at no less than the price of two tablets.

The alternate approach is called *stated preference* because it relies on individuals' statements about how they would behave in a hypothetical situation, or how much a hypothetical change in a nonmarket good is worth to them. For example, survey respondents might be asked whether they would be willing to pay $25 to eliminate one day of an acute respiratory symptom.

There are several revealed preference and stated preference methods; each method can be further classified as being *direct* or *indirect* (Mitchell and Carson 1989, pp. 74-87; Freeman 1993, pp. 23-25), but that distinction is not essential to the following discussion. In addition to revealed preference and stated preference approaches, some approaches to health valuation do not attempt to estimate WTP at all. The most widely used is the cost-of-illness method, which measures the direct and indirect costs of illness rather than WTP to avoid illness. The various methods of valuing non-cancer health effects are reviewed in more detail in Chapter 3.

VALUATION OF HUMAN HEALTH

Measuring WTP for health presents several additional problems beyond the issue of valuing a nonmarket good. First, when environmental quality improves, there are several health-related impacts on well-being; it is easy to overlook one or more of these, resulting in an underestimate of the value of health. A second issue is that the health of one person may affect the well-being of another, suggesting that the focus on each individual's WTP for his own health may be too narrow in some cases. Third, health effects of exposure to environmental contamination may be immediate or delayed, making it important to consider how the timing of health effects influences WTP. Finally, environmental contamination may not cause specific health effects with certainty, but rather may increase the risk of poor health. The theory of benefit-cost analysis and WTP measurement must be extended to handle situations involving risk.

Components of Individual Willingness to Pay for Health

A change in environmental quality may have many health-related impacts on well-being. The economic measure of these impacts is WTP, which reflects the total dollar value for a change in well-being that results from a change in health. Economists assume this measure reflects all the ways that changes in health affect a person's well being. Because analysts often rely on existing applied methods that do not capture the total WTP (i.e., they may reflect only a part of an individual's WTP or be only a monetary measure of benefits, such as COI), it is important to understand the components of WTP. In addition, understanding the components of WTP is vital for conducting benefits transfers.

Illness imposes direct costs such as expenses for medical care and medication, and indirect costs such as lost time from paid work, nonmarket work such as maintaining a home, and leisure. Illness also imposes less easily measured but equally real costs of discomfort, anxiety, pain, and suffering. A complete measure of the value of avoiding illness must include the economic value of reduced suffering.

Besides costs arising from the occurrence of illness, costs may be incurred to avoid illness or environmental hazards: some people purchase bottled water to avoid contaminated drinking supplies, install air purifiers at home, or adjust their schedules to remain indoors on days when air quality is poor. Defensive actions such as these may reduce both the severity and probability of suffering the health effect caused by a given level of environmental contamination. As a result, better environmental quality may raise well-being by improving health *and* by reducing the need for defensive action.

To illustrate the impact of defensive action on valuation, suppose an individual can completely avoid any adverse health effects of contaminated water supplies by purchasing bottled water. Cleaning the drinking water supply does not improve his health, because prior to the clean-up he had not been drinking from the public water supplies, but cleaning the drinking water does improve his well-being because he no longer has to spend the money and time required to buy bottled water. Analysts should calculate the risk reductions associated with a clean drinking water supply by accounting for the different behavioral responses individuals may have (i.e., based on the assumption that some people have avoided the risk by purchasing bottled water while others continue to use the public water supply). From this, it follows that the economic benefits of cleaning the drinking water supply would be *underestimated* by a procedure that multiplied the actual health effects avoided by a monetary value, because the improvement in well-being from no longer having to buy bottled water would not be counted.

Individual and Social Benefits of Improved Health

The conventional measure of the social benefit of a policy is the sum of individual benefits. Consequently, the theoretical basis of health effects valuation focuses on an individual's WTP for his own health. This approach ignores the possibility that the health of one person may affect the well-being of another. The journey from one person's health to another's well-being generally follows two paths: cost-shifting and altruism. Medical insurance and paid sick leave shift part of the monetary cost of illness from a sick individual to others. Costs borne by others will not affect the WTP of a self-interested person, and thus his WTP will not capture the full economic value of his health. As discussed in Chapter 3, valuation methods differ in how they account for shifted costs.

Apart from monetary costs of illness, a sense of altruism may lead one person to value the health of others. It is not easy to determine whether and how to account for "altruistic benefits," or WTP for the health of others, in a manner consistent with the individualistic ideas prominent in valuation theory. A relatively simple case occurs when members of a single household are concerned for one another. Since economists often treat the household, rather than the individual, as the basic

economic unit, measuring household WTP for the health of each of its members is quite consistent with common practice. For example, an economist might measure parents' WTP for their children's health. An additional third party value that may be included in a measure of household WTP is a child's value for parental health. In this case, the child's value may be motivated by both altruism and self-interest.

In addition, individuals within a household may also experience indirect welfare effects of an illness that are not centered on the sick individual. Shogren (1999) discusses the welfare effects that might accrue to healthy household members from having a sick family member. For example, if a sick caregiver must re-allocate time and household income to self-care and/or medical attention, a child might not benefit from the same level of care or opportunities provided by a healthy caregiver. Alternatively, if a caregiver has to care for a sick child, he or she might make decisions for the household that affect the quality of the family life. The medical expenses to care for a sick child might require that the caregiver hold a second job, thus making the caregiver less available to the family.

The situation is more complex if a person is concerned for others outside his own household. Recent theoretical research by Jones-Lee (1991, 1992) distinguishes between altruism focused exclusively on health, and more general concern for the overall well-being of others. If altruism extends only to health, then Jones-Lee's analysis supports adding altruistic benefits to the conventional measure of health benefits. Concern for the general welfare of others, however, implies concern for both the benefits and the costs they experience. Because benefit-cost analysis weighs costs against benefits for all members of society, if altruism is manifested as a more general concern for the overall well-being of others, there may be no reason to add separate measures of altruistic benefits.

Willingness to Pay and the Timing of Health Effects

Environmental contamination may cause immediate or delayed health effects, and the value of avoiding a given health effect likely depends on whether it occurs now or in the future. Clearly, the timing of financial commitments affects their value. If a person can borrow or save at an annual interest rate of ten percent, then a dollar borrowed or saved today is equivalent to $1.10 in a year. Put differently, $1.10 to be paid or received in a year has a *present value* of $1.00; the future value of $1.10 is *discounted* by the market interest rate to obtain the present value. Theoretical research predicts that people discount future risks of death similarly: the WTP today to reduce future risk of death equals the present discounted value of future WTP to reduce a contemporaneous risk of death (Cropper and Sussman 1990). The interest rate a person would use to discount a future risk of death need not equal the rate of interest on financial investments, however. Recent empirical research confirms that workers discount future risks of fatal injuries on the job; that is, they are willing to pay less to reduce a future risk than a present risk of equal magnitude (Viscusi and Moore 1989). The rates of interest at which workers discount future risks do not appear to diverge too greatly from market rates. In addition, a separate study that involved a survey of 3,000 members of the general public concludes that individuals value policies that yield health benefits in the present more highly than policies that yield the same benefits in the future (Cropper et al. 1992).

Health Effects Valuation under Risk

Environmental contamination may not cause an adverse health effect with certainty, but rather may increase the probability the effect occurs, its severity given that it occurs, or both. In thinking about this discussion it is important to distinguish risk from uncertainty. Risk is sometimes defined as exposure to a chance of injury or loss; the chance or probability inherent in risk is the source of uncertainty (Morgan and Henrion, 1990). The individuals who face health risks may be unsure about the level of environmental contamination, their opportunities for avoiding it, or many other factors affecting their welfare. Situations involving uncertainty present three additional complications for valuing health:

- First, the mathematical expectation of utility (i.e., probability of an outcome effect multiplied by its economic effect) may not adequately reflect individual motivations and behavior.

- Second, there may be wide divergence between scientific assessments of environmental health risks and the level of risk perceived by ordinary people. For example, in general people tend to overestimate the probability of small risks. The divergence between subjective risk perceptions and scientific estimates of risks complicates measurement of WTP using both direct and indirect methods to measure value from hypothetical and actual behavior.[4]

- Third, economic valuation under risk requires distinguishing between *ex ante* and *ex post* WTP. Individuals may take measures to reduce risk (i.e., an *ex ante* behavior); for example, undertaking measures to reduce the likelihood of contracting asthma. Alternatively, individuals may take measures to lessen the effect of the health condition (i.e., an *ex post* behavior); for example, using an inhaler to reduce asthma symptoms.

[4] This complex issue requires a much lengthier discussion than is possible to cover given the scope of this document. Useful general sources include Slovic (1987) and Fischhoff et al. (1978). In addition, Portney (1992) presents the issue relative to contamination perceptions in a town. The author gives an example of a town of residents who would be willing to pay to reduce the presence of a contaminant they feel is carcinogenic but risk assessors say is benign.

SUMMARY AND GUIDE TO FURTHER READING

This chapter has surveyed the economic theory which supports valuation of non-cancer and other human health effects. Key points include the following.

- Economic valuation can be a helpful tool to illustrate the benefits of public policies. For example, the estimates may be used in benefit-cost analysis, which evaluates the economic efficiency of a policy. A detailed analysis may show the distribution of costs and benefits by income, health status or other characteristic, but typically the focus is on total net benefit: the difference between benefits and costs summed over all affected individuals.

- Economists define benefits and costs as dollar equivalents of changes in well-being, and assume that each individual is the best judge of his or her own well-being. In economic theory, individual well-being depends on consumption of marketed goods and services, health, and other factors. Economists assume that people are willing to make tradeoffs among the factors which contribute to well-being; these tradeoffs imply that the value of health can be expressed in dollars.

- One measure of the economic value of improved health is the amount of money an individual would be willing to pay to obtain the health improvement. A second measure is the amount of money the individual would be willing to accept in compensation to forego a health improvement. Both WTP and WTA measure dollar equivalents of changes in economic well-being, but they are not identical. The difference between the two measures is likely to be small unless the change in health is large. In practice, most studies estimate WTP, because it often is less problematic to measure and quantify.

- WTP may vary over individuals according to differences in their desire for health, their income, or other personal characteristics. While policy analysis may require accounting for these differences, it is difficult to say, *a priori*, how these personal characteristics may affect WTP.

- The principle of revealed preference implies that market behavior reveals WTP for goods traded in markets.

- The revealed preference principle sometimes can be extended to measure WTP for nonmarket goods such as health. Stated preference methods, which rely on individuals' statements of value rather than actual behavior, also are used to value health. Other approaches often used by health economists, such as the cost-of-illness method, do not measure individual WTP for changes in well-being but instead measure the direct and indirect costs of poor health.

- When environmental quality improves, there are several health-related impacts on well-being. A complete valuation of health must account for all these, including changes in pain and suffering and defensive expenditures, which WTP/WTA is expected to reflect.

- If people incur costs to avoid health effects of environmental contamination, the value of reduced contamination will not be measured accurately by simply multiplying the number of actual health effects avoided by some monetary value -- the estimate must also include a measure of the avoided defensive expenditures.

- Some cases of health valuation may warrant consideration of altruistic benefits, or WTP for improvements in the health of others.

- It may be necessary to account for differences between costs borne by sick individuals and costs shifted to other people.

- Individuals may discount future health effects; that is, they may be willing to pay less today to avoid future, rather than present, health problems.

- Health effects valuation in the face of risk and uncertainty presents additional complications, including the difficulty of accounting for any divergences between actual risks and subjectively-perceived risks, and risk characteristics that may influence values such as immediacy of risk, amount of control over risk, or voluntariness.[5] In addition, it is important to distinguish between methods measuring *ex ante* or *ex post* values since nearly all health effects estimation involves individuals making decisions about risk under uncertainty.

Guide to Further Reading

There are many books on benefit-cost analysis, including Mishan (1988) and Hanley and Spash (1993). A widely cited text on valuation in environmental economics is Freeman (1993); his chapters on valuation under risk and on valuation of morbidity and mortality are particularly relevant. Johansson's books on environmental valuation (1987) and health valuation (1995) are also useful; see also Tolley et al. (1994). Viscusi (1993) provides a survey of valuation of morbidity and mortality risks, including empirical results; see also Cropper and Freeman (1989). A thorough explanation of the expected utility approach in the context of health valuation can be found in Desvousges, Johnson, Banzhaf (1994).

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[5] See Slovic, Fischhoff, and Lichtenstein (1979) for a more detailed discussion of the risk characteristics that may be influential to individual's values.

Researchers have used a wide range of approaches to value environmental health effects. Several available methods measure the theoretically preferred value of individual willingness to pay to avoid a health effect, while other methods that provide useful measures of the value of avoided morbidity are less well-grounded in economic theory. Methods also differ in the perspective from which valuation is measured (e.g., before or after the incidence of morbidity), and the degree to which they account for the major elements of willingness to pay outlined in Chapter 2.[6] This chapter reviews and evaluates each of the available primary methods for morbidity valuation.

The chapter consists of six major sections. The first section provides a brief overview of the key elements of available valuation methods. The second section presents some general issues that arise in the practice of measuring health effects and linking those measurements to valuation estimates. The next three sections present the theoretical basis, methodological concerns, and overall evaluation of each of the three methods most widely used for morbidity valuation: the cost-of-illness, contingent valuation, and averting behavior methods. The last section reviews five additional, less commonly employed methods for morbidity valuation. Note that this chapter focuses on primary methods of valuation. Chapter 4 discusses the practice of benefits transfer, a technique for transferring estimates from primary research to circumstances that may differ from that evaluated in the original research (e.g., to a new health effect or combination of effects).

OVERVIEW OF AVAILABLE METHODS

To develop an understanding of the methods available for estimating environmental morbidity values, it is first important to understand the various components of these values. The loss of social welfare associated with the incidence of one case of a health effect is comprised of four elements: the cost of treatment, the loss of output associated with the reduction in work activity in the labor market, the loss of value of non-market activities, and individual's pain and suffering. When the individual who suffers the disease bears the whole cost burden, the value of environmental morbidity

[6] Several methods also measure the theoretically preferred value of individual willingness to accept (WTA). As noted in Chapter 2, we focus our discussion on WTP, which is less problematic to measure and quantify, and most commonly found in the economics literature.

is the individual's maximum WTP to avoid the disease, equal to the monetized value of the four components. In the absence of sick pay, medical insurance, and/or charity, the value of environmental morbidity is the sum of the WTP to avoid the costs borne by the individual and costs borne third parties (e.g., insurance companies).

Three methods are used most often to value environmental morbidity. The first is the cost-of-illness method that directly measures values using observed behavior. This method is most prevalent in the medical economics literature. The cost-of-illness method does not measure willingness-to-pay compensation (WTP) for reduced morbidity, but the costs incurred as a result of illness, including direct costs such as medical expenses and indirect costs such as foregone earnings. Two other methods are more prevalent in the environmental economics literature. The contingent valuation method takes the stated preference approach described in Chapter 2 and measures respondents WTP for hypothetical health improvements. The averting behavior method takes the revealed preference approach and estimates WTP from observed behavioral responses to real situations. This method infers WTP from the cost and effectiveness of actions taken to defend against illness. Several other methods have been used less frequently to value environmental morbidity, including hedonic methods (a revealed preference approach), and several other methods that, similar to the cost-of-illness method, do not measure WTP: risk-risk tradeoffs and health-state indexes.[7] In addition, studies of jury awards are a potentially useful source of data.

An important feature of each method is whether it measures WTP for reduced incidence of illness or reduced risk of illness. Theoretically, approaches can be categorized as revealed preference and stated preference methods measuring values using actual or hypothetical behavior.[8] In situations involving risk of illness, rather than the certainty of illness, the various methods differ according to whether value measures are obtained from an *ex ante* or an *ex post* perspective. Finally, valuation methods can be distinguished in terms of how they account for the various economic effects of illness, such as medical expenses and pain and suffering. Exhibit 3-1 summarizes a number of distinctions among the methods based on these major distinguishing characteristics.

[7] Benefits transfer is an alternative to using one of the primary research methods to value health effects. This technique is described in detail in Chapter 4.

[8] As mentioned in Chapter 2, each method can be further classified as being direct or indirect (Mitchell and Carson 1989; Freeman 1993); however, this additional classification is not essential to the current discussion.

Exhibit 3-1

SUMMARY OF METHODS FOR MORBIDITY VALUATION

	Cost-of-illness	**Contingent Valuation**	**Averting Behavior**	**Hedonic Property**	**Hedonic Wage**	**Risk-Risk Tradeoff**	**Health State Index**	**Jury Award**[7]
Does the method estimate individual WTP?	No	Yes, Stated Preference	Yes, Revealed Preference	Yes, Revealed Preference	Yes, Revealed Preference	No	No	No
Is the perspective *ex ante* or *ex post*?	*Ex Post*	*Ex Ante or Ex Post*	*Ex Ante*	*Ex Ante*	*Ex Ante*	*Ex Ante*	*Ex Ante*	*Ex Post*
Does the method account for the following components of the value of avoided morbidity?								
Private Direct Cost	**T**	**T**	**T**	**T**	**T**	**T**	Rarely	**T**
Lost Earnings	**T**	**T**	**T**	**T**	**T**	**T**	**T**	**T**
Lost Nonmarket Work	Usually	**T**	**T**	**T**	**T**	**T**	**T**	**T**
Lost Leisure		**T**	**T**	**T**	**T**	**T**	**T**	**T**
Third-Party Costs	**T**							
Averting Costs		**T**	**T**	**T**	**T**	**T**		
Pain and Suffering		**T**	**T**	**T**	**T**	**T**	**T**	**T**
Altruism to Household Members		Sometimes	Sometimes	**T**	Sometimes	Sometimes	Sometimes	**T**
Altruism Toward Others		Sometimes						

[7] While a potentially useful source of data, jury awards have not been fully evaluated by economists as to their usefulness for valuation of health effects.

Among the three most commonly applied methods, each approach has its strengths and weaknesses, summarized in Exhibit 3-2 below. The cost-of-illness method is the most straightforward to implement and to explain to policy-makers. But it does not measure WTP and neglects the value of avoided pain and suffering. The contingent valuation method is the most flexible: in principle, surveys could be designed to value any illness. The method also appears to be the only way to measure dollar values for altruism toward people outside the immediate household. The hypothetical nature of contingent valuation, however, makes it quite controversial and introduces numerous sources of potential inaccuracy and imprecision. The averting behavior method is the only one of the three providing WTP estimates based on actual behavior, but it is difficult to measure the costs and health benefits of averting action.

Exhibit 3-2

EVALUATION OF THREE MOST COMMON METHODS FOR MORBIDITY VALUATION

Method	**Approach**	**Advantages**	**Disadvantages**
Cost-of-illness	Measures direct costs such as medical expenses and indirect costs such as foregone earnings.	Relative ease of application and explanation. Does not require household surveys. May be lower bound on WTP.	Does not measure WTP. Ignores important components of WTP such as pain and suffering.
Contingent Valuation	Surveys elicit WTP for hypothetical changes in health effects.	Flexibility allows application to variety of health effects. If designed properly, allows measurement of complete WTP, including altruism.	Hypothetical nature introduces many sources of potential inaccuracy and imprecision. Method is controversial and often expensive.
Averting Behavior	Infer WTP from costs and effectiveness of actions taken to defend against illness.	WTP estimates based on actual behavior.	Difficult to isolate value of health from other benefits of averting action. Difficult to measure individual perceptions of cost and effectiveness of averting action.

In summary, the economic value of health is a sometimes elusive concept that is difficult to quantify precisely. For that reason, it is useful to use more than one technique to estimate the value where possible. In addition, while any of the methods discussed in this chapter may provide a valuation estimate, it is important to critically evaluate the plausibility of an estimate for its reasonableness in a particular application. For example, if the estimated value of avoiding an acute, reversible effect exceeds other reasonable estimated values for avoiding long-term, chronic effects, then the acute effect value is probably too large and will be difficult to defend. On the other hand, willingness-to-pay values that are less than cost-of-illness values for the same effect are probably too low, particularly if the effect clearly results in some pain or other impairment of activity.

Although the scope of this document is limited to the valuation of morbidity outcomes, environmental contamination can increase both the risk of illness and the risk of premature death. Most analysts familiar with environmental health effects valuation would have more confidence in existing estimates of the "value of a statistical life" (i.e., the value of reducing mortality risk) than in existing values of reduced morbidity.[9] One reason for this discrepancy is simply that less research effort has been devoted to estimating WTP for morbidity avoidance. Another is that economists have exploited a close link between mortality risk and market behavior in examining tradeoffs between wages and job risk. There does not appear to be as close of a link between WTP for morbidity avoidance and market behavior.

