HANDBOOK FOR NON-CANCER
HEALTH EFFECTS VALUATION

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

Sponsored by:

EPA Science Policy Council
U.S. Environmental Protection Agency
401 M Street S.W.
Washington, DC 20460

December 2000

ACKNOWLEDGMENTS

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.

<table>
<tr><td colspan="4" align="center">**Exhibit ES-1**

EVALUATION OF THREE MOST COMMON METHODS FOR MORBIDITY VALUATION</td></tr>
</table>

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.

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

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.

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

Environmental Policy Analysis and Evaluation

Health Risk Valuation
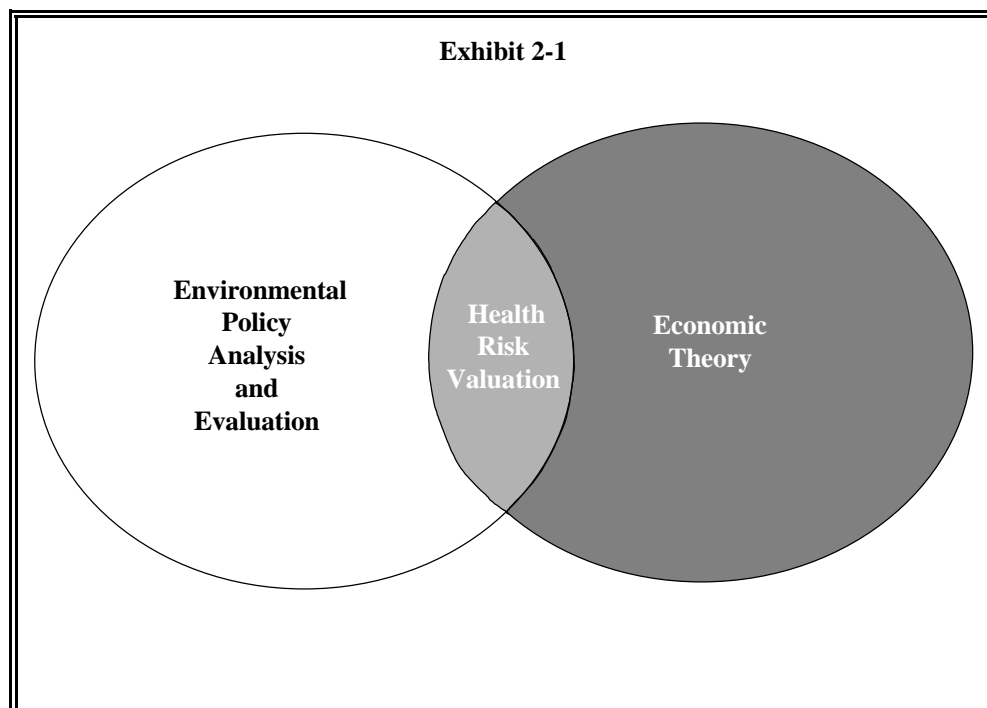
Economic Theory

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

---

[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.

---

[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).

---

[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	✓	✓	✓	✓	✓	✓	Rarely	✓
Lost Earnings	✓	✓	✓	✓	✓	✓	✓	✓
Lost Nonmarket Work	Usually	✓	✓	✓	✓	✓	✓	✓
Lost Leisure		✓	✓	✓	✓	✓	✓	✓
Third-Party Costs	✓							
Averting Costs		✓	✓	✓	✓	✓		
Pain and Suffering		✓	✓	✓	✓	✓	✓	✓
Altruism to Household Members		Sometimes	Sometimes	✓	Sometimes	Sometimes	Sometimes	✓
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.

---

[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).

---

[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).