HEALTH EFFECTS MEASUREMENT AND VALUATION

EPA has developed Agency-wide Guidelines for conducting economic analyses to reflect current understanding of environmental policy making and economic analysis. These Guidelines provide both a general framework for conducting an economic analysis (see Chapter 5, USEPA 2000), and a process for conducting the benefits analysis portion of the analysis (see Chapter 7, USEPA 2000). While the Guidelines provide discussion of many general issues that may arise in the course of conducting such an analysis, several practical issues specific to non-cancer health effects valuation are discussed in greater detail in this section.

[9] The value of a statistical life (VSL) measures the value of a given reduction in risk and an individual's willingness to pay to reduce that risk. The result of applying this method is not the value of an identifiable life, but instead the value of reducing fatal risks in a population. The VSL is calculated by measuring the willingness to pay for a small change in the risk of death among a population. For example, if an individual is willing to pay $100 to reduce his or her own annual risk of death by 1 in 10,000, then the value per statistical life is the willingness to pay for the risk reduction divided by that risk, or $1 million ($100 divided by 1/10,000). This method does not account for differences in value estimates that may be associated with varying population characteristics (e.g., age, income) and health states (e.g., mortality risk levels).

Differences in the kind and degree of morbidity can influence both the value of reduced illness and the choice of a valuation method. Analysts distinguish between short-term (acute) effects and longer-lasting or recurring chronic effects. Acute illness such as diarrhea or respiratory infections may vary in frequency and duration, while length of chronic impairment may vary because of differences in life expectancy or age at onset. Common sense and economic theory predict that a person will be willing to pay less to avoid a mild, short-term symptom that is easily relieved than a more severe, long-lasting impairment with no cure. Besides differences in duration and frequency, health effects may also differ in the following ways:

- **!** severity;
- **!** whether they are immediate or delayed (i.e,. the latency period);
- **!** how easily they are relieved or cured;
- **!** the characteristics of people typically affected (such as their age, income, and health status); and
- **!** the context of the health effect (e.g., whether the health effects have catastrophic versus more commonly encountered consequences; whether the risks are imposed versus borne voluntarily).[10]

Accounting for these differences in kind and degree of morbidity promotes accuracy in the estimation of benefits.[11]

While it may seem obvious that the value of avoiding a health effect depends on how adverse a person perceives the effect to be, morbidity often is measured in ways that bear little relation to individual perceptions of adversity. Freeman (1993) stresses that biomedical research often focuses on effects that individuals might not perceive as adverse, or even notice at all, such as reductions in forced expiratory volume in response to high ozone concentrations. This type of effect may have no economic value, because a person may be willing to pay to avoid an effect only if he perceives that it may reduce his well-being now or in the future. An example of this case may be found in the Appendix C discussion of the economic valuation of lung function. In this case study, because lung function decrements are not noticeable, it is difficult to describe their effect on well-being.

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[10] Zeckhauser (1996) provides a more detailed discussion of the psychological aspects of health effects that may influence individuals WTP.

[11] Chapter 5 includes discussion of the strategies for adjusting values to better match the definition of effects used in economic and health science studies.

Health effects measured by population surveys are by necessity closely linked to individual perceptions but often introduce a separate problem by confounding illness and behavioral responses to illness. Examples include "restricted activity days," when a person misses some of his normal activities; "work loss days," when a person does not work for pay due to illness or impairment; and "bed disability days," which indicate confinement to bed for most of the day. These measures reflect the presence of illness as well as a person's decision about how to react to illness. Research indicates that these decisions are related to economic factors such as employment, sick pay and nonlabor income, casting doubt on their validity as measures of illness alone (Freeman, 1993).

Besides the issue of matching morbidity measures to health effects perceived and valued by people, there is the problem of aggregating morbidity measures consistently with the likely effects of an environmental policy. Aggregate morbidity generally is measured either by *prevalence*, the total number of people having a disease, or by *incidence*, the number of people newly contracting the disease. Both prevalence and incidence also can be measured as *rates* (proportions of a relevant population). Hartunian et al. (1981) point out that prevalence-based measures are more appropriate for analyzing policies to relieve existing illness, while incidence-based measures are relevant for prevention. Chestnut and Violette (1984) argue that both types of measures are potentially useful because environmental policy may affect either prevalence or incidence, depending on the health effect being valued. For example, CO exposures may aggravate angina symptoms for people who already have heart disease. In this case, it is important to know how may people in the exposed population have the disease. In some cases there may be incidence-type outcomes that are linked to chronic disease. For example, pollution might be linked to emergency room visits for asthma, an incidence measure in the already-asthmatic population. Policy analysis needs to appropriately match the value to the health effect of the policy.

From a valuation standpoint, morbidity is an intermediate link between environmental change and economic value. There is a clear distinction in disciplines between estimating dose-response relationships for environmental exposures and the resulting health effects, and estimating the willingness to pay of affected individuals for avoiding those health effects. This distinction suggests two general approaches to health effects measurement for valuation (Dickie et al. 1987). The more common approach is to value health effects, while leaving assessment of the pollution-morbidity link to health scientists.

An alternate approach is to incorporate the environment-health relationship in a more comprehensive model of economic behavior. For example, researchers have attempted to discern correlations between pollution levels and the sum of medical and defensive costs incurred for potentially pollution-induced health effects. The result is a "reduced form" relationship between environmental and economic welfare indicators. This approach avoids the problem of poor linkage between measured health effects and those that individuals perceive and value, and has the added advantage of allowing better control for the costs and health effects of defensive behavior. The obvious disadvantages of this approach are that economists lack the specialized expertise which health scientists bring to morbidity assessment, and that the estimates are often based on correlations and may provide little insight into the causal links between pollution and health effects.

COST-OF-ILLNESS

The cost-of-illness method of morbidity valuation is closely related to the human capital approach to mortality valuation, which focuses on the present discounted value of earnings lost from premature death. The human capital approach predates Adam Smith (Landefeld and Seskin 1982), is used in damage assessments for wrongful death cases in Federal jurisdictions, the District of Columbia, and 39 states (Link 1992), and has been used frequently in benefit-cost analysis. However, under most conditions, the cost-of-illness method underestimates WTP because it excludes many components of value, including pain and suffering, defensive expenditures, lost leisure time, and altruistic benefits.

The cost-of-illness method also has been widely used for damage assessment and benefit-cost analysis. The method measures direct and indirect costs of morbidity. Direct costs include the value of goods and services used to diagnose, treat, rehabilitate and accommodate ill or impaired individuals. Indirect costs reflect the value of foregone productivity, most often measured as foregone earnings. The total cost of illness is the sum of direct and indirect costs. Standard references on cost-of-illness methodology include Rice (1966); Cooper and Rice (1976); Rice, Hodgson, and Kopstein (1985); Hartunian et al. (1981); and Hu and Sandifer (1981). The relative size of direct and indirect costs may vary by impairment as well as by estimation approach. Indirect costs account for about 60 percent of the total cost of illness in the United States, according to Cooper and Rice (1976), counting losses from both morbidity and premature mortality. The share of total costs attributable to morbidity-induced indirect costs alone is about 22 percent. For the major impairments studied by Hartunian et al. (1981) -- cancer, coronary heart disease, stroke and motor vehicle injuries -- indirect costs account for about 70 percent of the total, again counting both morbidity and mortality losses.

Link to Health Valuation Theory

The theoretical basis of the cost-of-illness method is quite limited. The major assumptions are that (1) direct costs of morbidity reflect the economic value of goods and services used to treat illness, and (2) a person's earnings reflect the economic value of his production. Some economists doubt whether these assumptions hold, owing to distortions in medical and labor markets, but the assumptions are broadly consistent with the economic view of the world.

The main theoretical issue concerning the cost-of-illness approach is that the method measures *ex post* costs rather than WTP. A number of researchers have examined the theoretical relationship between WTP and cost-of-illness or human capital measures of value. Studies of mortality valuation have concluded that foregone earnings from premature death are a lower bound on WTP-based values of statistical lives (Conley 1976; Arthur 1981). The comparison of the cost-of-illness and WTP-based morbidity values is not quite as straightforward, but most authors agree that under plausible conditions an individual's cost of illness is a lower bound on WTP (Harrington and Portney 1987; Berger et al. 1987).

The main reason the cost of illness is less than WTP is the failure to account for all the welfare effects of illness that are reflected in WTP. As shown in Exhibit 3-1, the cost-of-illness method ignores pain and suffering, defensive expenditures, lost leisure time, and any potential altruistic benefits. Unless the omitted items make up a constant proportion of WTP for all illnesses, the amount of divergence between individual costs of illness and WTP will vary by disease. There presently is little empirical evidence on the size of this divergence, but using and estimated adjustment factor to account for this divergence has been applied in at least one EPA analysis of the valuation of health effects (Chestnut 1995).

The fact that an individual's cost of illness falls short of his WTP, however, does not imply that the cost of illness, as usually computed, will be less than WTP. As discussed in Chapter 2, large portions of the costs of illness are shifted from the impaired individual to others, through insurance and sick pay. These costs will not be reflected in individual WTP, but cost-of-illness measures typically count third party costs as well as individual costs.

A related theoretical problem affecting the cost-of-illness method is that, especially for minor impairments, individuals exercise considerable choice over the amount of medical care and work loss they experience. The cost-of-illness method in effect measures the costs of these choices, rather than the dollar equivalent of the loss in well-being caused by the illness itself.

Methodological Problems

The most serious methodological problems affecting the cost-of-illness approach concern the measurement of the value of lost production. Key difficulties include: (1) accounting for the full impact of chronic illness on earnings; (2) choosing an appropriate wage rate to apply to work loss time, and (3) valuing time spent in unpaid work.

Morbidity can affect earnings in three distinct ways. A chronic or acute illness can cause a person to miss regularly-scheduled work time. A chronic illness also may limit a person's job options, causing him to work in a job with fewer regularly scheduled hours. The extreme case of this second effect is the complete withdrawal from the workforce of a totally disabled person. Finally, any restrictions on job opportunities caused by chronic impairment may result in a lower rate of pay per hour worked.

These distinctions are important because some measures of work loss count only hours missed from a person's usual work schedule, evaluated at the hourly wage. While this would be appropriate for most cases of acute illness, it would not capture longer-term effects of chronic illness on usual hours or wages.

The choice of a wage rate to apply to time lost from work raises difficult issues. Wages are closely linked to education and age or experience, as well as to gender and other demographic characteristics. The incidence rates of many health impairments also vary markedly by some of the same characteristics. If the wage rates applied to lost work time do not match the demographic

distribution of illness, indirect cost estimates will be inaccurate indicators of actual earnings loss. For example, more educated persons earn higher wages and are healthier, suffering fewer days of work loss than less-educated, lower-paid workers. Most cost-of-illness studies do not control for the effect of schooling on wages and work loss, leading to an overestimate of foregone earnings. Many studies do, however, account for age and gender differences when estimating indirect costs.

While a careful matching of wage rates to demographic characteristics promotes accuracy in estimating lost earnings, it has the implication that the cost of illness varies with personal characteristics, in a pattern that mirrors the distribution of wages. Some analysts prefer to avoid this outcome by making few if any adjustments for wage differences among demographic groups.

More practical problems arise for measuring foregone productivity of persons not employed in paid work, such as students, retired persons and homemakers, because no wage rate is observed for these individuals. Some studies do not value the time of these individuals. A more common approach is to apply the same wage rate used for comparable, employed persons. Two additional approaches have been proposed for valuing household work. The *market cost* approach measures the cost of hiring out all of the services typically performed by a homemaker, while the *opportunity cost* approach values a homemaker's time at the wage rate that could be earned in paid work by an individual with similar schooling and experience. The opportunity cost approach is conceptually more appealing to economists but is more difficult to implement. Most cost-of-illness studies in medical economics apply the market cost approach.

It is also important to recognize that, because treatments for illnesses change over time, the cost of illness is a dynamic concept. Older cost of illness studies may not account for changes in medical technology that might alter the cost or effectiveness of treatment. If older studies must be used, this factor needs to be explicitly considered.

Data Collection and Analysis

Costs of illness are measured on either a prevalence or an incidence basis. Prevalence-based measures assign costs of all existing cases of an illness to the year in which the costs are incurred. Incidence-based measures assign the present value of all costs of illness -- from onset to recovery or death -- to the year of onset.

There is little difference between prevalence-based and incidence-based costs for short-term illnesses, but the difference increases with duration. Usually, prevalence costs exceed incidence costs unless incidence is rising rapidly, and the difference is larger for indirect than for direct costs (Hartunian et al. 1981).

Besides differences in the magnitude of cost measures, prevalence and incidence-based approaches have different data requirements and different degrees of aggregation. Prevalence costs are often computed from aggregate data, while incidence costs are built up from costs of individual

cases. Prevalence costs often are estimated for broad disease categories such as "diseases of the respiratory system," while incidence costs focus on more narrowly defined impairments such as asthma. Prevalence-based morbidity costs are based on prices and wages observed in a given year, while incidence costs require forecasts of future medical costs and wages. Forecasting can be difficult; few analysts anticipated the rapid growth in medical costs and the slowing in wage growth that occurred during the past two decades.

Prevalence Approach

Prevalence-based applications of the cost-of-illness method typically follow some variation of the methodology set out by Rice (1966). Total US health care expenditures are divided into several categories such as hospital care, services of physicians and other health care professionals, nursing home care, drugs and medical supplies, and nonpersonal health care services. Expenditures in each category are allocated to specific diseases, and the direct cost of a disease is found by summing over expenditure categories. Expenditure data are available from the Health Care Financing Agency; one source of data used to allocate costs to diseases is the Hospital Discharge Survey.

Tolley et al. (1994) review a number of potential sources of inaccuracy in the methods used to assign costs to expenditure categories and to specific diseases. Despite these problems, a key advantage of this approach is that the costs of diverse diseases are estimated by a single methodology, making cost comparisons simpler. Also, the total direct cost of illness in the US is allocated across diseases using a consistent methodology (Cooper and Rice 1976).

Prevalence-based measures of indirect costs typically apply a fixed dollar value to the estimated duration of restricted activity. For example, Cooper and Rice apply mean earnings by age and gender to work loss days for employed individuals, and use a market-cost approach to value homemakers' bed disability days. This approach would not account for earnings losses caused by restrictions on employment opportunities of the chronically ill.[12] Data on work loss and bed disability days are taken from the Health Interview Survey of the National Center for Health Statistics, while earnings information is available from a number of sources, including the Labor Department's Current Population Survey.

[12] It is also important to note that while morbidity can reduce life expectancy in some cases, estimating the costs associated with premature mortality should be handled separately.

Incidence Approach

Incidence-based cost of illness measures often follow a methodology similar to that of Hartunian et al. (1981). This approach involves estimating the direct and indirect costs for each year of illness, weighted by the probability an individual would survive each year, and computing the present discounted value of this stream of costs.

Estimates of direct costs sometimes use data on actual costs incurred by patients; the National Medical Expenditure Survey is the major source of these data. But surprisingly little data exists on the costs of treating specific illnesses over time, even for major impairments. As a result, analysts often must estimate costs based on literature reviews or input from medical experts. This approach, used by Hartunian et al. (1981) and USEPA (2000b), involves estimating the costs of each component of treatment, and multiplying by the probability a patient will receive the treatment.

Hartunian et al. estimate indirect costs of long-term illnesses among the employed using estimates of the duration of impairment and the earnings differential attributable to disability. In principle, this approach will include all sources of lost earnings among impaired, employed individuals, including shorter work schedules and lower wages. However, data on earnings losses for chronic impairments are quite sparse. Hartunian et al. report studies of specific diseases, and some economists have estimated earnings losses among disabled men (Johnson and Lambrinos 1985; Haveman and Wolfe 1990). For short-term impairments, Hartunian et al. apply daily wages to estimates of restricted activity days. Lost housekeeping services are valued using a market cost approach.

Other Cost of Illness Techniques

The methodologies of Rice (1966) and Hartunian et al. (1981) represent comprehensive approaches to computing costs of illness. Smaller-scale applications of the basic methodology also have been employed. For example, the costs of specific treatment events, such as hospital admissions or doctors visits have been computed (Seskin 1979; Dickie and Gerking 1991). Also, household surveys of people with specific conditions (Chestnut et al. 1988), or of the general population, have been used to estimate costs of a few illnesses.

Evaluation

The cost-of-illness method has a number of advantages over WTP approaches. Cost-of-illness methods have been applied for many years and are well-developed, and measures of direct and indirect costs are easily explained without reference to complex economic theory. While the method does not attempt to value less tangible components of WTP such as pain and suffering, individual cost of illness is, under plausible conditions, a lower bound on WTP. The method often

accounts for costs shifted from impaired persons to others, and incidence-based studies are typically more transparent in calculating a present value of future costs than WTP studies. Finally, necessary data often can be obtained without expensive household surveys.

At the same time, the cost-of-illness method has several shortcomings which lead many economists to reject the approach as inadequate for benefit estimation. The most serious problem is that the method measures *ex post* costs of illness, rather than WTP. While individual costs of illness may be a lower bound on WTP, there is little empirical evidence on the size of the difference between illness costs and WTP, and no reason to expect the difference to be similar for different health effects. By not accounting for the value of avoiding pain and suffering, the method could be misleading about the relative damages of different diseases. Also, measures of the value of lost time are often incomplete or imprecise, even among the employed, but particularly for homemakers, children and retired persons. Finally, costs of illness are often shifted to third parties such as insurance companies. This "cost-shifting" can distort the costs of illness.

CONTINGENT VALUATION

Stated preference methods directly elicit individuals' valuations of a hypothetical commodity, usually using survey research methods. The method was first proposed a half century ago by Ciriacy-Wantrup (1947) and was first applied years later by Davis (1963). Early work often focused on valuing recreation benefits and air quality changes, but assessments of a whole range of values relevant to public policy, including values for avoided morbidity, currently use the method. One type of stated preference method, contingent valuation, has been used to value avoidance of respiratory and other symptoms of air pollution exposure, avoidance of asthma-related illness, reductions in skin cancer risk, and reductions in risk of chronic bronchitis.

Contingent valuation is quite controversial, especially when applied to estimate passive-use values (the value of simply knowing that a resource exists, as opposed to the value of actively using it). But the method has been accepted by the Federal government for use in estimating certain types of benefits, including values of recreation areas and oil spills. A standard reference on contingent valuation is Mitchell and Carson (1989). Cummings, Brookshire and Schulze (1986) and Bjornstad and Kahn (1996) also provide a comprehensive review of the method. Diamond and Hausman (1994) give a decidedly less sympathetic treatment of the method. The potential controversy in using values from survey methods (such as contingent valuation) makes it particularly important to seek plausibility checks for these estimates.

Link to Valuation Theory

The contingent valuation method measures WTP (or WTA) and so is consistent with the economic theory of health valuation. If respondents understand the commodity to be valued and answer valuation questions truthfully, the method yields estimates of individual WTP. Valuation

questions can ask for household WTP or even for the WTP an individual may have for others outside of the household (i.e., altruism). Contingent valuation appears to be the only method capable of measuring these altruistic benefits. As shown in Exhibit 3-1, contingent valuation potentially captures the full set of effects of illness on individual well-being. In situations involving risks, the method can elicit *ex ante* WTP values, though many contingent valuation studies have estimated *ex post* WTP instead.

Methodological Problems

Although the contingent valuation method sets out to find the theoretically correct measure of economic benefit, many economists doubt that the measures obtained actually correspond to individuals' true WTP (see Diamond and Hausman 1994). The main objections to contingent valuation center on the hypothetical nature of the transaction: because a respondent does not have to pay the amount he states, he may have little incentive to provide accurate answers. He may not think carefully enough about the question to give answers reflecting his preferences or opportunities, or may respond strategically in an effort to influence the outcome of the survey.

Most economists agree that strategic responses to contingent valuation questions are not a serious problem, but some economists argue that the responses do not reflect stable preferences with the generally held properties assumed by economists. For example, researchers have expressed concern that contingent valuation responses are "insensitive to scope" and are unduly sensitive to the sequencing of alternatives to be valued. Insensitivity to scope, for example, would occur if WTP to avoid five symptoms was no larger than the WTP to avoid one symptom. Sequencing problems would imply that the values of individual symptom avoidance were unduly sensitive to the order in which the symptoms were presented to respondents for valuation. In addition, researchers have noted that contingent valuation responses may include values for other related things, sometimes referred to as "embedded" values. For example, when individuals are asked their WTP to reduce the visual aesthetic effects of air pollution, there is some evidence that some respondents include value for reducing health effects of air pollution in their answers. One reason why this occurs is because respondents think both will be achieved by reducing air pollution.

A second criticism of contingent valuation involves the unfamiliarity of the valuation task. Respondents may not understand the commodity or the valuation task the way researchers intend, and respondents almost certainly lack experience paying for a commodity not normally traded in markets. For example, respondents may not have directly purchased relief from the specific illness being evaluated or purchased reductions in that health risk. This criticism is particularly apt for efforts to value health risks, especially for low probability illnesses, because of the apparent difficulties people have in understanding risk information.

Critics have proposed other reasons why contingent valuation responses may not reflect WTP. Respondents may express a general attitude about a commodity on a dollar scale only because that is the scale the survey offers; they may report a high WTP to obtain a "warm glow" from contributing to a worthy project such as environmental improvement; or they may state a WTP because they assume that by virtue of the survey, the commodity has some value. Furthermore, the amount an individual states he is WTP may be influenced by the survey's payment vehicle. For example, suppose two surveys are designed to measure a value for the same good, but one uses a hypothetical tax as the payment vehicle and the other a referendum bid. Respondents may provide different values depending on the payment vehicle (e.g., respondents may object to the tax increase but not the referendum bid). In addition, differences in respondents baseline health are not always accounted for. Some respondents may have undertaken averting behavior which affects their WTP to avoid health problems.

Proponents of contingent valuation argue that poorly designed studies may suffer from any number of problems, but well designed and executed studies provide reliable information about individual WTP. These economists believe that contingent valuation responses reflect stable preferences, in accordance with economic theory, and often correspond closely to value measures inferred from actual behavior (Hanemann 1994). Practitioners generally try to eliminate, minimize, or test for known sources of bias or imprecision through careful survey design and data analysis.

Data Collection and Analysis

The contingent valuation method generally is implemented using a survey that collects relevant information about respondents' personal characteristics, attitudes concerning the commodity to be valued, and valuation information. The three key components of the method are: (1) a description of the commodity to be valued, such as the symptoms to be avoided or the health risk to be reduced; (2) a method of hypothetically paying for the commodity, such as higher utility bills, taxes, or prices; (3) a method of eliciting respondents' WTP for the commodity.

The two major techniques used to elicit valuations are the "open-ended" and "referendum" approaches. Two other methods are used less frequently: "contingent ranking" and "contingent behavior" (see Freeman 1993). Early research typically used open-ended questions of the form "What is the most you would be willing to pay for...?" Respondents might circle a dollar figure from a set of values on a "payment card," or they might simply state a value. A variant of this approach is the "bidding game" in which the interviewer suggests an initial dollar amount. If the respondent indicates he is willing to pay that amount, successively higher values are suggested until reaching a value the respondent would be unwilling to pay. If the respondent was unwilling to pay the original amount, lower values are suggested until reaching one the respondent would be willing to pay.

In principle, the open-ended approach directly elicits each respondent's maximum WTP. But respondents appear to find it quite difficult to answer this type of question, as evidenced by high rates of nonresponse, zero responses, or implausibly high values. Presumably, these problems arise because people rarely have to decide the most they would pay for something; most purchases involve a simpler decision of whether or not to buy an item at a posted price.

Since the mid-1980s, many researchers have favored the referendum approach to contingent valuation, in which respondents are asked whether or not they would be willing to pay an amount specified by the researcher. Different amounts are randomly assigned to different respondents. This procedure places the respondent in a situation similar to normal purchase decisions, or to voting in a referendum on a public policy with a specified cost. The disadvantage of the method is that it reveals less information per response: a "yes" answer reveals a lower bound, and a "no", an upper bound, to WTP. More information can be obtained by asking a follow-up valuation question, or by econometric analysis of the responses.[13]

One valuation method of the stated preference approach that has recently been applied to environmental economics is conjoint analysis. Conjoint analysis is related to contingent valuation in that it relies on the respondent making a choice regarding a hypothetical situation. However, with the conjoint method individuals are presented with several suites of options having various amenities and prices. As discussed in Smith (1997), the method elicits estimates of marginal WTP based on a respondent ranking, rating, or constructing equivalent sets of alternatives. For example, respondents may be asked to rank or rate their preference for living in one of two areas where at each location there is a risk of incurring an adverse health effect (e.g., kidney disease at one location versus lung disease at another). Alternatively, respondents may be asked to indicate what change in the level of risk associated one alternative would make them indifferent between two competing alternatives (e.g., how would the risks of incurring kidney disease from exposure in one location need to change to make the respondent indifferent between the two locations).

One advantage of conjoint methods in health valuation is the ability to construct scenarios that provide information on the valuation of disease attributes, or symptoms. The application of conjoint analysis methods to health symptom research includes a recent effort funded by Environment Canada (Johnson et al. 1997), for example. By identifying individual preferences for different alternatives, the analyst can assess the marginal value for a particular “characteristic” or, in this case, symptom.

This technique is not without its disadvantages, however, as noted in Smith (1997). There are only a few current empirical studies that use the technique for non-market valuation (the technique originated from marketing research); the lack of experiences with the technique makes it difficult to compare its results with those from the contingent valuation method. In addition, the

[13] A variety of literature exists that provides a more thorough discussion of the survey issues associated with the contingent valuation approach, including Mitchell and Carson (1989) and a 1992 expert panel of economists review of the contingent valuation method (USDOC 1992).

limited amount of work in this area makes it difficult to resolve issues related to estimation techniques and theoretical consistency. Smith (1997) provides a more detailed discussion of these technical issues.

Regardless of the value elicitation procedure, many researchers prefer in-person interviews to telephone or mail surveys. In-person interviews allow researchers to maintain greater control over the information presented to respondents and permit the use of more complex survey designs with follow-up questions that depend on answers given previously. Lower nonresponse rates usually occur, but in-person surveys are more costly may be susceptible to "interviewer effects" in which respondents answers are influenced by the person collecting the data.

Issues of sampling and survey design are critical to implementation of the contingent valuation method. Most researchers naturally prefer some form of random sampling from the relevant population, with a sample size large enough to support precise estimation of values and detailed analysis of responses from subgroups of interest. Nonetheless, some contingent valuation studies have employed small, convenience samples. Nonresponse, both to the survey itself and to the valuation question, is a particularly important issue. For example, people who return a mail survey may be the people most concerned about a particular health or environmental problem, leading to biased inferences about the population at large.

Contingent valuation researchers stress that respondents must understand the commodity to be valued, believe that the level of the commodity could be changed as described in the survey, and view the method of making payment as plausible. When contingent valuation is used to assess WTP for light symptoms, most respondents presumably have a clear understanding of the commodity. Respondents would be less familiar with rare diseases, and might require much information about the nature of the disease before expressing a meaningful value for avoiding it. Contingent valuation surveys aiming to value risk reductions often place great emphasis on explaining risks to respondents or eliciting respondents' own risk perceptions. Researchers, though must be careful to avoid using survey instruments that influence a respondent's thought process in ways that distort WTP. Practitioners recommend extensive use of focus groups and pre-tests of survey design. The goals of focus groups and pretesting often include insuring that respondents interpret contingent valuation questions as intended.

Methods of data analysis vary with the form of the valuation question and other factors. Researchers generally report mean or median WTP, and often correlate responses with individual characteristics such as income. Frequently, additional analysis is used to test whether responses accord with predictions of economic theory, or whether they suffer from any known sources of bias.

Evaluation

The contingent valuation method estimates WTP, accounts for all effects of illness on individual well-being, and appears to be the only method capable of eliciting dollar values for altruism towards persons outside the household.[14] Unlike the averting behavior or cost-of-illness methods, it can be applied to value risks of illness lacking any connection to market transactions. The method is quite controversial, however, and potentially susceptible to numerous sources of bias and inaccuracy. In contrast to the cost-of-illness method, it requires costly data collection methods.

AVERTING BEHAVIOR METHOD

The averting behavior method is a revealed preference approach used to infer WTP from actions taken to prevent or to mitigate adverse health outcomes of pollution. Averting behavior can take several forms, including (1) the purchase of a durable good, such as an air purifier or water purifier; (2) the purchase of a nondurable good such as bottled water or a service such as medical care; or (3) a change in daily activities, such as staying indoors. Thus, averting actions may be intended to avoid exposure to environmental contamination, or to mitigate the health effects of exposure.

The theory linking averting behavior to WTP originated in the 1970s and early 1980s (Hori 1975; Courant and Porter 1981), with continued development in recent years (Bresnahan and Dickie 1995). The first empirical applications concerned cleaning activities to reduce soiling damages from air pollution, but the focus quickly turned to health damages. The most frequent empirical application has involved actions taken to avoid contaminated water supplies (Abdalla, Roach and Epp 1992; Harrington, Krupnick and Spofford 1989). Other applications have investigated individuals' efforts to avoid potential hazardous waste contamination (Smith and Desvousges 1985), to reduce radon concentrations in the home (Akerman, Johnson and Bergman, 1991; Doyle et al. 1991; Smith, Desvousges and Payne 1995), or to reduce asthma or angina symptoms (Chestnut et al. 1988). Researchers also have examined use of medical care to offset effects of air pollution exposure (Cropper 1981; Gerking and Stanley 1986; Dickie and Gerking 1991b). This offsetting behavior method incorporates the WTP aspect, because individuals are able to choose medical care to most effectively alleviate the illness. In addition, researchers have investigated the use of air conditioners to reduce exposure (Dickie and Gerking 1991a), and reductions in time spent outdoors on days of poor air quality (Bresnahan, Dickie, and Gerking 1997).

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[14] Although we have focused our discussion on WTP, WTA measures are usually more consistent with policy concerns for reasons mentioned in the previous section. However, WTA measures are often more difficult to measure because the value an individual states is not bound by his income. These measures may, therefore, be biased upward. In addition, WTA questions often result in higher refusal rages than WTP questions (i.e., respondents are more likely to say that no dollar amount is acceptable).

Link to Health Valuation Theory

The averting behavior method is based on generally accepted economic theory and the revealed preference approach to measuring WTP. Because it measures WTP, the approach accounts for all of the effects of health on individual well-being, including altruism toward other household members if averting actions are taken jointly (for example, if everyone in the household drinks bottled water).

The theory of averting behavior predicts that a person would take protective action as long as the perceived benefit exceeded the cost. If there is a continuous relationship between defensive action and health improvement, then in theory the individual will continue to avert until the cost just equals his WTP for the health improvement. For example, if substituting a gallon of bottled water for a gallon of tap water yields a risk reduction of one in five million at a cost of $1, the individual will purchase bottled water until his WTP for a one in five million risk reduction just equals $1. Thus marginal WTP, or the WTP for a small change in health or health risk, is inferred from two pieces of information: (1) the cost of the averting good, and (2) its effectiveness, as perceived by the individual, in reducing risk or improving health.

As discussed in Chapter 2, measuring nonmarginal WTP, or WTP for large changes, using revealed preference methods is generally more difficult than estimating marginal WTP. Bartik (1988) showed that under certain conditions, averting costs are a lower bound on nonmarginal WTP. For example, a person who avoids drinking contaminated tap water by spending $20 a month on bottled water is willing to pay at least $20, though perhaps not exactly $20, to avoid the contamination. Several studies have used averting expenditures to estimate a lower bound on WTP to avoid contaminated water. Empirical efforts to estimate the exact WTP for a nonmarginal change, rather than simply to bound it, require complex theoretical and econometric methods (Dickie and Gerking 1991; Agee and Crocker 1996).

Methodological Problems

Although the basic theory is straightforward, several strict conditions must be imposed to estimate WTP using the averting behavior method (see Bartik 1988). The most serious problem involves isolating the WTP for a health improvement from the values of other services provided by a good. For example, a person using sunscreen reduces skin cancer risk but also reduces suntanning and sunburning of skin. An analyst interested in the skin cancer valuation only may find it difficult to isolate from the value of suntanning or sunburning. Similarly, use of air conditioning may reduce symptoms from exposure to ambient air pollution, but the main reason for running the air conditioner, presumably, is to cool the house. Disentangling the value of health from other values associated with taking averting action can be quite complicated.

A related difficulty is that many averting actions to do not have an easily observed market price to use in computing their costs. A person may stay indoors to avoid air pollution, for example, but it is difficult to assign a cost to this action. There is no monetary price, and no compelling reason to use the wage rate since the time spent indoors is not entirely lost.

Even when the cost of averting action is clear, the perceived benefit of the action may be difficult to infer. A person's choice of averting behavior, and thus the value revealed by his actions, is based on his *perception* of the resulting health effects. As discussed in Chapter 2, individuals perceptions about health risks may differ from the assessments made by experts. Implementation of the averting behavior method may require detailed surveys to elicit individuals' perceptions of the effects of behavior on health risks.

Finally, averting behavior often involves a discrete choice of whether to take an action, rather than a decision about the level of a continuous variable. For example, a person decides whether or not to purchase an air purifying or water purifying system. As discussed in Chapter 2, discrete choices by themselves do not directly reveal WTP, but only bound it. It is possible to use discrete choice data to estimate the exact WTP by applying complex methods (Dickie and Gerking 1991; Agee and Crocker 1996), but most researchers either ignore the issue or simply use averting expenditures to bound WTP.

Data Collection and Analysis

Most applications of the averting behavior method use surveys to collect data on averting actions taken, their costs, and perhaps on the actual or perceived health effects. Information on respondents' health status, attitudes and socioeconomic characteristics generally is also obtained. A measure of the value of time such as the hourly wages is particularly important, since many averting actions require time. In many cases, surveys have been timed to occur during or immediately after incidents of temporary water contamination.

Data on averting actions taken and their costs are sufficient to estimate averting expenditures and a lower bound on WTP. More precise estimation requires more complete information on the actual or perceived effects of defensive behavior, such as the reduction in symptoms or health risk, or the increase in a child's birthweight.

A second way of implementing the averting behavior method avoids the difficulties of household surveys by simulating costs and health effects of protective actions. For example, Murdoch and Thayer (1990) estimated the defensive expenditure that would be necessary to avoid increased skin cancer incidence from ozone depletion. However, with this approach, it is important to first find evidence that individuals would undertake such behavior. Establishing this behavioral evidence provides the information necessary to link cost to WTP. Data necessary to implement this type of approach are obtained from literature reviews and experts on the health effects in question.

Finally, a third approach employs aggregate data on defensive expenditures together with technical information on the health improvement or risk reduction that would be achieved by defensive behavior. Dardis (1980) applied this method to data on smoke detectors to estimate WTP for reduced risk of death, but there do not appear to have been any applications to valuation of environmental health effects.

Methods of data analysis vary widely in averting behavior studies, ranging from simple tabulations of averting expenditures to the estimation of sophisticated econometric models. Generally, attempts to bound WTP with averting costs require the least complex data analysis, while more complex methods are required to quantify relationship between averting action and health effects based on household data, or to estimate nonmarginal WTP.

Evaluation

Unlike the cost-of-illness approach, the averting behavior method measures WTP. As a revealed preference method, it avoids many of the objections raised by critics of contingent valuation. It accounts for the impact of defensive expenditures on health to a greater extent than any method, and in some applications accounts for individuals' own perceptions of the health effects of their actions.

There are a few major weaknesses of using the averted behavior approach that should be noted. First, it is difficult to isolate WTP for health from the other impacts of averting behavior on well-being. Second, averting actions often are discrete choices without readily observed costs, and implementation may require information on the perceived benefits of averting action. Finally, there are often multiple benefits of an averted expenditure, and at time negative effects. For example, bike helmets reduce the severity of head injuries as well as the risk of death, but they can also be uncomfortable to wear and aesthetically displeasing. These characteristics complicate the interpretation of the amount paid for the bike helmet, because there are multiple benefits of using a bike helmet and costs that go beyond the purchase price.

OTHER METHODS OF HEALTH VALUATION

The cost-of-illness, contingent valuation and averting behavior methods have been the most widely used approaches for valuing environmental morbidity. Several other methods have been used less frequently, namely hedonic methods, risk-risk tradeoffs, and health-state indexes. In addition, other potentially useful quantitative information might include studies of jury awards.

Hedonic Price Method

Hedonic methods are based on the idea that goods and services often can be viewed as "bundles of characteristics." For example, a house could be described by characteristics of the dwelling itself, such as square footage, number of bedrooms and age, and by characteristics of the neighborhood such as quality of nearby schools, ambient air quality, or distance to a hazardous waste site. In hedonic theory (Rosen 1974), the price of the house reflects the characteristics it offers, and individuals' valuations of those characteristics. It follows that the characteristics have *implicit prices* which measure the increase in housing price attributable to an increase in the amount of a characteristic.

For example, if two houses were identical except for distance from a hazardous waste site, the hedonic model predicts that the house closer to the site would sell for less. If one of the houses is a mile closer to the site and sells for $1000 less, then the implicit price of **?**distance to the hazardous waste site" is $1000 per mile. The revealed preference principle then implies that the marginal WTP for distance from the site must be $1000 per mile. If the relationship between distance to the site and perceived health risk were known, it might be possible to convert the WTP for distance into a value for reduced health risk.

The hedonic method is implemented using multiple regression methods to estimate the implicit prices of characteristics. Data from markets for houses, automobiles and jobs have been used to estimate marginal WTP for improvements environmental quality or reductions in risk of death or injury. As discussed previously, it is often much more difficult to estimate WTP for nonmarginal changes using revealed preference methods, and this is particularly true of hedonic methods (see Epple 1987; Bartik 1987). Although established estimation approaches exist (Biddle and Zarkin 1988), they are complex.

The major drawback of the hedonic property method for valuing morbidity is that the implicit price of **?**distance to hazardous waste site," for example, may reflect more than the WTP for better health. A greater distance from the site may be associated with less odor, noise or traffic, or with a better view. The value of all these factors would be reflected in the implicit price of distance from the site. Similarly, the implicit price of better air quality at a site may reflect the value of less soiling, less odor, or better visibility as well as the value of better health. In practice, it is quite difficult to isolate the marginal WTP for health from the values of other characteristics.

Hedonic Wage Method

The hedonic method also has been applied to the labor market, where wages reflect the economic value of characteristics of workers and jobs. According to the theory, employers must pay higher wages to attract workers to jobs viewed as more dangerous or less pleasant than alternate occupations. Application of the theory requires that careful consideration be given to the many factors causing wages to differ. For example, while neurosurgery is less dangerous than logging, the differences in compensation for these occupations is probably better explained by differences in the

amounts of specialized education, training and experience required to perform the job. In practice, studies that adopt this approach must carefully control for these factors that affect compensation for employment in order to isolate the "wage-risk premium" demanded by workers to compensate for choosing a more risky occupation.

There have been two main applications of the hedonic wage method to environmental valuation. One of these matches workers' wages to characteristics of their location, such as crime rates, climate or average air pollution concentrations, to estimate implicit prices for these characteristics. The second application is more closely linked to health: it involves estimating the tradeoff between wages and risk of death or injury on the job. Estimated wage-risk tradeoffs underlie many calculations of the **?**value of a statistical life." After controlling for differences in education and experience of workers, and other characteristics of their jobs, the wage decrease associated with a small reduction in job risk reflects the marginal WTP for reduced risk. Reviews of the theory and empirical results can be found in Fisher, Chestnut and Violette (1989), Miller (1990), and Viscusi (1992, 1993).

Wage-risk tradeoffs have been applied to value reduced risk of death, with several extensions to value risks of nonfatal injuries. Many economists regard estimated wage-risk tradeoffs as the most successful application of the economic theory of health valuation. Unfortunately, wage-risk tradeoffs often are unsuitable for morbidity valuation. Apart from premature death, the health effects of environmental contamination are quite different from the types of injuries occurring on the job. It would be difficult, for example, to infer the value of an avoided asthma attack from the wage-death risk relationship. The risk-risk tradeoff method, however, offers one way of linking wage-risk tradeoffs to the valuation of serious illnesses.

Risk-Risk Tradeoffs

The risk-risk tradeoff method involves asking individuals about tradeoffs they would be willing to make between two different risks, for example risk of death and risk of contracting some chronic disease. In the first application of the method, Viscusi, Magat and Huber (1991) presented people with a hypothetical choice between residence in two cities, which differed in the risk of a fatal automobile accident and risk of chronic bronchitis. The authors used an interactive computer program to present alternate combinations of the risks until reaching the point where an individual's response implied indifference between a death risk of one magnitude and a chronic bronchitis risk of another magnitude. For example, the median rate of tradeoff was 0.32, indicating that the median respondent viewed chronic bronchitis as about one-third (0.32) as adverse as a fatal automobile accident.