4-1

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

STEP 1
DESCRIBE THE POLICY CASE

⬇

STEP 2
FIND RELEVANT STUDIES

⬇

STEP 3
ASSESS THE SUITABILITY OF EXISTING STUDIES FOR TRANSFER

⬇

STEP 4
TRANSFER VALUATION INFORMATION FROM STUDIES TO THE POLICY CASE

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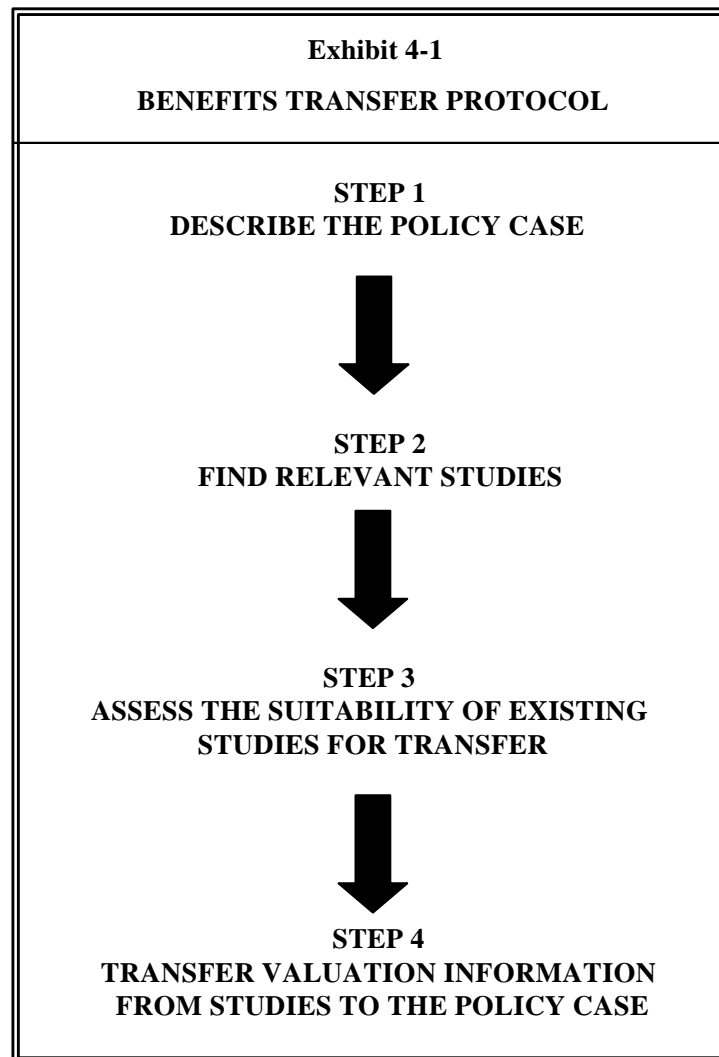
[15] See, for example, Snell, Unsworth, and Dickie, 1993.

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:

  C   similarity of health effects;
  C   similarity of populations experiencing the effects; and
  C   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.

     C   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.

     C   Similarity of health effects.
     C   Similarity of populations.
     C   Ability to adjust for differences.
     C   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.

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.

---

[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.

---

[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,

---

[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
  Lower
	
	$22,574 - $36,604
	$32,422 - $67,847

Cardiac Abnormalities
  Truncus Arteriosus
  Transposition/DORV
  Tetralogy of Fallot
  Single ventricle
	
	$317,613 - $378,312
	$109,343 - $124,754
	$164,308 - $200,083
	$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$.

<div align="center">

Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES

</div>

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

<table>
<tr>
<td colspan="6" align="center">**Exhibit 6-3**

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)</td>
</tr>
<tr>
<th>Study (Date)</th>
<th>Date Data Collected</th>
<th>Methodology</th>
<th>Number of Respondents or Cases Studied</th>
<th>Non-cancer Health Effects Valued</th>
<th>Reported Range of Values[1]</th>
</tr>
<tr>
<td>Dickie and Gerking (1991a and 1991b)</td>
<td>1985-1986</td>
<td>Household production function</td>
<td>226 respondents</td>
<td>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)</td>
<td>$0.49 - $1.90 to relieve one symptom for one day</td>
</tr>
<tr>
<td>French and Mauskopf (1992)</td>
<td>Not reported</td>
<td>Quality-of-life (based on value of a statistical life)</td>
<td>Not applicable</td>
<td>Asthma, headache, cough, chronic bronchitis, and chronic arthritis</td>
<td>$186 - $10,780 to avoid the illness</td>
</tr>
<tr>
<td>Harrington, Krupnick and Spofford (1989)</td>
<td>1984</td>
<td>Cost of illness; averting behavior</td>
<td>176 respondents (cost of illness); 50 households (averting behavior)</td>
<td>Giardiasis</td>
<td>$858 - $1,255 cost of illness per case; $455 - $1,540 averting behavior per household (best estimate)</td>
</tr>
</table>