The risk-risk approach is based on respondents' statements rather than their actual behavior and so is potentially susceptible to many of the criticisms leveled at the contingent valuation method. A possible advantage of the risk-risk approach over CV, however, is that it may be easier for respondents to make tradeoffs between two risks than between risk and dollars, as they would have to if CV were applied to value chronic bronchitis. A major disadvantage of the method is that it does

not yield WTP estimates; but it offers an obvious chance to link morbidity valuation to wage-risk tradeoffs. For example, Viscusi, Magat and Huber apply a $2 million value of a statistical life to the median bronchitis-death risk tradeoff to estimate a value per statistical case of chronic bronchitis of $640,000. The risk-risk method would appear to be a promising area for further valuation research, but there have been few applications to date.

Health State Indexes

Another set of methods has been used by health economists to evaluate individuals' preferences over different health outcomes. The idea behind these methods is to construct a scale or index which ranks health outcomes in terms of how adverse individuals believe them to be. Often, the extreme points on the scale are ?perfect health" and ?immediate death," but some applications allow for health outcomes that might be viewed as worse than death. These methods do not yield estimates of WTP, but are quite informative about individuals' views of different illnesses and may be useful in benefits transfer (see Desvousges, Johnson, and Banzhaf 1994). Health state index methods that are keyed to tradeoffs with immediate death are sometimes used to develop quality-adjusted life year (QALY) estimates, particularly in the health economics literature.

There are three main approaches to constructing health-state indexes. The *standard gamble* approach is similar to the risk-risk method and relies heavily on expected utility theory. A respondent might be presented with two situations: (1) the certainty of having chronic bronchitis, or (2) a risky prospect involving, say, a 10 percent chance of death and a 90 percent chance of perfect health. The idea is to find the risk of death which the respondent thinks is just as adverse as having chronic bronchitis with certainty. Thus, respondents are not making tradeoffs between risk of death and risk of chronic bronchitis, as in the risk-risk approach, but between risk of death and certain chronic bronchitis.

A second approach is the *time-tradeoff* method, which asks respondents to trade years of life in full health against years of life with a chronic ailment. For example, a respondent might be asked to compare a given remaining life span in full health to a longer life span with chronic bronchitis. Finding the number of years which makes the respondent indifferent gives an alternate measure of the adversity of chronic bronchitis relative to perfect health and to death.

The third approach is the *rating scale* method, in which respondents are asked to score different health outcomes on a numerical scale, such as a one-to-ten scale. If immediate death is assigned the value one, and full health the value 10, then the ranking of a given impairment indicates how adverse it is relative to the two extremes. Analysts often compress the scale to lie in the zero-one interval.

Each of these methods provides potentially useful information about individual preferences over different health outcomes. An obvious question is whether the three methods would yield similar results. It appears that, at a minimum, the three indexes rank health outcomes in the same order. But whether each method would yield the same measure of the adversity of a disease is not quite as clear. Desvousges, Johnson, and Banzhaf cites evidence that consistent results are obtained from all the three methods, but other authors have found differences (Dolan et al. 1996).

More importantly, it is not clear that the ranking of health outcomes obtained by health state indexes would match the ranking obtained by knowing individuals' WTP for various health effects. As discussed by Johansson (1995), health-state indexes rely on much more restrictive assumptions about the nature of individual preferences that are normally made in WTP studies. For example, the time-tradeoff method assumes that chronically ill individuals are willing to trade a constant proportion of their remaining life years for better health, regardless of their current age and life expectancy. Restrictive assumptions about the substitution of income for health and the discounting of future health effects also are implicit in health-state indexes.

Several analysts have attempted to develop schedules of nonfatal health effects valuations by application of the results of health-state indices (see, for example, Miller et al. 1989 and Miller 1997). Health-state index methods may be used to develop estimates of quality-adjusted life years, which in turn are sometimes combined with estimates of the value of a statistical life year (VSLY) to generate a value for avoidance of a particular health effect. Health effects valuation estimates of this sort suffer from two problems: (1) as noted above, the health-state index results do not estimate WTP, and reflect a set of restrictive economic assumptions; (2) VSLY estimates, typically derived from annualizing value of statistical life measures, reflect an additional set of restrictive assumptions about the valuation of avoided mortality over time and among various age groups (see EPA's Guidelines for Economic Analysis for further discussion of this issue). An example of the second class of problems is that current estimates of VSLY assume all life-years have the same value, although no current empirical evidence supports this assumption. As a result, valuation estimates that rely on QALYs and VSLY, while a potential future source of data on economic valuation of a wide range of health effects, do not provide reliable estimates of WTP.

Other Quantitative Evidence

The compensation paid to victims of accidental injuries is another potentially useful source of information, although they have not been fully evaluated by economists as to their usefulness for valuation of health effects. Injuries affect individual well-being in much the same way as illnesses: injured persons may incur direct and indirect costs and may endure pain and suffering. Many injured persons receive substantial compensation for their injuries, but most sources of compensation (health and automobile insurance, paid sick leave, workers' compensation) cover only some portion of direct and/or indirect costs of injuries. Compensation for pain and suffering generally is available only through the liability system (i.e., by filing a liability insurance claim or a lawsuit, or by negotiating directly with the parties liable for the accident). Insurers and other parties potentially liable for injury

agree to pay compensation for pain and suffering to settle claims in cases where a court might award damages for pain and suffering. Most states allow recovery for pain and suffering in personal injury cases, though most states restrict recovery to financial losses of survivors in wrongful death actions.

Thus the nature of the injury and the source of compensation affect the relevance of information on injury compensation for health valuation. Only compensation for nonfatal injuries paid through the liability system will be indicative of comprehensive values for health, inclusive of pain and suffering. While most claims are settled out of court, the compensation paid to settle claims generally is not reported. Studies of injury compensation usually must rely on jury award data. There is no comprehensive system, however, for recording either all jury awards or a random sample of awards (Leebron 1989). Available databases often rely on voluntary and incomplete reporting by attorneys and court officials. In addition to these limitations, it is important to remember that damage awards represent a source of data that economists are only beginning to understand relative to economic theory -- in short, damage awards are not welfare measures, nor are they WTP or COI estimates. The monetary equivalent of the change in an individual's well being may have no bearing on what is agreed to in a legal settlement or judged by a jury to be fair compensation. However, with further research analysis of damage awards may provide insights into the pain and suffering component of some health effects.

A brief overview of empirical research on compensation for personal injury and its potential relevance in understanding the pain and suffering component of WTP is provided in Appendix B. The result of empirical research highlight two obstacles to using damage awards to value non-cancer health effects. First, the injuries compensated through jury awards are not representative of all personal injuries. The vast majority of injuries do not lead to a liability claim, and only a small minority of claims reach a jury. Legal scholars agree that the cases which come to trial are not randomly selected (Priest and Klein 1984). Viscusi's (1988) results, in one of the few studies including data on settlements and trial verdicts, point to a similar conclusion. He found that settlement amounts differ significantly from the damages awarded by juries. Moreover, the nonrepresentative nature of the universe of jury awards is compounded by the nonrandom sampling of these awards in available data caused by the irregular reporting of awards.

The second problem associated with the use of damage awards for valuation of environmental health effects is that most personal injuries are unlikely to resemble the non-cancer health effects influenced by environmental policy. The major causes of injury reported by Hensler et al. (1991) would appear much more likely to result in fractures, sprains, or lacerations than in respiratory disorders, diseases of internal organs, heart attacks or strokes, or fertility problems. This suspicion is supported by examining the list of injuries in Viscusi's (1988) product liability study, few of which would be affected by environmental policy. Injuries from medical malpractice, however, may match environmental health effects more closely. Any use of damage awards to value environmental health effects should pay careful attention to the match between the personal injuries being compensated and the health effects to be valued.

Damage awards represent compensation for an injury that has already occurred. The more appropriate value for policy analysis is the WTP to reduce the risk of an injury which, from the perspective of any one person, may or may not occur. As discussed in Chapter 2, the *ex post* and *ex ante* values are not necessarily the same. Similarly, the injured individual is identified when damages are awarded, whereas in policy analysis the identities of the persons who may suffer adverse health effects usually are unknown in advance. This distinction may affect the nature of the values obtained (Chestnut and Violette 1990; Pratt and Zeckhauser 1996). In addition, some of the significant determinants of damage awards, such as the liability rule applied or whether a regulatory violation occurred, are largely irrelevant to determining individual WTP to avoid adverse health effects. The distinction between determinants of damage awards and WTP reflects fundamental differences in the two monetary valuations. Jurors (or liability claims adjusters) are not asked to estimate individual WTP; they provide instead a third-party, group evaluation of damages. In summary, damage awards are a rich source of data on the economic value of personal injury, but they do not provide estimates of WTP. Further research is warranted to examine the relationship between damage awards and WTP, and more generally to investigate the suitability of damage awards for valuation of environmental health effects.

VALUING NON-CANCER HEALTH EFFECTS USING BENEFITS TRANSFER

CHAPTER 4

Benefits transfer is another technique, in addition to the primary methods discussed in Chapter 3, for valuing health effects. In benefits transfer, valuation information from one or more existing studies is used to assess benefits in a new policy setting. The techniques of benefits transfer have been used for many years to evaluate public policy options and to assess natural resource damages. Benefits transfer often is used when insufficient time or money is available to gather the primary data required for a new valuation study.

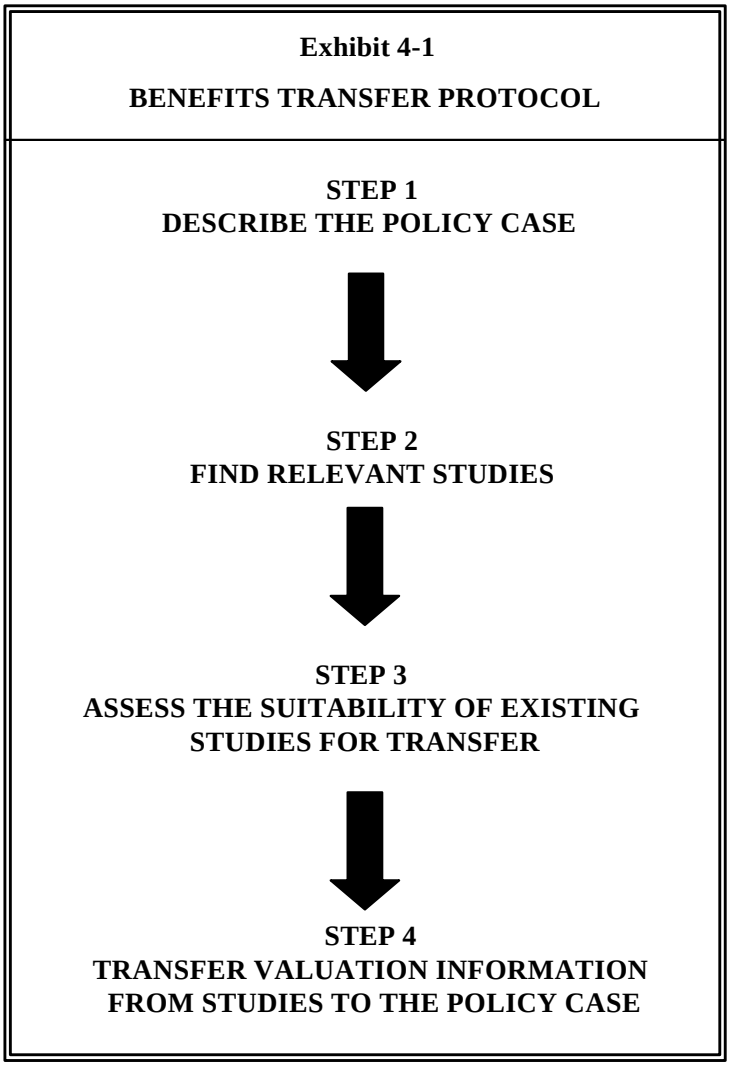
Existing applications of benefits transfer and assessments of the methodology often have focused on natural resource damage assessments. The typical application might involve using existing value estimates developed for one or more sites ("study sites") to estimate monetary damages at another site (the "policy site").

There also have been a number of attempts to transfer estimated values of health effects to new situations; for example see EPA's *The Benefits and Costs of the Clean Air Act, 1970 to 1990*. Applications of benefits transfer to value health effects often have aimed to provide only rough approximations of the monetary benefits of avoiding morbidity. For example, the Clean Air Act analysis calculates ranges of values for multiple symptom health effects by combining results of studies of each of the individual health effects, and adjusted available WTP valuation estimates for avoidance of severe chronic bronchitis to reflect the milder severity of chronic bronchitis cases anticipated to result from exposure to high level of ambient particulate matter and other air pollutants. Applications of benefits transfer to value children's health has been equally difficult. Because the number of existing child-specific value estimates is limited, transfers for estimating the value of children's health effects will likely involve values developed for adults. However, analysts are unclear on how well children's preferences reflect such things as their understanding of risk. In addition, children typically face different opportunity constraints than adults. As a result, transferring adult values to estimate children's benefits is not a straightforward process. EPA has recently given greater thought to how children should be treated in this type of analysis. In particular, the Agency has begun to explore the difficulties and issues of using adult values for estimating children's benefits in the *Children's Health Valuation Handbook* (USEPA, forthcoming).

This chapter explains how benefits transfer can be used to value environmental health effects. It evaluates the merits of benefits transfer relative to primary valuation research, and discusses key issues involved in conducting a benefits transfer. The chapter also outlines a four-step procedure for applying benefits transfer to value morbidity, illustrated in Exhibit 4-1. The procedure draws heavily from previous work, including work conducted to support EPA's ongoing analyses of the Clean Air Act.[15]

Exhibit 4-1

BENEFITS TRANSFER PROTOCOL



[15] See, for example, Snell, Unsworth, and Dickie, 1993.

DECIDING WHETHER TO CONDUCT A BENEFITS TRANSFER

The advantages of benefits transfer over primary research are clear. Primary research is costly and time-consuming, and in advance of conducting the research there is no guarantee the results will prove defensible for use in a regulatory or policy analysis. Benefits transfers usually can be conducted much more quickly and at lower cost using studies whose appropriateness and defensibility can be assessed in advance. Also, when several relevant studies are available, combining them may to some extent mitigate problems or errors specific to any one study.

The disadvantages of benefits transfer are equally clear: the resulting estimates are unlikely to be as accurate or precise as estimates from primary research tailored specifically to the new policy issue. Previous analyses suggest that results from benefits transfers must be interpreted with caution. For example, Smith (1992) compared results of two transfer-based studies that estimated benefits of reducing effluent discharges from the same paper mills to the same rivers. He found that the benefit estimates generated by the two studies led to different policy conclusions. Loomis (1992) tested and rejected the hypothesis that the valuation functions for sport fishing in two separate regions were identical, implying that the results from one region would not accurately reflect benefits in the other. While neither of these examples is specific to health valuation, they suggest that benefits transfers should be conducted and interpreted with careful consideration of potential sources of inaccuracy or imprecision. An additional problem specific to morbidity valuation is that the number of health effects for which WTP estimates exist is quite limited: there is not much available to transfer. Exhibit 4-2 presents an overview of the advantages and disadvantages of conducting benefits transfer.

Exhibit 4-2

BENEFITS TRANSFER COMPARED TO PRIMARY VALUATION RESEARCH

Advantages of Benefits Transfer	Disadvantages of Benefits Transfer
C Less costly than primary research. C Less time-consuming than primary research. C Quality of existing studies can be assessed in advance of transferring benefits, while quality of primary research unknown in advance. C Combining several existing studies (i.e., through meta-analysis) may mitigate errors in any one study.	C Benefit estimates generated are unlikely to be as accurate or precise as estimates from primary research. C There are few existing studies of WTP for reduced morbidity.

In view of the likely tradeoff between the relatively low cost of benefits transfer and the reliability of the resulting benefit estimates, the question of whether to apply benefits transfer may be best considered within the context of the policy decision and the options available for assessing benefits. Factors worth considering include: the accuracy required of the resulting estimate; the

availability of relevant existing studies; the degree to which additional primary research would improve the accuracy or reduce the uncertainty of the resulting benefit estimate; and the time and financial resources available to conduct the analysis (Atkinson, Crocker and Shogren 1992).

Not surprisingly, the two major issues involved in benefits transfer concern (1) the *quality* of existing studies, and (2) their *applicability* to the new policy situation. Applicability refers to the match between the *study case*, or the situation examined in the original study, and the *policy case*, or the situation relevant to the new policy. Key elements of this match include the correspondence between the "commodity," or health effect, valued in the study case and the health effect of the policy; and the similarity between the population examined in the study case and the population affected by the policy. As discussed in Chapter 2, the value of avoiding a health effect depends on characteristics of the effect, such as severity and duration, as well as on characteristics of the population affected, such as income or baseline health status. Ideally, the analyst would prefer that the health effects and populations considered in the study and policy cases be quite similar. Secondarily, the analyst would prefer a defensible method to adjust for important differences. In addition to the quality and applicability of existing studies, a third important issue in benefits transfer is determining the *extent of the market*, or the number of persons affected by the policy.[16] These issues are listed in Exhibit 4-3 and are discussed more fully in the presentation of the proposed benefits transfer protocol.

Exhibit 4-3

SOME IMPORTANT ISSUES IN BENEFITS TRANSFER

1. Quality of existing studies.

2. Applicability of existing studies to the policy case:

- similarity of health effects;
- similarity of populations experiencing the effects; and
- ability to adjust for differences.

3. Extent of the market: number of persons affected by the policy.

[16]It is important to note that determining the extent of the market is a necessary concern anytime an aggregate benefit estimate is developed. The issue is not exclusively associated with the benefits transfer method.

Our proposed protocol has four steps:

- ***Step 1 -- Describe the policy case***. In the first step, the analyst describes in detail the health effects of the policy, the resulting impacts on economic well-being, and the characteristics of the affected population.

- ***Step 2 -- Identify existing, relevant studies***. The second step generally involves literature searches and discussions with researchers in the field.

- ***Step 3 -- Evaluate the suitability of existing studies for benefits transfer***. The third step concerns assessing the quality and applicability of identified studies.

- ***Step 4 -- Transfer the benefit estimates***.

Often, benefits transfer requires that adjustments be made to account for differences between the circumstances of the original study and the policy application. The analyst should discuss the rationale for making any adjustments, the empirical basis for doing so, and the potential direction and magnitude of error in the final value estimates. These four steps are described in more detail in the next four sections of this chapter.[17]

POLICY EFFECTS ON HEALTH AND WELL-BEING

Step 1 of the protocol is a careful description of the policy case. The ability to identify relevant existing studies, assess their suitability for transfer, and conduct the transfer first depends on an accurate and thorough description of how the policy will affect health and economic well-being. As summarized in Exhibit 4-4, such a description involves: (1) initial consideration of the measurement of health effects; (2) a thorough description of the characteristics of the health effect likely to influence WTP; (3) a complete accounting of how a change in the health effect will affect well-being; and (4) a description of the population experiencing the change in the health effect. When planning an assessment of health benefits, it is important for economists and risk assessors to work together early in the process to establish the link between these four steps. This communication will help to ensure that the change in health effects is closely linked to a change in environmental quality.

[17] For a discussion of the broader use of the transfer technique in policy analysis, consult Desvousges et. al (1998). In this book the authors define transfer as the "use of existing information designed for one specific context to address policy questions in another context" (p. 4).

Exhibit 4-4

STEP 1 OF BENEFITS TRANSFER PROTOCOL: DESCRIBE THE POLICY CASE

1. Consider how health effects of the policy are measured.
2. Determine characteristics of the health effects likely to influence WTP, such as severity and duration.
3. Account for how the health effects influence individual well-being.
4. Describe characteristics of the population experiencing the change in health.

Measurement of Health Effects

It may be useful first to consider some initial questions about the measurement of health effects of the policy.

- Would people perceive the effect as adverse? As discussed in Chapter 3, health scientists often measure effects that ordinary people might not notice or perceive as affecting their well-being. It is difficult or impossible to place a meaningful economic value on these effects.

- Does the measure reflect a health effect alone, such as an asthma attack, or an indirect outcome as well, such as a day of work lost?

- What is the degree of uncertainty in the health effect measurement? Generally, greater efforts at precision in benefit estimation are warranted when health effects are measured with greater precision.

Characteristics of Morbidity Affecting WTP

A critical element of describing the health effects of the policy is to account for the characteristics of the health effect which influence WTP. Accounting for these characteristics is a necessary precondition for matching the policy case to existing studies. As discussed in Chapters 2 and 3 of this report, key factors include:

- What is the *baseline level*, and *policy-induced change*, in the frequency, duration, severity or probability of the health effects? The convexity of preferences, discussed in Chapter 2, makes it particularly important to account for these characteristics. For example, an individuals' total WTP to avoid an effect will increase as duration increases. Convexity also suggests that WTP for a given reduction in an adverse health effect may be higher, the greater is the baseline level of the effect.

- How easily is the effect avoided or relieved? The easier it is avoided or relieved, the lower is WTP for prevention of the effect.

- Does a health effect occur alone or as part of a group of symptoms? Does the occurrence of one effect increase the likelihood of another? The WTP to avoid a set of symptoms, for example, may be less than the sum of the values of avoiding each symptom individually.

- Is the effect immediate or delayed (i.e.,experienced after a latency period)? As discussed in Chapter 2, avoidance of delayed effects may be valued less than avoidance of immediate effects.

Categorize the Impacts on Well-Being

The next aspect of describing the policy is to categorize the health-related impacts on well-being. As discussed in Chapter 2, several economic effects may arise from improved health, including reductions in:

- medical expenses;
- foregone earnings;
- losses in nonmarket production;
- lost leisure time;
- averting costs;
- pain and suffering.

In addition, some cases of health valuation may warrant consideration of altruistic benefits. It will often not be possible to value all of these effects without primary research. For example, the only available information may come from a cost of illness study, which would account only for the first three items above. Thus, this part of the protocol is helpful in identifying studies which may provide information on some of the components of WTP, if not a comprehensive value.

Describe the Affected Population

Finally, a complete description of the policy will include a portrayal of the affected population. The focus would be on personal characteristics likely to affect WTP, such as income, age, education, and health status. It is important to review EPA policy and guidance on the appropriate method to address potential differences between the affected population and the population evaluated in available primary research. EPA's recent guidance on these topics is summarized in EPA (2000a). It is important as well to distinguish between health effects occurring in the general population, and those restricted to certain types of individuals, such as asthmatics, children or the elderly. This distinction influences the total size of the affected population, which is a key determinant of aggregate benefits. Other features to consider include the amount of information affected individuals have concerning the health effect, and the accuracy of their perceptions of it.

IDENTIFY EXISTING, RELEVANT STUDIES

The second step in the benefits protocol, summarized in Exhibit 4-5, is to identify existing studies which may be relevant to the policy case. Using the description of the effects of the policy as a guide, the analyst can search the literature for relevant existing studies. Ideally, the analyst will find several high-quality studies that value a similar health effect in a similar population, but more often some compromises must be made in the quality of the study, its applicability, or both. A comprehensive search for relevant studies would include searches of published literature; reviews of survey articles; examination of economic, medical and environmental databases; and consultation with researchers to identify government- or university-sponsored publications, unpublished research, and works in progress.

Exhibit 4-5

STEP 2 OF BENEFITS TRANSFER PROTOCOL: FIND RELEVANT STUDIES

1. Use description of policy case from Step 1 as guide.
2. Search published literature.
3. Review survey articles.
4. Examine economic, medical and environmental databases.
5. Contact researchers.

ASSESS THE SUITABILITY OF EXISTING STUDIES FOR TRANSFER

The third step of the proposed protocol is to assess the suitability of existing studies for benefits transfer. As summarized in Exhibit 4-6, determining whether an existing study is appropriate for benefits transfer will involve two main factors: the quality of the original research, and the applicability of the research to the new policy situation. Quality refers to the defensibility of the research methodology employed and the reliability and precision of the estimates obtained. In a later chapter of this memorandum, detailed guidelines are presented for assessing the quality of cost of illness, contingent valuation and averting behaviors studies. These guidelines should be helpful in judging whether a study is appropriate for benefits transfer, and a full discussion of the assessment of quality of existing studies is deferred to the later chapter. Some general issues to consider, however, are:

- Were current "best research practices" used in the original study?
- Has the study been peer-reviewed? How is it viewed in the professional community?
- How do the results obtained in the study compare with results in other studies, or with expectations from theory?

Applicability concerns whether available studies involve health effects and populations similar to the policy case, and whether adjustments can be made for important differences. Similarity can be assessed by describing the health effects, impacts on well-being, and affected population in a manner parallel to the description of the policy. A careful comparison of the descriptions of the study and the policy case will reveal the characteristics which are similar, and the nature and extent of differences. Typically, there will be some important differences in the health effects or populations considered in available studies, and those relevant to the policy case. The analyst would then consider prospects for adjusting for these differences.

Exhibit 4-6

STEP 3 OF BENEFITS TRANSFER PROTOCOL:
ASSESS THE SUITABILITY OF EXISTING STUDIES FOR TRANSFER

1. Assess the quality of original study.

- See Chapters 2 and 3 for guidelines for assessing quality of cost of illness, averting behavior, and contingent valuation studies.

2. Assess the applicability of the study to the policy case.

- Similarity of health effects.
- Similarity of populations.
- Ability to adjust for differences.
- Temporal stability of values estimated in study.

Two general kinds of adjustments may be made. Most commonly, analysts adjust the study estimates to better match the policy case. Less frequently, analysts may adjust the description of the health effects of the policy to match the available estimates. Adjustments to the study estimates typically involve one of four procedures:

1. The most basic type of adjustment considers how WTP changes with the scope of the health change by applying estimates of the WTP per unit of health change from an original study to the number of units expected as a result of the policy. Health units might include the number of days with particular symptoms, the number of emergency room visits, or the number of new cases of chronic bronchitis. At a minimum, therefore, the original study needs to provide WTP values for specific quantitative changes in health outcomes of interest.

2. The analyst may use a valuation function estimated in the study to account for differences in health effects or populations. A valuation function expresses WTP as a function of explanatory variables, such as the nature of the health effect and personal characteristics such as income. For example, if the study includes a valuation function with the level of baseline risk as a determinant of WTP, then the analyst may insert the level of baseline risk relevant to the policy case into the study's valuation function.

3. The analyst may estimate the impact of a difference between the study and the policy by combining results from several studies. For example, if different contingent valuation studies have estimated WTP for the same symptom of varying duration, then it may be possible to infer a relationship between duration and WTP from the group of studies. This relationship then could be used to adjust for differences in the duration of symptoms in the policy case and the durations valued in the studies.

4. The analyst may use judgment or economic theory to bound the likely effects of differences between policy and study cases.

As illustrated by these examples, the ability to adjust for differences between the study and policy cases is enhanced considerably when the study provides an estimated valuation function, which can be evaluated at alternate values of explanatory variables, rather than simply a unit value estimate, such as mean WTP. The range of adjustments that might be conducted expands further if data from the original study are available.

An alternative to adjusting the estimates from the available studies is to alter the description of the health effects of the policy. For example, an analyst might estimate the work loss or medical expenses caused by a particular health effect in order to apply existing cost-of-illness estimates. A more extensive adjustment procedure might follow the recent work of Desvousges, Johnson, and Banzhaf (1994) and French et al. (1996). Those authors convert health effects into a health-state index. The index indicates the adversity of the impairment relative to other health effects, some of which have been valued in other research. The value of the health effect of the policy then can be computed by adjusting the WTP estimate for a different health effect by the relative adversity factor implied by the health-state index. Although health-state indexes suffer from several potential shortcomings discussed in Chapter 3, this approach may warrant further research, especially to compare WTP estimates implied by this approach to those generated by primary research.

A final issue to consider in assessing the applicability of a study, particularly an older study, is whether the values estimated are likely to remain stable over time. As economic growth raises incomes, WTP for better health should rise over time. Changes in the technology, cost and method of delivering medical services also may affect WTP to avoid some health effects. In addition, a rising price level inflates monetary values over time. At a minimum, when using an older study it is important to standardize units by expressing all monetary values in the dollars of some relevant base year.

USE INFORMATION IN THE STUDY TO ESTIMATE BENEFITS

The fourth and final step of the protocol is to transfer the valuation information from the studies to the policy case. The actual transfer of benefit estimates itself may involve four substeps, as shown in Exhibit 4-7: (1) combining existing estimates; (2) applying the estimates to the policy case; (3) aggregating benefits to the relevant population; and (4) considering the uncertainties and limitations of the procedure.

Exhibit 4-7

STEP 4 OF BENEFITS TRANSFER PROTOCOL:
TRANSFER VALUATION INFORMATION FROM STUDIES TO THE POLICY CASE

1. Combine existing estimates.
2. Apply existing results to the policy case to estimate individual monetary values.
3. Aggregate benefit estimates to the whole of the affected population.
4. Discuss qualitatively, and quantitatively where possible, uncertainty, potential bias, and other limitations.

Combining Existing Estimates

Often, several relevant studies will be available, or a single study will provide different estimates of the same value based on different subsamples, assumptions or estimation procedures. Some of the estimates may be discarded as unreliable or inapplicable to the policy case. Common approaches for combining the remaining estimates include simple averaging, choosing a single "best" estimate, and developing low-, mid- and high-range values. More sophisticated procedures have been employed by some analysts. For example, Desvousges, Johnson, and Banzhaf (1994) converted health effects to a single metric using health-state indexes and then applied meta-analysis, or formal statistical procedures for combining results from several studies. Analysts may weight results of different studies according to the reliability of the estimates, as indicated by sample size, standard error, or even subjective judgments of the quality of the original research. Also, it is important not to forget the simple fact that dollar values from studies conducted in different years must be converted to the constant dollars of some base year by adjusting for inflation.

Estimate Individual Benefits in the Policy Case

Once the available estimates are combined in some manner, they can be applied to estimate the individual benefits in the policy case. At its simplest, this would involve directly applying values from the studies to the health effects in the policy case. For example, the analyst might multiply the expected number of work days lost by an appropriate daily wage rate. In other cases, available studies may provide an estimate of only one component of the value of a health effect; the analyst may sum these values to obtain a more comprehensive estimate. For example, one study may estimate the associated medical expenses, while another provides information on work loss. Executing this part of the procedure often requires accounting for differences between the study and policy cases, as discussed under Step 3.

Aggregate Benefits

After computing individual benefits, the analyst often will want to aggregate over the population affected by the policy to compute an overall benefit estimate. This step requires careful consideration of what economists call the "extent of the market," or simply the number of people affected. One approach to aggregation involves multiplying an average per-person benefit by the number of people affected. In other cases the analyst may want account for effects of income, age or other characteristics by aggregating benefits separately within population categories. As noted earlier, careful aggregation of benefits is an important step of benefits transfer and in cases where primary research has been conducted.

Consider Uncertainties and Limitations

The final step is to evaluate sources of uncertainty and possible bias in the benefits transfer. Benefits transfer involves a series of judgments and assumptions, each of which affects the final outcome to some degree. The simple technique of sensitivity analysis is quite helpful in assessing the plausible range of benefits. The analyst can modify assumptions or procedures to gauge the impact on the overall estimate of benefits. If available resources warrant, simulation techniques can be used to estimate a probability distribution for benefits. For example, Monte Carlo procedures were used to gauge the uncertainty in benefit estimates in EPA's *The Benefits and Costs of the Clean Air Act, 1970 to 1990*.

At a minimum, benefits transfer studies generally include a verbal description of the uncertainties and possible inaccuracies involved. In some cases there will be known sources of bias whose direction, if not magnitude, is clear. For example, an analyst may have transferred cost-of-illness estimates but was unable to value the pain and suffering components of value; all else equal, this would result in an underestimate. More generally, inaccuracy or imprecision may flow from the original estimates of health effects or economic values; from differences between existing studies and the policy case; and from judgments made in conducting the transfer. Each of these potential sources of inaccuracy and/or imprecision may be discussed qualitatively, and quantified where appropriate.

ISSUES IN APPLYING THE VALUATION LITERATURE CHAPTER 5

Valuation of health effects is generally of interest when an estimate of the reduction in risk of that effect can be established. Understanding the health science basis for the effect, however, and properly applying the relevant economic literature is not always straightforward. For example, values for individual health effects are not always available, or existing dose-response relationships may address slightly different health effects than the economics literature. This chapter suggests strategies for avoiding common pitfalls in the application of the valuation literature.

As noted in previous chapters, there are many reasons to exercise caution in the application of economic values for health effects. Three situations that are commonly encountered are: (1) No one has designed studies to provide willingness-to-pay compensation (WTP) values -- often, a cost-of-illness measure can be developed relatively easily, but the pain and suffering component is not captured, and the pain and suffering component can be a major factor in valuation of some chronic effects; (2) Existing WTP values are poorly matched to the effect of concern -- this can lead to issues of double-counting and increased uncertainty in benefits transfers; and (3) The health effect itself is poorly characterized in the relevant health science literature. In this section, we discuss strategies for dealing with each of these three situations. Exhibit 5-1 provides an overview of the chapter.

ESTABLISHING AN ECONOMIC VALUE FOR PAIN AND SUFFERING

Pain and suffering refers to the personal and subjective harms of illness: physical pain and attendant suffering, mental anguish, emotional distress, anxiety, embarrassment, inconvenience and loss of the enjoyment of good health. The term "pain and suffering" usually applies to the individual experiencing an illness, but sometimes it refers more broadly to the distress of family and friends as well.

Exhibit 5-1

TYPICAL PROBLEMS IN APPLYING THE VALUATION LITERATURE

Problem	Strategies for Addressing the Problems
No measure of pain and suffering is available.	Compare willingness-to-pay compensation (WTP) and costs of illness (COI).
	Examine damage awards (settlements and jury verdicts) in personal injury cases.
	Compare values for quality-adjusted life years (QALYs) and COI.
	Conduct direct valuation using contingent valuation, averting behavior, or COI methods.
Unclear whether the health effect valuation closely matches the existing value.	Examine the source of the risk of health effects.
	Examine the severity of health effects.
	Examine the duration of health effects.
	Examine the baseline risk experienced by exposed individuals.
	Examine whether the effect is an aggregate of multiple effects or symptoms.
	Examine selection bias associated with the choice of residence of study subjects.
Health effect is poorly characterized in the relevant health sciences literature.	Define the nature of the health effect.
	Calculate the hazard quotient (to determine how a contaminant dose compares to the reference dose for that contaminant)

The degree and duration of pain and suffering varies for different health effects. "Discomfort" may be more apt a term than pain for the subjective effects of acute symptoms associated with temporary decrements in lung function. Kidney disease, in contrast, would involve more intense suffering of longer duration.

Although everyone would no doubt agree that some illnesses hurt more than others, there is no accepted scale to measure the quantity of pain or suffering. This immeasurability complicates valuation, but monetization of pain and suffering would remain difficult and controversial even if the amount pain could be quantified.

Despite its intangibility, pain and suffering is recognized as an important consequence of illness or injury by the law, by respondents to health surveys, and by cost-of illness researchers.

- In the law, pain and suffering is a compensable component of damages from personal injury in the US, as well as in each of 10 other countries surveyed by Pfennigstorf and Gifford (1991); legal origins of financial compensation for "pain or distress of body or mind" date to ancient Rome (O'Connell and Carpenter 1983).

- Survey respondents have ranked pain or discomfort, emotional distress, and the lost enjoyment of normal activities as more important effects of angina (Chestnut et al. 1988), asthma (Rowe and Chestnut 1985), or light symptoms (Berger et al. 1987) than the medical expenses and lost income that are the focus of the cost-of-illness approach.

- Cost-of-illness researchers generally recognize that the omission of pain and suffering implies that "the cost relationship among diseases is thus not completely correct" (Cooper and Rice 1976, p. 21).

Valuation of Avoided Pain and Suffering

In this section we evaluate four strategies for monetizing pain and suffering. The first three approaches involve comparisons of values to attempt to isolate the economic value of avoided pain and suffering based on existing information. The fourth is primary research to monetize pain and suffering directly.

1. Comparisons of WTP and costs of illness (COI).

2. Damage awards (settlements and jury verdicts) in personal injury cases.

3. Comparisons of values for quality-adjusted life years (QALYs) and COI.

4. Direct valuation using contingent valuation, averting behavior (AB), or COI methods.

The section continues with an overview of pain and suffering in relation to the cost of illness, followed by brief summaries of empirical evidence on the value of pain and suffering from WTP/COI comparisons, damage awards, and QALY valuations. Primary research options are discussed next, followed by conclusions and recommendations on valuation of pain and suffering. Appendix C to the report includes a more complete evaluation of empirical evidence from prior research.

Pain and Suffering and the Cost of Illness

The cost of illness is the dominant approach to monetizing health effects, an outcome which leads to widespread neglect of the economic value of avoiding pain and suffering. As discussed in Chapters 2 and 3, the effects of illness on economic well-being include:

- medical expenses
- foregone earnings (or foregone market production)
- foregone nonmarket production
- lost leisure time
- averting costs
- pain and suffering.

The cost-of-illness approach focuses on medical expenses, foregone earnings, and in some studies, the value of foregone nonmarket production. The approach omits the value of leisure time, averting costs, and the value of avoiding pain and suffering. Neglecting these elements of illness implies that the COI understates economic benefits of reduced illness. Environmental policies resulting in reduced illness therefore appear less economically beneficial than they actually are. Knowledge of the value of avoiding pain and suffering would be useful in bridging the gap between the COI and WTP.

Summary of WTP / COI Comparisons

Relevant results from six studies that report estimates of WTP and COI are presented in Exhibit 5-2. All monetary amounts have been converted to 1996 dollars using the Consumer Price Index (a conversion which does not affect the ratio of WTP to COI). The first four studies listed compare estimates of WTP and individual COI from a common data source. (Individual COI excludes costs borne by persons outside the ill individual's household, through insurance, paid sick leave, or other programs.) The other two studies listed compare estimates of WTP and social COI taken from separate studies using different data sources. (Social COI includes costs borne by persons outside the ill individual's household.) Further details on the original studies are given in the appendix.

The difference between WTP and COI is a measure of the value of avoiding subjective harms of illness, including pain and suffering, while the proportionate mark-up of WTP over COI is indicated by the WTP/COI ratio. Economic theory predicts that WTP will exceed individual COI because individual COI does not include a WTP to avoid pain and suffering.

Results presented in Exhibit 5-2 support the contention that WTP exceeds individual COI, by a margin that may vary widely depending on the health effects or pollution reductions considered, the populations affected, or the data and methods used. Among the four studies estimating WTP and COI from common data, ratios of WTP to medical expenses range from 1.9 to 9.8. The median of the ratios shown is 3.7; the mean is 3.8. Corresponding ratios of WTP to COI range from 2.0 to 31.5 (excluding one extreme outlier based on only 5 observations), with a median of 3.9 and a mean of 8.1.

Some economists have suggested that WTP can be approximated as a constant mark-up of COI. Rowe and Chestnut (1985) and Chestnut (1995) suggest there is sufficient evidence to expect that WTP exceeds COI by at least a factor of two for certain health outcomes (i.e., hospitalizations for respiratory or cardiovascular illness and restricted activity days). While this conclusion was reached in this one case, each situation needs to be evaluated separately. Cropper and Freeman (1989) argue that WTP/COI ratios will vary by illness and by population group considered (Cropper and Freeman 1989). The wide range of ratios presented in Exhibit 5-2 casts doubt on the proposition that the WTP/COI ratio is constant, and a formal statistical test discussed in the appendix leads to rejection (at the one percent significance level) of the hypothesis of a constant ratio.

The WTP/COI ratios from the two studies comparing estimates of WTP and social COI taken from different data sources range from 2.1 to 20.0, suggesting that individual WTP exceeds (per capita) social COI. These results also provide evidence that WTP/COI ratios vary according to characteristics of individuals involved, such as age or choice of medical treatments.

Summary of Damage Award Studies

Damage awards provide a second source of information about the economic value of pain and suffering and other subjective harms of illness or injury, although the data are limited in their applicability because of the lack of a basis in economic theory. As discussed in Chapter 3, damage awards are not estimates of WTP, and the sign and magnitude of the difference between damages and WTP is unknown. In general, further research is needed before damage award estimates can be established as a source of economic values for *avoidance* of health effects. Nonetheless, damage awards appear to reflect reasoned judgments about appropriate levels of total compensation for inflicted injury, and available data represent large numbers of injuries of many different types.