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

<table>
<tr><td colspan="6" align="center">Exhibit 6-3

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)</td></tr>
</table>

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

<table>
<tr><td colspan="6" align="center">**Exhibit 6-3**

SUMMARIES OF NON-CANCER HEALTH EFFECTS VALUATION STUDIES (continued)</td></tr>
<tr>
<th>Study (Date)</th>
<th>Date Data Collected</th>
<th>Methodology</th>
<th>Number of Respondents or Cases Studied</th>
<th>Non-cancer Health Effects Valued</th>
<th>Reported Range of Values[1]</th>
</tr>
<tr>
<td>Wittels, Hay and Gotto (1990)</td>
<td>1985-1986</td>
<td>Cost of illness</td>
<td>Not applicable (based on cost of treatment model)</td>
<td>Coronary heart disease (including acute myocardial infarction, angina pectoris, and unstable angina pectoris</td>
<td>$9,078 - $51,211 per event over five years</td>
</tr>
<tr><td colspan="6">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.</td></tr>
</table>

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.

REFERENCES

This bibliography lists all of the citations for chapters one to six in alphabetical order and also lists several relevant citations that are not cited in the text, but that have abstracts in the *Annotated Bibliography* (Appendix A). The articles that have been summarized in the *Annotated Bibliography* have italicized *keywords* below their citations which correspond to the abstract categories in Appendix A. The abbreviations AB, CV, and COI are used for averting behavior, contingent valuation, and cost of illness respectively.

Abdalla, C.W., B.A. Roach, and D.J. Epp. "Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination." *Land Economics* 68(2): 163-169. May 1992.
Keywords: applications: AB, CV, COI

Agee, M.D. and T. D. Crocker. "Parental Altruism and Child Lead Exposure: Inferences from the Demand for Chelation Therapy." *The Journal of Human Resources* 31(3): 677-691. Summer 1996.
Keywords: applications: AB, CV, COI

Akerman, J., F.R. Johnson and L. Bergman. "Paying for Safety: Voluntary Reduction of Residential Radon Risks," *Land Economics* 67: 435-46. November 1991.
Keywords: applications: AB, CV, COI

Arthur, W.B. "The Economics of Risks to Life." *American Economic Review* 71(1): 54-64. March 1981.
Keywords: valuation theory and methods

Atkinson, S., T. Crocker, and J. Shogren. "Bayesian Exchangeability, Benefit Transfer, and Research Efficiency." *Water Resources Research* 28(3): 715-722. March 1992.
Keywords: valuation theory and methods

Baird, S.J., J.T. Cohen, J.D. Graham, A.I. Shlyakhter, and J.S. Evans. "Non-cancer Risk Assessment: A Probabilistic Alternative to Current Practice." *Human and Ecological Risk Assessment* 2(1): 79-102. March 1996.
Keyword: valuation theory and methods

Bartik, T.J. "The Estimation of Demand Parameters in Hedonic Price Models." *Journal of Political Economy* 95(1): 81-88. February 1987.
Keywords: valuation theory and methods

Bartik, T.J. "Evaluating the Benefits of Non-Marginal Reductions in Pollution Using Information on Defensive Expenditures." *Journal of Environmental Economics and Management* 15(1): 111-27. 1988.
Keywords: applications: AB, CV, COI

Beggs, S.D. *Diverse Risks and the Relative Worth of Government Health and Safety Programs: An Experimental Survey*. US Environmental Protection Agency, EPA-223-04-85-005. June 1984.

Bentkover, J.D., V.T. Covello and J. Mumpower. *Benefits Assessment: The State of the Art*. Holland: D. Reidel Publishing Company. 1986.
Keywords: valuation theory and methods

Berger, Mark C. et al. "Valuing Changes in Health Risks: A Comparison of Alternative Measures." *The Southern Economic Journal* 53: 977-984. 1987.
Keywords: valuation theory and methods

Biddle, J.E. and G.A. Zarkin. "Worker Preferences and Market Compensation for Job Risk." *The Review of Economics and Statistics:* 660-667. 1988.
Keywords: valuation theory and methods

Bjornstad, D.J. and J.R. Kahn. *The Contingent Valuation of Environmental Resources: Methodological Issues and Research Needs*. Brookfield, VT: Edward Elgar. 1996.

Blincoe, Lawrence J. "The Economic Cost of Motor Vehicle Crashes, 1994." Technical Report of the National Highway Traffic Safety Administration, Plans and Policy, Washington, DC. 1994.

Blodgett, J. *Health Benefits of Air Pollution Control: A Discussion*. CRS Report for Congress. Congressional Research Service, The Library of Congress. February 27, 1989.
Keywords: valuation theory and methods

Bovbjerg, R.R., F.A. Sloan, A. Dor and C.R. Hsieh. "Juries and Justice: Are Malpractice and Other Personal Injuries Created Equal?" *Law and Contemporary Problems* 54(1): 5-42. Winter 1991.

Bovbjerg, R.R., F.A. Sloan and J.F. Blumstein. "Public Policy: Valuing Life and Limb in Tort: Scheduling 'Pain and Suffering.'" *Northwestern University Law Review* 83: 908-976. Summer 1989.

Braden, J.B. and C.D. Kolstad, eds. *Measuring the Demand for Environmental Quality*. Netherlands: Elsevier Science Publishers BV. 1991.
Keywords: valuation theory and methods

Brajer, V., J.V. Hall and R. Rowe. "The Value of Cleaner Air: An Integrated Approach." *Contemporary Policy Issues* 9: 81-91. April 1991.
*Keywords: general application*s

Brennan, K.M. and R.M. Black III. *Methodology for Valuing Health Risks of Ambient Lead Exposure*. Report to the Ambient Studies Branch, Office of Air Quality Planning and Standards, US Environmental Protection Agency. Mathtech, Inc., NJ. December 1987.
Keywords: regulatory support document

Bresnahan, B.W. and M. Dickie. "Averting Behavior and Policy Evaluation." *Journal of Environmental Economics and Management* 29(3) Part 1: 378-92. November 1995.
Keywords: valuation theory and methods

Bresnahan, B.W., M. Dickie and S. Gerking. "Averting Behavior and Urban Air Pollution." *Land Economics* 73(3): 340-357. August 1997.
Keywords: applications: AB, CV, COI

Buzby, J.C. and T. Roberts. "ERS Updates US Foodborne Disease Costs for Seven Pathogens." *Food Safety* 19 (3). September-December 1996.

Buzby, J.C., T. Roberts, C.T. Jordan-Lin, J.M. MacDonald. *Bacterial Foodborne Disease: Medical Costs and Productivity Losses.* USDA, ERS, Agricultural Economic Report Number 741. August, 1996.

Cambridge Economics, Inc. *Contingent Valuation: A Critical Assessment*. Report of a Symposium sponsored by Exxon Corporation. Cambridge, MA: Cambridge Economics, Inc. April 2 and 3, 1992.
Keywords: valuation theory and methods

Carson, R.T. and R.C. Mitchell. "Contingent Valuation and the Legal Arena" in *Valuing Natural Assets: The Economics of Natural Resource Damage Assessment* edited by R.J. Kopp and V.K. Smith. Washington, DC: Resources for the Future. 1993.

Centers for Disease Control (CDC). *Prevention Effectiveness: A Guide to Decision Analysis and Economic Evaluation.* Oxford University Press. 1996.

Centers for Disease Control (CDC). *Screening Young Children for Lead Poisoning: Guidance for State and Local Health Officials.* Atlanta: CDC. 1997.

Chase, O.G. "Helping Jurors Determine Pain and Suffering Awards." *Hofstra Law Review* 23: 763-790. Summer 1995.

Chestnut, L.G. *Human Health Benefits from Sulfate Reductions Under Title 4 of the 1990 Clean Air Act Amendments.* Final Report to the Office of Air and Radiation, US Environmental Protection Agency. 1995.
Keywords: general applications

Chestnut, L.G. et al. *Heart Disease Patients' Averting Behavior, Costs of Illness, and Willingness to Pay to Avoid Angina Episodes*. Final Report to the Office of Policy Analysis, US Environmental Protection Agency. October 1988.
Keywords: applications: AB, CV, COI

Chestnut, L.G. and D.M. Violette. *Estimates of Willingness to Pay for Pollution-Induced Changes in Morbidity: A Critique for Benefit-Cost Analysis of Pollution Regulation*. Report to the Office of Policy Analysis, US Environmental Protection Agency. September 1984.
Keyword: applications: AB, CV, COI

Chestnut, L.G. and D.M. Violette. *The Relevance of Willingness-to-Pay Estimates of the Value of a Statistical Life in Determining Wrongful Death Awards*. US Environmental Protection Agency 230-07-90-079. June 1990.