Exhibit 5-2

COMPARISON OF WTP AND COI ESTIMATES

Study and Health Effect	Metric	WTP Method	WTP Estimate	COI Estimate	Ratio WTP/ COI	Lost Earnings Included?	Social or Individual COI?
Berger et al. 1987, Air Pollution-related Symptoms	***One Symptom Day***	***CV***				***Yes***	***Individual***
- Cough			$114.74	$18.38	6.2		
- Sinus Congestion			$41.26	$10.25	4.0		
-Throat Congestion			$66.34	$21.55	3.1		
- Itchy Eyes			$73.21	$21.99	3.3		
- Heavy Drowsiness			$214.44	$2.72	78.9		
- Headache			$164.16	$5.21	31.5		
- Nausea			$72.30	$3.78	19.2		
- All Symptoms			$121.76	$5.93	20.5		
Chestnut et al. 1988, 1996, Angina Episodes	***One Episode***	***CV, AB***				***Yes***	***Individual***
		AB	$54.40	$18.54	2.9		
		CV	$57.26		3.1		
		CV	$60.13		3.2		
		CV	$147.45		8.0		
Rowe and Chestnut 1985, Asthma Severity	***Reduce bad asthma days***	***CV***				***No***	***Individual***
			$631.70	$196.91	3.2		
			$919.98	$196.91	4.7		
			$697.86	$70.89	9.8		

Exhibit 5-2

COMPARISON OF WTP AND COI ESTIMATES

Study and Health Effect	Metric	WTP Method	WTP Estimate	COI Estimate	Ratio WTP/ COI	Lost Earnings Included?	Social or Individual COI?
Dickie and Gerking 1991, Unspecified Health Effects of Ozone	***Eliminate days of ozone***	***AB***				***No***	***Individual***
	>12 ppmh		$138.53	$36.45	3.8		
			$167.69	$84.57	2.0		
			$249.35	$67.08	3.7		
			$304.76	$160.40	1/9		
	> 9 pmmh		$249.35	$59.79	4.2		
			$298.93	$131.24	2.3		
			$380.58	$94.78	4.0		
			$457.87	$215.81	2.1		
Agee and Crocker 1996, Child Lead	***Reduce child body lead 1 percent***	***AB***				***Yes***	***Social***
	All		$670 mill.	$219 mill.	3.1		
	No chelation		$461 mill.		2.1		
	Chelation		$4.38 bill.		20.0		
USEPA 1997, Chronic Bronchitis	***One Case***	***Risk-risk tradeoff***				***Yes***	***Social***
	All ages		$260 K				
	Age 30			$77 K	3.4		
	Age 40			$58 K	4.5		
	Age 50			$60 K	4.3		
	Age 60			$41 K	6.3		

Notes: CV is contingent valuation, AB is averting behavior, see Appendix C case study for more information on individual studies.

Compensatory damages consist of *special damages* (financial losses like medical expenses and foregone earnings) plus *general damages* (nonfinancial losses like pain and suffering). Typically, only total damages are reported, without itemization of special and general components; researchers impute general damages from the total and from available information on financial losses.

The damage award studies reinforce the conclusion that a comprehensive valuation of injury or illness, inclusive of pain and suffering, exceeds purely financial costs by a nontrivial margin. Ratios of total to special damages fall in a broad range (1.3 to 24.2), but are less widely dispersed than WTP/COI ratios. Mean ratios by study are 1.9 (Viscusi 1988), 5.9 (Rodgers 1993), 2.9 (Hammitt 1985), 3.2 (Bovbjerg et al. 1989) and 12.7 (Cohen 1988). Cohen's study focuses on injuries to victims of violent crime and yields a markedly higher share of general damages in total damages. Setting the Cohen study aside as unrepresentative of valuations of unintentional injuries, the hypothesis that total damages are a constant mark-up of special damages is rejected at the one percent significance level. This result accords with rejection of a constant WTP/COI ratio and is consistent with regression results presented in four of the original studies (Hammitt 1985; Viscusi 1988; Bovbjerg et al. 1991; Rodgers 1993).

Summary of QALY/COI Comparisons

Studies comparing COI to valuations of quality-adjusted life years (QALYs) provide a third option for valuing pain and suffering, though the results of these studies should be viewed with caution. These studies estimate the number of QALYs lost for a given illness, and then monetize the lost QALYs using an estimate of the value of a life-year. As discussed in Chapter 3, current estimates of the value of a life year are highly uncertain, in part because of the restrictive assumptions required to generate these estimates (for example, there is an implicit assumption that all life years should be valued equally, although no empirical evidence exists that all QALYs have the same value). The QALY valuation procedure is a benefits transfer from studies of the value of a statistical life applied to a QALY health outcome measure. The injury is not monetized directly, either by individuals affected (as in WTP studies), or by third parties (as in damage award studies). As discussed in Chapter 3, there is little or no evidence concerning how well a QALY-based valuation would match direct estimates of the WTP to avoid injury.

Nonetheless, ratios of QALY values to COI in existing literature also suggest that there is a significant value for pain and suffering that is omitted from COI studies. Two studies that provide a basis for developing ratios are Miller, Luchter and Brinkman (1989) and Miller (1997); these are described in more detail in the appendix Ratios of QALY values to COI in these studies range from 3.2 to 14.9, with a mean of 8.8 in the first study and 6.2 in the second. The hypothesis that the ratio of the QALY valuation to COI is constant is rejected at conventional levels of statistical significance.

Primary Research for Valuation of Pain and Suffering

Each of the three most widely used methods of valuing environmental health effects (cost-of-illness, contingent valuation and averting behavior) could be used to estimate the value of avoiding pain and suffering. Contingent valuation appears to be the most promising approach, but no firm conclusions can be reached because of the limited amount of prior research.

More fundamentally, use of contingent valuation (or averting behavior) to value pain and suffering would be neither more straightforward nor less costly than using the method to estimate a comprehensive WTP to avoid the entire illness. Unless the resulting value for pain and suffering could be transferred to other health effects (and evidence on the variability of WTP/COI ratios highlights the difficulties of doing so), there would seem to be little advantage in primary research to value pain and suffering.

Contingent Valuation

The flexibility available when designing a contingent valuation study is potentially a major advantage for directly estimating a separate value for avoiding pain and suffering. Only one contingent valuation study, however, has been designed specifically for this purpose. Schwab, Christe and Soguel (1996) asked respondents to assume that they would be compensated by insurance for all financial losses in a study of the pain and suffering of victims, and relatives of victims, of traffic accidents in Switzerland.

Schwab, Christe and Soguel found that WTP to avoid the pain and suffering is larger for a permanent, severe disability than for a fatal accident. The value of avoiding the pain and suffering of a statistical victim of a fatal accident is in turn somewhat lower than earlier contingent valuation estimates of the value of a statistical life (after adjusting for inflation and exchange rates), which would be expected if the value of life includes financial losses. Reported WTP increases significantly with the severity of a nonfatal injury and with respondent income. Somewhat surprisingly, the bereavement of relatives is assigned a higher value that the pain of the victim, although this difference is not statistically significant.

This study is useful primarily in demonstrating the feasibility of contingent valuation for valuing pain and suffering, though the validity of the approach cannot be assessed based on only one study. The specific valuations obtained are less useful, for two reasons. First, no estimates of financial losses of accident victims were presented for comparison to pain and suffering values. Second, the validity of transferring valuations of traffic accidents in Switzerland to environmental health effects in the US would be questionable.

Cost of Illness

Discussions of the omission of pain and suffering from the cost of illness generally neglect the fact that some illness costs are incurred for treatment or control of pain and suffering, though this expenditure probably falls short of the WTP to avoid pain. As discussed in Chapter 2, people generally are willing to pay more than they actually pay for all but the last unit of a good purchased. This excess of WTP over expenditure, or the consumer surplus of avoiding pain and suffering, would not be reflected in financial costs of medication, therapy, or treatment for physical pain or emotional suffering. Also, treatments used may only limit, rather than eliminate, pain and suffering, leaving the value of avoiding the residual pain and suffering unaccounted. In short, no application of the cost-of-illness approach will account fully for pain and suffering, but illness costs may include a partial monetization.

Averting Behavior

To the extent that people voluntarily make expenditures to avoid pain and suffering, the averting behavior approach method offers a third valuation approach. The AB would rely on similar expenditures to those used in the COI (costs for treatment of pain and suffering), but would examine the expenditures from the perspective of an individual deciding whether to bear the costs in view of pain and suffering relieved, rather than treating the costs as externally imposed consequences of illness. Also, the AB method would recognize the distinction between expenditures incurred and WTP.

The inability to measure the amount of pain and suffering relieved per dollar of expenditure would be a major obstacle for the AB method, because it would be difficult to quantify the benefit obtained from the expenditure. A second limitation arises with prescription medication if the amount prescribed does not match the amount the individual would choose. The AB method, like the COI, is unlikely to suffice as a general methodology for monetizing pain and suffering.

Conclusions

1. **Available evidence indicates that WTP exceeds individual COI, as well as social COI, by a margin that varies with the health effects and populations considered.** Evidence from damage awards bolsters the view that pain and suffering and other nonfinancial impacts of illness comprise a substantial share of the economic value of illness. Consequently, the COI can be viewed as a lower bound estimate of WTP, but the accuracy of the bound is uncertain.

2. **Available evidence does not support estimating WTP by marking up illness costs using a WTP/COI ratio, except in preliminary, screening analyses of benefits.** In addition to any methodological problems in the studies providing WTP/COI ratios (including the use of small samples unrepresentative of the national population), the unexplained variation in the ratios precludes their use where high degrees of accuracy and precision are required. The use of WTP/COI ratios could be defended in screening analyses of benefits if the health effect to be valued is matched carefully to the effect with the estimated WTP/COI ratio. In matching health effects, key considerations would be the pain and suffering of the effects and of their treatment.

3. **Available evidence does not justify the use of damage awards for pain and suffering, or ratios of total to special damages, to adjust the COI for pain and suffering.** Damage award data provide a monetary valuation of pain and suffering which, like WTP/COI ratios, may be useful in preliminary, screening analyses of benefits. A fundamental problem is that the quantitative relationship between damage awards and WTP is unknown. In addition, a key consideration would be finding a close match between the environmental health effect and a corresponding damage award, because the types of injuries compensated by damage awards often bear little resemblance to non-cancer health effects likely to be influenced by environmental policy. This difficulty might be overcome by using medical malpractice awards, or by scaling injuries according to severity (as in the Rodgers 1993 and Bovbjerg et al. 1989 studies). A further complication is that amounts awarded are highly variable, even within severity categories. It is not clear whether this variability indicates errors in valuing similar injuries, or whether the severity categories are too broad to distinguish important differences in injuries.

4. **Further research is warranted on the suitability of damage award data for valuation of environmental health effects.** Research comparing damage awards to WTP for specific health effects would be helpful in resolving the key question of the sign and magnitude of the difference between damage awards and WTP. Other questions of interest include whether special damages closely approximate estimates of the COI for the same health effects, and the extent to which the dispersion of awards is reduced by using narrower injury definitions.

5. **Further research is also warranted on the suitability of QALY-based injury valuation data for valuation of environmental health effects.** QALY-based valuations provide another source of information on the potential value of avoiding pain and suffering, but valuations obtained by combining values of life years with QALYs do not measure WTP. These estimates reflect a series of simplistic, restrictive assumptions about the substitution of income for health, the discounting of future health effects, and individual's valuations for reduction of mortality risk that must be addressed before the estimates would be suitable for valuation of environmental health effects.

6. **Primary research to estimate WTP to avoid pain and suffering is feasible, but would not appear to be any less costly or more beneficial than primary research to estimate an overall WTP to avoid illness.** Contingent valuation seems the most promising approach for direct valuation of pain and suffering. Unless the WTP estimates obtained could be transferred across health effects, however (and the variability in WTP/COI ratios highlights the difficulty of doing so), there would be no advantage in using CV to value pain and suffering, as opposed to using CV to value avoidance of the illness.

7. **If comprehensive illness valuations are required, inclusive of pain and suffering, then WTP to avoid illness is the ideal economic measure to use for practical application of existing methods.** In practice, primary estimation of WTP generally is preferable to benefits-transfer procedures like adjusting COI using WTP/COI ratios or damage awards. Likewise, primary estimation of overall WTP to avoid an illness appears superior to attempting to estimate a separate WTP to avoid pain and suffering. However, in theory, WTA is the ideal economic measure to use to value illness. As mentioned earlier, the WTA approach is ideal when the property rights belong to those at risk, but is often not used because it is more problematic to measure and quantify than WTP.

IMPROVING THE MATCH OF THE HEALTH EFFECT DESCRIPTION TO AN EXISTING VALUE

In this section, we discuss issues that may arise in attempting to match economic values to health effects evaluated in the health science literature. EPA health benefits analyses have traditionally applied a "damage function approach" to estimate the aggregate benefits of avoiding morbidity. The damage function approach involves multiplying unit economic values per case or per symptom-day of morbidity (derived from the economics literature) by the expected number of cases

or symptom-days avoided (derived from the health science literature). Before applying the damage function approach to specific illnesses, however, it is useful to consider whether any general conclusions may be reached concerning the sources of potential errors introduced by a potentially poor match in the description of effects in the economics and health science literature.

There are at least six potential sources of errors that should be considered when attempting to match health effects and economics literature in the damage function approach:

- The source of the risk of health effects (e.g., environmental versus workplace exposure);
- The severity of health effects;
- The duration of health effects;
- The baseline risk experienced by exposed individuals;
- Whether the effect is an aggregate of multiple effects or symptoms; and
- Selection bias associated with the choice of residence of study subjects.

We discuss the potential impact of each of these factors and strategies to address these concerns below.

Source of Risk

Unit economic values and/or health effects from the relevant literature do not always match the actual health effect occurring in the population. Often, the "risk scenario" presented to subjects in the economic valuation studies differs from the environmental cause that is being evaluated in the analysis (e.g, air pollution or groundwater contamination). For example, groundwater pollution risks differ from risks in the workplace in that workplace risks are for the most part borne voluntarily and the nature of workplace risks may be more familiar and better understood by the affected population. Although there is some empirical literature on this topic in the mortality valuation literature (Beggs 1984, Litai 1980, Fisher et al. 1989, Weinstein and Quinn 1983), efforts to establish broad adjustment factors for this effect have been largely unsuccessful. The available literature notes that at least four types of differences in the source of risk and its perception may be important in estimating WTP to avoid risk:

- Voluntary versus involuntary exposures;
- Controllable versus uncontrollable exposures;

- Ordinary versus catastrophic risks;
- Old versus new risks.

These studies are in general agreement that individuals are willing to pay less to reduce familiar, controllable risks borne voluntarily. Furthermore, many analysts agree that risks presented by environmental exposures fall into the involuntary category, although these exposures can sometimes be mitigated through averting behavior. In general, quantitative adjustments to WTP are possible based on available literature, but this concern must nonetheless be recognized in evaluating potential sources of uncertainty in benefits estimates.

Severity of Health Effects

It can sometimes be difficult to assess how closely the severity of effects predicted by health effects literature resembles the severity of effects valued in the economics literature. In most cases, dose-response functions do not distinguish effects according to severity and presumably could be taken to represent cases of average severity. There are notable exceptions, however. For example, the Viscusi, Magat and Huber (1991) study of chronic bronchitis indicates that the description of chronic bronchitis given to respondents in their survey represents a relatively severe case of this morbidity effect. In this case, subsequent analysis of survey data was performed by another team of analysts who developed a quantitative severity adjustment procedure (Krupnick and Cropper 1992). In most cases, however, there is little reliable information to support quantitative adjustment of valuation estimates for differences in severity. A qualitative analysis of the direction of effect may be all that is possible. Where the severity of effect is greater in economic studies compared to health effects literature, benefit estimates are overstated, and vice versa.

Duration of Illness Avoided

Several contingent valuation studies (Loehman et al. 1978, 1979; Rowe and Chestnut 1986; and Tolley et al. 1986) provide evidence that WTP per symptom-day avoided declines as the number of symptom-days avoided increases. As a result, simply multiplying marginal WTP for a single day by the number of symptom-days avoided plainly overstates WTP for avoidance of multiple symptom days in the presence of declining daily values. To estimate the magnitude of this error or to attempt to correct for it requires an estimated relationship between daily WTP and duration of symptoms avoided. Hall (1989) estimated this relationship by pooling data from several contingent valuation studies and provides a quantitative adjustment procedure for this effect.

Number of Symptom-Days Currently Experienced and Baseline Risk

Both Loehman et al. (1978) and Tolley et al. (1986) report that estimated WTP for avoiding a given number of symptom days increases with the number of days the symptom is currently experienced. These results are derived from regressions in which income (as opposed to utility) is held constant. Implicitly, an individual moves to a lower indifference curve as symptom-days experienced increases while income is held constant. Thus this effect is separate from the effect of duration on daily WTP, which concerns movements along a given indifference curve.

Several studies have examined how health risk valuations vary with baseline risk; most of the evidence favors the idea that individuals at higher risk are willing to pay more for a given risk reduction (see Viscusi 1992). Thus, baseline risks may affect values for reducing risk of chronic illness in the same way as baseline symptom frequency affects symptom avoidance values.

Avoidance of Multiple Symptoms

Improved environmental quality may reduce several related symptoms concurrently. If daily WTP to avoid a given symptom depends on the number of symptom days avoided, it is natural to question whether WTP to avoid one symptom varies with joint reductions in other symptoms. Does WTP for a joint reduction in several symptoms equal the sum of the individual symptom values? There is evidence in some valuation contexts that WTP is subadditive (i.e., WTP for joint changes is less than the sum of WTP for separate changes), but the effect may be small. For example, Tolley et al. (1986) report WTP to avoid individual symptoms as well as WTP to avoid groups of three and five symptoms jointly, for durations of one and thirty days. In each case, the sum of mean WTP values for individual symptoms slightly exceeds the mean WTP for avoiding the group of symptoms.

Professional judgment applied on an illness-by-illness basis is the best way to mitigate this type of error. One useful approach is to attempt to bound the appropriate unit value for a multiple symptom effect using estimates for the individual symptoms. A useful upper bound is the sum of the WTP values for each of the relevant symptoms, while a lower bound can be developed from a high-end value for a single symptom. This type of approach can be used to develop rough estimates that are useful in conducting sensitivity tests and uncertainty analysis, but may be more difficult to defend as the basis of primary benefits estimates.

Selection Bias Arising from Respondent Choice of Residential Location

Some of the available economic literature that employs a survey-based approach (e.g,. contingent valuation studies), may draw respondents from relatively small geographic areas. Two examples are the Dickie et al. (1986) and Rowe and Chestnut (1986) studies of air pollution effects. Both Dickie et al. and Rowe and Chestnut drew respondents from Glendora, while Dickie et al.

include additional subjects from Burbank. These are heavily polluted areas east of Los Angeles, with Glendora in particular experiencing severe ozone pollution. If individuals living in Glendora differ from similar individuals living elsewhere in terms of preferences for health, then errors will occur when extrapolating results from these two studies to the national population.

This issue becomes important if preferences for health vary across individuals, individuals perceive health effects from air pollution, and people have at least some discretion in choosing where to live. Under these conditions, a randomly chosen person from a heavily polluted city such as Glendora is less likely, other things equal, to place a high value on health than is a similar individual from a less-polluted area. In other words, we would expect that persons with the lowest values for avoiding health effects would "self-select" the areas with the lowest level of environmental health amenities. Therefore, all else equal, WTP estimates from studies that focus on heavily exposed areas may be derived from individuals who place a lower than average value on respiratory health improvements.

Other Determinants of Unit Values

The damage function approach is prone to error whenever unit values vary significantly over the population, if illness reductions are concentrated among individuals with high or low values, or if the factors causing unit values to vary affect utility in a nonlinear fashion. Potentially relevant factors not discussed above include health information and incentives for averting or mitigating action. For example, changes in air quality may affect incentives to acquire information about health effects or to undertake averting/mitigating action. Since neither health effects nor valuation estimates typically control for these incentives, the resulting behavioral changes could produce errors in both the health effects predicted and the estimated unit values. Although this effect seems plausible, the importance of these factors currently is not clear.

Summary

There are several important factors associated with the transfer of existing economic values for use in policy analyses that could cause the aggregate benefits estimate to differ from the "true" value. In most cases, two of these factors, caused by inconsistencies in the duration and severity of effects, are likely to cause economic values to overstate the true value. On the other hand, several attributes of the subjects in the relevant economic studies, including the influence of their choice of residence, their baseline risk level, and their perception of the attributes of the risk scenario, may cause available estimates to understate the true value. In a few cases, available literature supports an adjustment to economic values to correct for these errors. In all cases, however, benefits analysts need to be aware of the potential influence of these factors on the overall benefits estimates, collect information from the relevant health effects and economics literature that are being considered as the basis for benefits estimation, and carefully consider the uncertainties in valuation for individual health effects of concern.

CHARACTERIZATION OF NON-CANCER HEALTH EFFECTS

In this section, we discuss issues in understanding the nature of non-cancer health effects estimates derived from the health effects literature. In order to monetize the benefits associated with avoiding a non-cancer health effect, an analyst must first develop a full characterization of the effect itself. This includes a clear definition of the nature of the effect and a method for quantifying the likelihood of its occurrence within an exposed population. The degree to which studies of non-cancer health effects define the nature of the effect range across a wide spectrum, from detailed descriptions of specific symptoms in humans (e.g., kidney damage) to very general descriptions of a collection of effects in animals that may or may not have direct corollaries in humans (e.g., muscoskeletal toxicity). Furthermore, with the exception of the criteria air pollutants, the magnitude of a non-cancer health effect associated with contaminant exposure is characterized only as being above or below a dose at which there is no appreciable risk of the adverse effect. There is no indication of the probability of exposed individuals contracting such an effect nor any measure of the severity of the effect.

Defining the Nature of a Health Effect

Health scientists use several types of studies to help define the adverse effects of exposure to contaminants. At the simplest level, these studies can be divided into epidemiological studies of human populations and dosing studies conducted on a wide array of animals, frequently mice or rats. Epidemiological studies are often preferable because they allow for the direct measurement of an effect in humans. However, it can be difficult to interpret the results of these studies because they are not controlled studies of the effects of contaminant exposure. The contaminant exposure levels may be poorly characterized and there may be many confounding factors ranging from exposures to other agents to the presence of behavioral factors, such as smoking, that may contribute to the occurrence of an effect.

On the other hand, dosing studies of animals are conducted using measured exposure levels in a controlled environment that is designed to minimize the influence of any potentially confounding factors. However, these advantages are offset by difficulties in translating the effects measured in animals to corresponding human effects. Some effects observed in an animal dosing study may have no direct relevance to humans because of cross species differences in how the contaminant is metabolized. For example a contaminant may be transformed into a more toxic compound when it is metabolized in rats, but detoxified by metabolic processes in humans. The reverse can also occur.

Even if the animal effect can be linked to a specific human effect, several challenges remain for health scientists in applying animal dose-response information to humans. First, the dose applied to the animals must be scaled to humans. This is commonly accomplished by using a factor based on the relative body weights of the test animal and humans raised to a power of 0.75. The analyst should be aware that this scaling represents an additional source of uncertainty in characterizing the health effect. Second, there may be differences in the variability of responses among animals and human

populations. This factor complicates the identification of threshold dose level below which all members of the human population, including sensitive individuals, are at negligible levels of health risk.

Quantification of Non-Cancer Health Effects

EPA's current methods for assessing non-cancer and cancer risks differ dramatically. While standard cancer risk assessment methods can be used to quantify the magnitude of risk, analogous methods are not available for quantifying non-cancer risks. Specifically, cancer risk assessment methods can produce estimates of the probability associated with contracting cancer as a result of exposure to a contaminant.[18] In contrast, available non-cancer risk assessment methods do not provide quantitative estimates of the probability of experiencing non-cancer effects from contaminant exposures. Non-cancer risk assessments are typically based on the use of the hazard quotient, a ratio of the estimated dose of a contaminant to the dose level below which there will not be any appreciable risk (the Reference Dose or RfD).[19] Such an approach can only be used to determine how a contaminant dose compares to the RfD for that contaminant. If the dose for an exposed population is equal to or greater than the RfD, then the population is at risk of contracting the adverse effect associated with the contaminant.

RfDs for individual contaminants are derived from the health effects literature. The first step is to identify the critical effect for a contaminant; the adverse effect that occurs at the lowest dose. The second step is to determine the highest exposure level at which there are no statistically or biologically significant increases in the frequency or severity of this effect. This is called the No Observed Adverse Effect Level (NOAEL). In the final step for defining the RfD, the NOAEL is divided by uncertainty factors to account for several sources of uncertainty in characterizing human responses to contaminant doses, including extrapolation of health effects data across species, inter-individual variability in response, and the quality of the health effects data.

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[18] Standard practice for cancer risk assessment yields a plausible upper-bound estimate of the probability of contracting cancer per unit intake of a chemical over a lifetime. In general, EPA's cancer risk assessment protocol involves calculation of the upper 95th percent confidence limit of the slope of the cancer dose-response curve (i.e., there is only a five percent chance the probability of a response could be greater than the estimated value on the basis of the experimental data and model used). See USEPA 1989, *Risk Assessment Guidance for Superfund, Volume 1, Human Health Evaluation Manual (Part A), Interim Final*, EPA/540/1-89/002, Chapter 7, for more details.

[19] The Reference Dose (RfD) is used to define the safe dose level for the oral exposure route. EPA develops a similar measure for the inhalation exposure routes expressed as a contaminant concentration rather than dose. It is called the Reference Concentration (RfC).

The RfD for a contaminant is derived for a single critical effect. There are usually multiple adverse effects observed, however, as the dose is increased above the threshold for the critical effect. Risk assessors refer to these as prevalent effects. In evaluating the non-cancer risks for exposure to a contaminant it is important to consider both the critical and prevalent effects. Even though prevalent effects may occur only at higher doses, they may be more severe than the critical effect. This raises the question of how can we evaluate the risks for prevalent effects. Current practice within the agency is to assume that a population is at risk for the critical and prevalent effects when dose equals or exceeds the RfD (i.e., the hazard quotient $ 1). EPA's Science Advisory Board has accepted this approach as reasonable.[20] Alternatively, if one or more of the prevalent effects is severe and the data are sufficient, health scientists may derive separate RfDs for these effects.

EPA has begun to develop an alternative approach to developing RfDs that represents a step toward a more quantitative characterization of non-cancer risks. This approach relies on statistical dose-response modeling to establish a benchmark dose (BMD) that produces a predetermined level of change in adverse response (e.g., 5 percent). The BMD is then used instead of a NOAEL in defining the RfD. An RfD developed in this way still suffers from the primary limitation of not producing a quantitative estimate of the probability of an individual contracting the effect at different levels of contaminant exposure; however it does give an indication of the risk level associated with exposures in the range of the BMD. This information on the risk probability at the BMD may be of limited use if the estimated exposure level is substantially below the BMD.

EPA is continuing to investigate approaches for developing more quantitative estimates of non-cancer risks. One such effort undertaken by OPPE involves using dose-response data (equivalent to data used to derive the BMD) and linear low dose extrapolation to produce a quantitative estimate of the probability of contracting a non-cancer effect over a wide range of exposure levels, similar to those commonly estimated for cancer risks. This type of approach represents an initial step in developing dose-response data for non-cancer health effects that will yield quantitative estimates of the number of cases of illness. While it is promising for the purposes of valuation, this method is not currently available for use. It is still in a preliminary stage and has yet to undergo a full internal and external peer review.

Summary

There are significant constraints in our ability to characterize and quantify non-cancer health effects in ways that can be monetized. These include difficulties in defining the nature of the effect itself and in quantifying the probability that a given exposure level will result in an individual

[20] US Environmental Protection Agency and Science Advisory Board. *Superfund Site Health Risk Assessment Guidelines: Review of the Office of Solid Waste and Emergency Response Draft Risk Assessment Guidance for Superfund Human Health Evaluation Manual by the Environmental Health Committee*. February 1993.

contracting the effect. There are, however, steps that an analyst can take to help frame the potential value of non-cancer risks associated with a specific contaminant exposure.

One approach is illustrated in Exhibit 5-3. First, one can identify the critical and prevalent non-cancer effects for a contaminant using health effects data published in EPA's Integrated Risk Information System (IRIS). In some cases, IRIS will contain enough information to develop a general description of the nature of the specific effects. If needed, additional information can be obtained by reviewing the health effects studies cited in IRIS. As suggested by the third column of the exhibit, it may be possible to develop a unit valuation for the effects depending on how clearly they are defined. Such a valuation may be based on cost-of-illness data or the transfer of willingness-to-pay data.

Finally, by looking at the population that is subject to doses at or above the RfD, one can estimate the number of people at risk of contracting the effects. Thus, even without an estimate of the probability that people exposed at this level will contract the effects, arraying the available information in this manner provides helpful insight into the valuation of the effects. Furthermore, this type of analysis can suggest whether additional investigation of the health effects data (e.g., dose-response data) is warranted.

Exhibit 5-3

SAMPLE TEMPLATE FOR CHARACTERIZATION OF NON-CANCER HEALTH RISKS AND VALUATION DATA FOR CADMIUM

Health Effect	Description of Effect	Unit Valuation (Cost of Illness or Willingness to Pay)	Population Exposed Above the RfD
Critical Effect			
Kidney Toxicity			
Prevalent Effects			
Gastrointestinal Effects			
Liver/Hepatotoxicity			
Muscoskeletal Effects			

COLLECTING INFORMATION TO SUPPORT NON-CANCER HEALTH EFFECTS ANALYSES

CHAPTER 6

The previous chapters provide the reader with a basic understanding of the theory and methods of non-cancer health effects valuation as well as some insight into the major issues that could be encountered in health effects analyses. An understanding of the economic basis for health effects valuation is critical to producing sound and effective analyses, regardless of the nature of the regulatory or policy issue of interest.

In this chapter we provide information that will help the reader get started on a non-cancer health effects benefits analysis. Exhibit 6-1 provides an overview of the chapter. In the first section, we discuss several information sources used by risk assessors to characterize the types of health effects that are associated with prevention of contaminant exposures. A basic knowledge of the methods of risk assessment and the underlying studies that characterize health effects is helpful to the economist or benefits analyst in conducting non-cancer health effects analyses. In the next section, we discuss several useful sources of information on existing economic studies of non-cancer health effects, including references to several documents EPA has developed that can facilitate a literature review. The chapter concludes with a brief review of health benefits approaches used in other Federal agencies and departments. In some cases, these non-EPA efforts provide helpful information to design strategies for valuation.

Exhibit 6-1 COLLECTING INFORMATION TO SUPPORT NON-CANCER HEALTH EFFECTS ANALYSES	
Understanding the Underlying Health Effect Literature	Epidemiological studies of human populations
	Animal Studies
	Detailed descriptions of specific symptoms in humans
	Dos-response relationships
	Health risk evaluations (toxicity information)
Identifying Existing Economic Valuation Literature	Regulatory Impact Analyses
	Programmatic Analyses
	Compendiums of relevant values and studies
	On-line inventories and databases
	Guidelines for Preparing Economic Analyses, US EPA (2000a)
Other Federal Government Analyses of Non-Cancer Health Effects	Department of Health and Human Services: Food and Drug Administration, Centers for Disease Control, Agency for Toxic Substances and Disease Registry, National Institutes of Health
	Department of Labor
	Department of Transportation
	US Department of Agriculture
	Consumer Product Safety

UNDERSTANDING THE UNDERLYING HEALTH EFFECT LITERATURE

Evaluation of non-cancer health benefits of a regulatory or policy action often starts with understanding the health effects of potential interest. Analyses of the health effects of interest are largely undertaken by health scientists and related experts; the results of those analyses may then be provided to economists and policy analysts and are a critical starting point for benefits analysis. The analyses conducted by risk assessors often identify those categories of health effects that may be influenced by the action and describe the nature of the effects — risk assessors may refer to this process as "hazard identification." The economist or benefits analyst may desire to gain a good understanding of the underlying scientific research behind the health effects assessments in order to better apply the existing economic valuation literature. Often the best way to do this is to establish a relationship with risk assessment professionals. This understanding is also useful on a broader basis to design economic analyses that recognize the strengths and limitations of the underlying health risk assessment.

Information on the effects likely to be associated with control of particular environmental contaminants may be derived from epidemiological studies of human populations or from animal studies. Epidemiology generally involves developing statistical relationships between estimates of exposure and the incidence of health effects. Such studies may be conducted in a variety of ways; for example, an epidemiologist may link the observed incidence of illness to ambient levels of

contaminants, or to levels of contaminants in specific body tissues. Another technique epidemiologists may use is to link disease incidence to proximity to a specific source of contaminants.

Data from animal studies also may be used to identify the health effects associated with specific contaminants. This type of research measures the relationship between dose and the incidence of health effects in a controlled environment designed to minimize the influence of any potentially confounding factors. However, it is often difficult to translate animal doses and health impacts into human terms, or to use these studies to determine how human responses might vary in response to changes in dose.

Regardless of the method used to estimate health impacts, the scientific data used to establish a link between exposure to pollutants and these effects will often include information important to the ensuing valuation process. For nonfatal effects, the degree to which health scientists can define the nature of the effect will vary. For some contaminants and health effects, detailed descriptions of specific symptoms in humans are available (e.g., kidney damage). In other cases, only general descriptions of effects on animals may be available (e.g., musculoskeletal toxicity) that may or may not have direct human corollaries.

In addition, EPA is just beginning to develop information on dose-response relationships for non-threshold contaminants, including most non-carcinogens. All that may be currently available for many contaminants are data on the dose at which adverse effects are unlikely to occur even in sensitive individuals (e.g., the Reference Dose, or RfD). As discussed in Chapter 5, this information, by itself, is not sufficient to determine the full range of health effects potentially associated with a contaminant, the magnitude or severity of these effects, or the change in the number of cases attributable to different exposure levels.

The results of health risk evaluations of environmental contaminants are available from a variety of sources. One frequently used source of contaminant toxicity information is EPA's Integrated Risk Information System (IRIS) — it provides summaries of a wide range of toxic, reproductive, developmental, and other effects associated with particular environmental contaminants, based on both epidemiological and animal studies. IRIS also reports the RfD, where one has been estimated, for inhalation, ingestion, and/or dermal exposure routes. Other sources of information include chemical profiles developed under the auspices of the Agency for Toxic Substance and Disease Registry (ATSDR) and a wide range of materials developed by EPA's program offices to support health risk evaluations and benefits characterization.

One example of the types of materials available from program offices is the Office of Water's Contaminant Specific Fact Sheets, which provide basic information on health effects attributable to regulated drinking water contaminants.[21] For each constituent, the fact sheets list short-term and long-term health effects of potential concern. For example, short-term health effects linked with cadmium exposure through drinking water are nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock, and renal failure; long-term health effects linked with cadmium exposure through drinking water are kidney, liver, bone, and blood damage. These materials, along with others, may provide a good starting point for non-cancer health effects analysis for environmental contaminants.

In summary, while the types of health risk information that will prove useful in any specific case will vary, understanding the basis for estimating health risk informs the process of selecting an appropriate economic valuation approach. At a minimum, benefits analysts and economists should educate themselves on the strengths and limitations of the results of health risk characterizations, preferably by working closely with health risk professionals but also through basic research into the data sources, methods, and perhaps even a sample of the primary research typically used for that type of risk assessment.

IDENTIFYING EXISTING ECONOMIC VALUATION LITERATURE

Using the best available descriptions of the effects of concern, an analyst can begin to assess the adequacy of the existing economic literature to support a non-cancer health benefits assessment. If the literature on the effect of concern appears sparse, studies of effects that are similar in nature can also be reviewed. In some cases, the existing economic valuation literature will focus on health effects that are similar, but not identical, to the effects of concern for a particular regulation. In these cases benefit transfer techniques are often useful (see Chapter 4). These techniques may include adjustments to reflect differences in the severity of the health condition, the duration of the effect, or the affected populations. For example, the available risk assessment literature tends to focus on moderately severe cases of chronic bronchitis; however, the best available valuation studies focus on the severe case of chronic bronchitis (see Viscusi, et al. 1991). Krupnick and Cropper (1992) discuss how to make these adjustments using this available literature. In addition, if a policy application requires a value for emphysema, the analyst might find the chronic bronchitis literature useful because of the similarities in symptoms and activity restrictions of the two health conditions. Alternatively, differences between the effects studied and the effects of the regulations can be addressed qualitatively and presented as one of the uncertainties inherent in the analysis.

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[21] The Contaminant Specific Fact Sheets are available in two versions, *Consumer* and *Technical*, and can be downloaded from EPA's "Drinking Water and Health" Internet site at http://www.epa.gov/OGWDW/hfacts.html.

In many cases, estimates in the literature will need to be standardized to reflect the value of a dollar in a certain specified base year (e.g., all estimates might need to be adjusted to 1998 dollars). Adjustments such as this are relatively straightforward and are often made using the Gross Domestic Product (GDP) Implicit Price Deflator, the general Consumer Price Index (CPI), or one of the CPI components (e.g., for medical expenditures). Time series for these indices are provided in the *Economic Report of the President*, published each year by the Executive Office of the President.[22]

Several resources are available to help in locating potentially relevant existing studies. For example, existing Regulatory Impact Analyses (RIAs) may provide references to relevant primary literature. Most, if not all, EPA offices have produced RIAs with examples of health effects and valuation strategies that may prove useful, and in many cases those RIAs reflect the results of extensive peer review and evaluation. Broader programmatic analyses, such as the Office of Air and Radiation's (OAR) and Office Policy Planning and Evaluation's (OPPE) retrospective study of the costs and benefits of the Clean Air Act (EPA 1997a), and the Office of Water's ongoing retrospective analyses of Clean Water Act provisions, may include references to primary economic valuation literature.[23] A wide range of commercial on-line search services may also be helpful in locating specific subjects, titles, or authors in the primary literature. In some cases, ongoing research may be useful — EPA and the National Science Foundation, for example, continue to fund a wide range of economic analyses that are potentially relevant to benefits valuation efforts.

EPA is also developing compendiums of relevant values and studies that can be useful for benefits analysis. For example, the Office of Prevention, Pesticides, and Toxic Substances has recently developed cost-of-illness estimates for many cancers, chronic conditions, and developmental effects — a list of conditions assessed and ranges of cost-of-illness estimates suggested in the document are summarized in Exhibit 6-2 (EPA 2000b).[24] In addition, the National Center for Environmental Economics (NCEE), has developed on-line inventories of cost-benefit analyses,

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[22] For example, Exhibit 6-2 includes an estimate for the cost of illness for lung cancer of $38,569 (1996$). This value can be adjusted to 1997 dollars using the CPI-Medical Care index values for 1996 (the base year) and 1997 (the target year). The February 1998 *Economic Report of the President* reports these index values are 228.2 and 234.6, respectively (the relevant tables are on page 349 in the 1998 report). The adjustment factor used is the ratio of these two values, 234.6/228.2 = 1.028, indicating an increase in the medical care index of approximately 2.8 percent for the year. Multiply the adjustment factor by the base year valuation figure of $38,569 to yield an estimate of $39,649 in 1997 dollars.

[23] For example, EPA plans to evaluate changes in human health effects as part of a retrospective analysis of the Chesapeake Bay watershed.

[24] To obtain a copy of the *Cost of Illness Handbook* call the Economic and Policy Analysis Branch of the Economic Exposure and Technology Division in OPPTS.

benefits studies, and selected Internet links. These databases are accessible through the Internet.[25] Exhibit 6-3 includes a tabular summary of some of the relevant non-cancer health effects studies included in the NCEE database, as well as other studies, and the range of values derived. Exhibit 6-3 does not reflect an exhaustive literature search for all potentially relevant values; in addition, inclusion of a study in the table and summary of the values derived does not imply that the study is recommended or approved for use in EPA analyses, although many of the studies referenced may have been used in previous EPA work. In general, analysts need to apply judgement in the use of these values or others available in the literature. We suggest analysts interested in using an existing study read the applicable study carefully, evaluate the quality of the study in light of the information presented in Chapters 2 and 3 on the theory and methods used in high-quality economic research, compare the results to other similar studies, where possible, and consult Chapter 4 for information on the conduct of benefits transfer exercises.

NON-EPA ANALYSES OF NON-CANCER HEALTH EFFECTS

In response to a wide range of regulatory requirements, several federal agencies are involved in assessing the economic impacts of non-cancer health effects. These agencies have analyzed the costs and benefits of morbidity effects stemming from a variety of circumstances. The analyses are often geared towards assessing the effects of a particular standard, disease, or incident, as opposed to a particular health effect or morbidity symptom.

Because the valuation approaches are often not symptom-based, the approach these agencies take precludes a simple transfer of values for specific health effect assessments; however, the research provides an important source of valuation information for non-cancer analyses involving "bundles" of symptoms. For instance, studies by the USDA on salmonella include costs associated with several concurrent health effects (e.g., nausea, stomachache, vomiting). To the extent that other non-cancer effects involve the same group of symptoms, these estimates may provide transferable value estimates for an analysis of those adverse health situations. This section presents a brief overview of other federal agencies' analyses that assess the costs and benefits associated with morbidity effects.

[25] The National Center for Environmental Economics home page can be found at the following Internet URL address: http://www.epa.gov/economics. Follow the directions on the home page for a listing of the available online inventories.

Exhibit 6-2

SUMMARY OF SELECTED COST OF ILLNESS VALUES[1]

Condition Evaluated	Present Value Estimates of Per-Patient Medical Costs (1996$, except where noted)
Breast Cancer	$80,143 - $99,303
Childhood Acute Lymphoblastic Leukemia	$300,922 - $342,104
Kidney Cancer	$111,901 - $120,250
Lung Cancer	$38,569[2]
Skin Cancer	$2,776 - $2,997
Asthma	$18,865 - $81,321
Coronary artery disease	$51,415 - $54,079
High blood lead levels (asymptomatic)	$5,135 - $5,200 [3]
Hypertension	$6,887 - $17,496
Chronic obstructive pulmonary disease	$15,531 - $28,041 [4]
Low Birth Weight	$47,814 - $153,312
Cleft Lip and Palate	$19,507 - $25,664
Limb Reductions	
Upper	$22,574 - $36,604
Lower	$32,422 - $67,847
Cardiac Abnormalities	
Truncus Arteriosus	$317,613 - $378,312
Transposition/DORV	$109,343 - $124,754
Tetralogy of Fallot	$164,308 - $200,083
Single ventricle	$125,271 - $230,719
Spina Bifida	$149,644 - $264,160
Cerebral Palsy	$195,386 - $700,570
Down's Syndrome	$156,155 - $353,379

Source: USEPA, *Cost of Illness Handbook*, August 1997.

[1] Values vary depending on age at onset of illness and discount rate assumptions.
[2] Not discounted because lung cancer tends to be fatal within the first year after diagnosis.
[3] This figure calculated for a risk level IV patient. See source document for more information.
[4] Estimate in 1988$.

Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES

Study (Date)	Date Data Collected	Methodology	Number of Respondents or Cases Studied	Non-cancer Health Effects Valued	Reported Range of Values[1]
Berger et al. (1987)	1984-1985	Contingent valuation	119 respondents	Seven light symptoms (coughing spells, stuffed sinuses, throat congestion, itching eyes, heavy drowsiness, headaches and nausea)	$27 - $142 per additional symptom day avoided
Chestnut et al. (1988)	1986	Cost of illness; contingent valuation; averting behavior	50 respondents	Angina	$14,359 annual cost per person (cost of illness); $40 willingness to pay per avoided additional episode (contingent valuation); $2,151 average annual expense (averting behavior)
Chestnut et al. (1996)	1986	Cost of illness; contingent valuation; averting behavior	50 respondents	Angina	Negligible cost for incremental increase in episodes (cost of illness); $38 average expenditure per perceived episode avoided (averting behavior); $40-$103 willingness to pay per avoided additional episode (contingent valuation)
Colditz (1992)	1980	Cost of illness	Not reported	Diseases resulting from obesity (non-insulin-dependent diabetes mellitus, hypertension, cardiovascular disease, gallbladder disease, and cholecystectomy)	$37.4 billion nationwide annually

Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)

Study (Date)	Date Data Collected	Methodology	Number of Respondents or Cases Studied	Non-cancer Health Effects Valued	Reported Range of Values[1]
Cropper and Krupnick (1990)	1977-1978	Cost of illness	Sample of 2,215 men for data on lost earnings; 14,000 households for data on medical costs (of which 4,789 persons report disease of interest)	Selected chronic diseases (including bronchitis, emphysema, hypertension, ischemic heart disease, and non-specific heart disease)	$566 - $11,050 annual loss in earnings; $97 - $1,257 average annual medical expenses
Dickie et al. (1987)	1986	Contingent valuation	221 respondents (165 with symptoms)	Ozone-related symptoms (sinus pain, cough, throat irritation, chest tightness, could not breath deep, pain on deep breath, out of breath easily, and wheezing/whistling breath)	$0 - $3.11 (revised bids) per symptom day avoided

Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)

Study (Date)	Date Data Collected	Methodology	Number of Respondents or Cases Studied	Non-cancer Health Effects Valued	Reported Range of Values[1]
Dickie and Gerking (1991a and 1991b)	1985-1986	Household production function	226 respondents	26 respiratory symptoms related to air pollution (including cough; throat irritation; husky voice; phlegm, sputum or mucous; chest tightness; could not take a deep breath; pain on deep respiration; out of breath easily; breathing sounds, wheezing or whistling; eye irritation; could not see as well as usual; eyes sensitive to bright light; ringing in ears; pain in ears; sinus pain; nosebleed; dry and painful nose; runny nose; fast heartbeat at rest; tired easily; faintness or dizziness; felt spaced out or disoriented; headache; chills or fever; nausea; and swollen glands)	$0.49 - $1.90 to relieve one symptom for one day
French and Mauskopf (1992)	Not reported	Quality-of-life (based on value of a statistical life)	Not applicable	Asthma, headache, cough, chronic bronchitis, and chronic arthritis	$186 - $10,780 to avoid the illness
Harrington, Krupnick and Spofford (1989)	1984	Cost of illness; averting behavior	176 respondents (cost of illness); 50 households (averting behavior)	Giardiasis	$858 - $1,255 cost of illness per case; $455 - $1,540 averting behavior per household (best estimate)

Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)

Study (Date)	Date Data Collected	Methodology	Number of Respondents or Cases Studied	Non-cancer Health Effects Valued	Reported Range of Values[1]
Hartunian, Smart and Thompson (1981)	Varies (generally 1970s)	Cost of illness	Not applicable (based on cost of illness model)	Coronary heart disease (including myocardial infarction, coronary insufficiency, and angina pectoris uncomplicated) and stroke	$20,784 direct and indirect costs for coronary heart disease; $1,510 - $9,269 direct and $11,968 - $41,429 indirect costs for strokes (present values)
Hu and Sandifer (1981)	Varies (generally 1970s)	Summarizes previous cost of illness, cost effectiveness, and cost-benefit studies	Not applicable (summarizes available studies)	13 categories of diagnostic illnesses: infective and parasitic diseases; neoplasms; endocrine, nutritional, and metabolic diseases; mental disorders; diseases of the nervous system and sense organs; diseases of the circulatory system; diseases of the respiratory system; diseases of the digestive system; diseases of the genitourinary system; diseases of the musculoskeletal system; congenital anomalies; perinatal morbidity and mortality; and accidents, poisonings and violence	Varies (no summary values provided)
Krupnick and Cropper (1992)	1989	Paired comparison (risk-risk and risk-income trade-offs)	189 respondents	Chronic bronchitis	$530,000 - $1.6 million to avoid a statistical case
Loehman et al. (1979); Loehman and De (1982); and Green et al. (1978)	1977	Contingent valuation	396 respondents	Shortness of breath, coughing and sneezing, head congestion (including eye, ear, and throat irritation)	$2 - $79 median per avoided symptom day (as reported in Green et al.)

Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)

Study (Date)	Date Data Collected	Methodology	Number of Respondents or Cases Studied	Non-cancer Health Effects Valued	Reported Range of Values[1]
Magat, Viscusi and Huber (1988)	1984	Contingent valuation and paired comparison	368 respondents	Gas poisoning from bleach, child poisoning from bleach or drain opener, hand burns from drain opener	$0.5 - $1.4 million per avoided statistical case
Magat, Viscusi and Huber (1992)	1990	Paired comparison	178 respondents	Peripheral neuropathy	$1.6 million per case avoided
Rice, Hodgson and Kopstein (1985)	1980	Cost of illness	Not reported	16 diagnostic categories: infectious and parasitic diseases; neoplasms; endocrine, nutritional, metabolic diseases and immunity disorders; diseases of blood and blood-forming organs; mental disorders; diseases of the nervous system and sense organs; diseases of the circulatory system; diseases of the respiratory system; diseases of the digestive system; diseases of the genitourinary system; diseases of the skin and subcutaneous tissue, diseases of the musculoskeletal system and connective tissue; congenital anomalies; symptoms, signs and ill-defined conditions; injury and poisoning	$455 billion nationwide annually ($211 billion in direct costs, $68 billion for morbidity, and $176 billion for mortality)
Rowe and Chestnut (1985 with 1986 addendum)	1983	Contingent valuation	82 respondents	Asthma	$21 average for a one day reduction in bad asthma days

Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)

Study (Date)	Date Data Collected	Methodology	Number of Respondents or Cases Studied	Non-cancer Health Effects Valued	Reported Range of Values[1]
Schwartz et al. (1985)	Not reported	Cost of illness	Not applicable (based on cost of illness model)	Lead-in-gasoline related effects, including children's health and cognitive effects and high blood pressure in adults	$3,500 per child, $228 per hypertensive per year
Strauss et al. (1986)	Not reported	Cost of illness	213 patients	Chronic lung disease	$6,979 average per patient per year
Thompson (1986)	Not reported	Contingent valuation	247 respondents	Rheumatoid arthritis	$5,160 annually (adjusted mean) for cure
US Environmental Protection Agency (1997)	Various years	Cost of illness	Varies by health effect	Nonfatal cancers, selected chronic conditions, and developmental effects	See Exhibit 6-2 above for summary
Tolley et al. (1986)	1984-1985	Contingent valuation	176 respondents (personal interviews)	Seven light symptoms (coughing, stuffed sinuses, throat congestion, itching eyes, drowsiness, headache, and nausea) and angina	$25 - $50 average to relieve one additional day of a light symptom; $66 - $279 average to relieve one additional day of angina
Viscusi, Magat and Forrest (1988)	1986	Paired comparison	785 respondents	Inhalation poisoning paired with skin poisoning or child poisoning from insecticide	$2,080 - $3,680 average per pair of injuries prevented
Viscusi, Magat and Huber (1991)	1988	Paired comparison	389 respondents	Chronic bronchitis	$457,000 to $1.2 million per statistical case avoided
Weiss, Gergen and Hodgson (1992)	1980-1987	Cost of illness	Not reported	Asthma	$6.2 million nationwide in 1990

Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)

Study (Date)	Date Data Collected	Methodology	Number of Respondents or Cases Studied	Non-cancer Health Effects Valued	Reported Range of Values[1]
Wittels, Hay and Gotto (1990)	1985-1986	Cost of illness	Not applicable (based on cost of treatment model)	Coronary heart disease (including acute myocardial infarction, angina pectoris, and unstable angina pectoris	$9,078 - $51,211 per event over five years

Source: EPA/NCEE Benefits Studies database, supplemented by recent literature searches.

[1] Estimates have not been standardized to reflect the value of a dollar in a certain specified base year. Standardizing values to a single year's dollars is most often done using the Gross Domestic Product (GDP) Implicit Price Deflator, the general Consumer Price Index (CPI), or one of the CPI components (e.g., for medical expenditures). Time series for these indices are provided in the *Economic Report of the President*, published each year by the Executive Office of the President.

Department of Health and Human Services

Within the Office of Public Health and Science in the Department of Health and Human Services, several organizations are involved in non-cancer valuation studies. The Food and Drug Administration, Centers for Disease Control Epidemiology Program Office, Agency for Toxic Substances and Disease Registry, and National Institutes of Health have conducted a variety of analyses to quantify the impact of adverse health effects.

Food and Drug Administration

The Food and Drug Administration (FDA) has quantified the value of non-fatal illnesses for a number of Regulatory Impact Analyses (RIAs). Using a health status index and willingness-to-pay approach, the FDA has estimated values associated with food labeling, the human health effects from the presence of lead in food, and imported food that violates Federal Food, Drug and Cosmetic regulations (Sargeant 1989).

For Department of Health and Human Services regulations restricting the sale and distribution of cigarettes and smokeless tobacco to individuals under the age of 18, the FDA estimates the economic impact of the health effects associated with tobacco use using an actual cost of avoidance technique (61 FR 44395 1996). The FDA compares the total medical costs and lost work days of smokers versus nonsmokers over their lifetimes. This OMB-reviewed rulemaking analysis does not value specific health effects; instead, the foregone earnings and total medical expenditure approach estimates the costs of a group of adverse health effect symptoms associated with tobacco use.

The FDA most recently is conducting a study of the economic impact of increasing the quality of mammographies (currently undergoing OMB review). The study estimates the benefits of cancer fatalities avoided and reduced anxiety associated with higher quality mammographies. The details of this research are currently unavailable.

Centers for Disease Control

To evaluate the costs effectiveness of health-related regulatory strategies associated with specific diseases, the CDC's Epidemiology Program Office (EPO) uses several economic valuation techniques.[26] Although currently unavailable, this office will have a bibliography of their major cost-

[26] Note that cost effectiveness analysis evaluates the relative effectiveness of different interventions, and not the total costs and benefits of a given alternative.

effectiveness analysis efforts on the World Wide Web in the near future ("An Ounce of Prevention," http://www.cdc.gov). In these analyses, the EPO has applied the cost-of-illness, quality-adjusted life-years (QALY), and willingness-to-pay approaches to estimate costs and benefits. The CDC reports their standards for cost-effectiveness evaluation in *Prevention Effectiveness: A Guide to Decision Analysis and Economic Evaluation* (CDC 1996).

CDC studies include assessments of the human health costs of various diseases, including spina bifida, diabetes, cryptosperdiosis, and giardiasis. All analyses measure costs of a "bundle" of health effects attributable to each disease and do not include symptom-specific costs. In one such study, the EPO evaluates the cost-effectiveness of efforts to limit folic acid intake in order to reduce the risk for neural tube birth defects such as spina bifida (Kelly et al. 1996).[27] To do this, the EPO applies epidemiological data to quality-adjusted life years (QALYs) gained and years of life gained approaches to capture premature mortality and morbidity effects. The morbidity effects associated with spina bifida evaluated in this analysis include incontinence, impairments of mobility, vision, and cognitive function (Kelly et al. 1996). The analysis tests the sensitivity of costs to varying dietary supplementation and food supply fortification strategies to identify the most cost-effective intervention strategy.

The EPO has also assessed the benefits and costs of a universal screening for elevated blood lead levels in one-year old children. This analysis uses the human capital approach to value IQ and other neurological behavior phenomenon (CDC 1997). Using a methodology of foregone earnings, the study reports the prevalence of elevated blood lead levels at which universal blood lead level screening is most cost effective. The CDC presents these values as guidance for health departments.

Agency for Toxic Substances and Disease Registry

The Agency for Toxic Substances and Disease Registry (ATSDR) has estimated the overall economic impact of the incidence of selected health effects associated with exposure to hazardous wastes. Currently, the Agency is in the process of publishing a paper on the costs of health affects attributable to ingestion of water contaminated with volatile organic compound (VOC) from Superfund sites (Lybarger et al., in press). The study focuses largely on the value of birth defects and strokes, but also includes discussion of other ailments, including urinary tract disorders, diabetes, eczema and skin conditions, anemia, and speech and hearing impairment. To calculate the costs of these effects, ATSDR combines estimated medical costs, long-term care costs, and lost productivity costs due to morbidity or premature mortality.

[27] Spina bifida is one of the most common types of neural tube defects causing premature mortality and serious lifelong disabilities (Kelly et al., 1996).

National Institutes of Health

The National Institutes of Health (NIH) conducts occasional studies of the cost of illness as part of their overall assessment of health effects. For example, the Task Force on the Cost Effectiveness, Quality of Care, and Financing of Asthma Care conducted a literature review of cost-of-illness studies from five different countries and developed a range of costs of asthma (NIH 1996). The Task Force estimated the total annual cost of this respiratory illness and estimated the component direct medical and indirect costs that make up the total annual cost. Costs per patient per year were also estimated. NIH's goal in these types of studies is to identify cost-effective management strategies for selected conditions.

Department of Labor

The Occupational Safety and Health Administration (OSHA) estimates the costs and benefits associated with a variety of occupational accidents in their economic analyses of proposed rules. The evaluated costs are associated with specific standards and not specific injuries or health effects. For example, for a particular working condition, OSHA may provide a cost estimate incorporating costs associated with falls, muscular and skeletal disorders, and amputations.

OSHA recently developed a system for evaluating costs associated with lost work days and injury under different working circumstances using worker's compensation data. Current OSHA analyses apply this methodology to calculate medical cost, worker's lost income, miscellaneous administrative costs associated with the accident, and indirect costs such as those associated with the disruption at a site due to an accident.

Department of Transportation

Within the Department of Transportation (DOT), the Federal Highway Administration (FHWA) conducts economic analyses to estimate accident costs for selecting among alternative transportation improvements. In their analyses, the FHWA commonly calculates comprehensive costs including: property damage, lost earnings, lost household production, medical costs, emergency services, travel delay, vocational rehabilitation, workplace costs, administrative, legal and pain and lost quality of life. The FHWA also refers to this latter cost as a "willingness-to-pay cost" (USDOT 1994).

To calculate costs, DOT analysts rely on a cost database developed by the National Public Services Research Institute to evaluate a standardized table of injuries of varying severity (Miller et al. 1988). This cost database reports costs per injury using: (1) an abbreviated injury scale; and (2) an injury severity scale. The abbreviated injury scale measures provide cost per injury for "minor","moderate", "serious", "severe", "critical", or "fatal" accidents. The severity scale provides

cost per injury for "fatal", "incapacitating", "evident", "possible", or "property damage only" accidents. For the various severity levels, this model calculates two types of costs: human capital costs, such as medical costs and productivity losses, and using jury verdict data, intangible quality of life losses, such as pain and suffering and immobility costs.

The FHWA uses these cost data to assess the impacts associated with accidents, but not specific injuries, in an attempt to reflect individuals' willingness to pay to avoid accidents. A 1984 FHWA report presents a method to incorporate individuals' willingness to pay to reduce injury accidents into the costs of fatal, injurious, and property damage accidents (FHWA 1984). In 1991, the FHWA provided a comprehensive review of accident costs, presenting the comprehensive costs associated with injury accidents, including individuals' willingness to pay to avoid injury (Urban Institute 1991).

The DOT's National Highway Transportation Safety Administration (NHTSA) also analyzes the economic costs of accidents. Blincoe (1994) uses the Miller et al. (1988) approach to update the estimates of the economic costs associated with motor vehicle crashes. The costs presented in this study only reflect the human capital costs associated with motor vehicle crashes, and not intangible costs such as pain and suffering. Jointly with the Center for Disease Control (CDC), NHTSA conducted an assessment of injury impacts in the US (Rice et al. 1989). In this report NHTSA assessed the magnitude of injury impact on individuals, government programs, and society at large. Conclusions from the report indicate high costs of injury associated with life years lost, medical resources, and pain and suffering of injured persons, families, and friends.

USDA

To support USDA's efforts to ensure the safety and quality of the US food supply, the Economic Research Service (ERS), Food Safety Branch, conducts benefit-cost analyses of various USDA regulations. These studies estimate a cost encompassing all adverse health effects associated with a particular cause (e.g., costs associated with salmonella, where symptoms include abdominal pain, nausea, stomachache, vomiting, cold chills, fever, exhaustion). Depending on the source of the health effect, the estimated values may include morbidity values measured using a value of a statistical life. In other cases, the ERS analyses estimate morbidity effects associated with certain diseases or pathogens using a cost-of-illness approach.

In a 1996 report, Buzby et al. (1996) estimate the benefits and costs of reducing the presence of microbial pathogens from all food sources to avoid foodborne disease. The report applies a cost-of-illness approach, comprised of lifetime medical costs and lost productivity (e.g., foregone earnings). The costs of productivity losses are related to premature mortality and morbidity. The report derives a value of a statistical life from Landefeld and Seskin's (1982) human capital/willingness-to-pay approach. This analysis reports morbidity and mortality effect estimates for six pathogens, each causing several types of adverse health effects. In *Food Safety*, Buzby and

Roberts (1996) update the estimates from this report. In 1997, Crutchfield et al. (1997a) use the results from the Buzby and Roberts article to present the benefits and costs associated with reducing pathogens from only meat and poultry food sources.

In 1997, Crutchfield et al. (1997b) estimate the value of reducing nitrates in water. The report uses a contingent valuation survey to estimate respondents willingness to pay for a drinking water filtration system that could reduce the health effect risks associated with nitrates in water. Respondents were told that "nitrates are chemical substances hazardous to human health if taken in large quantities"; the survey did not specify actual health effects associated with lower nitrate levels.

In an earlier effort, Crutchfield et al. (1995) use secondary research to estimate the value of groundwater contamination from agricultural chemical runoff. Although this contamination has adverse human health risks associated with it, these risks are unspecified in the analysis.

Consumer Product Safety Commission

The Consumer Product Safety Commission (CPSC) measures the costs associated with acute injuries from unregulated products after 1973 (e.g., homes, schools, recreational areas, all-terrain vehicles, furniture, lawnmowers). The Commission collects data on product injury and applies it to an injury cost model developed by National Public Services Research Institute (Miller et al., 1989). This model, also used by DOT, calculates human capital and quality of life costs. The CPSC has used this methodology to assess human health impacts related to specific products. To assess the costs associated with environmental sources of impacts, such as asbestos, the CPSC also has relied on a cost-of-illness study by Rice et al. (1989). This study assesses the magnitude of injury impact on individuals, government programs, and society at large. The CPSC has conducted analyses related to effects of benzene, petroleum distillate, and methylene chlorides in specific products. Since the focus of CPSC studies is on specific products and not environmental effects, it is difficult for the Commission to access relevant health effect analyses resulting specifically from environmental conditions.

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