Chestnut, L.G. and D.M. Violette. *Valuing Risks: New Information on the Willingness to Pay for Changes in Fatal Risks*. prepared for the Office of Policy, Planning and Evaluation, US Environmental Protection Agency. 1989.

Chestnut, L.G., L.R. Keller, W.E. Lambert, and R.D. Rowe. "Measuring Heart Patients' Willingness to Pay for Changes in Angina Symptoms." *Medical Decision Making* 16: 65-77. 1996.
Keywords: applications: AB, CV, COI

Cifuentes, L.A. and L.B. Lave. "Economic Valuation of Air Pollution Abatement: Benefits from Health Effects." *Annual Review of Energy and the Environment* 18: 319-342. 1993.
Keywords: general applications

Ciracy-Wantrup, S.V. "Capital Returns from Soil-Conservation Practices." *Journal of Farm Economics* 29: 1181-1196. 1947.
Keywords: applications: AB, CV, COI

Cohen, M.A. "Pain, Suffering and Jury Awards: A Study of the Cost of Crime to Victims." *Law and Society Review* 22: 537-555. 1988.

Colditz, G.A. "Economic Costs of Obesity." *American Journal of Clinical Nutrition* 55: 503S-507S. 1992.
Keywords: applications: AB, CV, COI

Conley, B.C. "The Value of Human Life in the Demand for Safety." *The American Economic Review* 66(1): 45-55. March 1976.
Keywords: valuation theory and methods

Cooper, B.S. and D.P. Rice, "The Economic Cost of Illness Revisited." *Social Security Bulletin:* 21-36. February 1976.
Keywords: applications: AB, CV, COI

Courant, P.N. and R.C. Porter. "Averting Expenditure and the Cost of Pollution." *Journal of Environmental Economics and Management* 8(4): 321-329. December 1981.
Keywords: valuation theory and methods

Croley, S.P. and J.D. Hanson. "The Nonpecuniary Costs of Accidents: Pain and Suffering Damages in Tort Law." *Harvard Law Review* 108: 1785-1917. June 1995.

Cropper, M.L. "Measuring the Benefits from Reduced Morbidity." *American Economic Association Papers and Proceedings* 71(2): 235-240. May 1981.
Keywords: valuation theory and methods

Cropper, M.L. *Outline: Benefits Estimation Seminars: Valuing the Health Impacts of Water Pollution*. January 23, 1996.
Keywords: valuation theory and methods

Cropper, M.L., and A.M. Freeman III. "Environmental Health Effects." *Measuring the Demand for Environmental Quality.* J.B. Braden and C.D. Kolstad (ed.) North-Holland, New York. 1991.
Keywords: valuation theory and methods

Cropper, M.L. and A.M. Freeman III. *Valuing Environmental Health Effects*. Washington, DC: Resources for the Future. March 1990.
Keywords: valuation theory and methods

Cropper, M.L. and A.M. Freeman III. *Estimating Individuals' Values for Health Benefits*. CRS Report for Congress. Congress Research Service, The Library of Congress. January 1, 1989.
Keywords: valuation theory and methods

Cropper, M.L. and A.J. Krupnick. *The Social Costs of Chronic Heart and Lung Disease*. Resources for the Future, Washington, DC. June 1990.
Keywords: applications: AB, CV, COI

Cropper, M.L. and F.G. Sussman. "Valuing Future Risks to Life." *Journal of Environmental Economics and Management* 19(3): 160-174. September 1990.
Keywords: valuation theory and methods

Cropper, M.L., S. Ayded, and P. Portney. *Public Preference for Life Saving*. Resources for the Future, Washington, DC. May 1992.
Keywords: applications: AB, CV, COI

Crutchfield, S., J.C. Cooper, D. Hellerstein. *Benefits of Safer Drinking Water: The Value of Nitrate Reduction.* USDA, ERS, Agricultural Economic Report Number 752. June 1997b.

Crutchfield, S.R., P.M. Feather, D.R. Hellerstein. *The Benefits of Protecting Rural Water Quality: An Empirical Analysis.* USDA, ERS, Agricultural Economic Report Number 701. January 1995.

Crutchfield, S., J.C. Buzby, T. Roberts, M. Ollinger, C.-T. Jordan-Lin. *An Economic Assessment of Food Safety Regulations: The New Approach to Meat and Poultry Inspection.* USDA, ERS, Agricultural Economic Report Number 755. July 1997a.

Cummings, R.G., D.S. Brookshire, and W.D. Schulze, eds. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method.* New Jersey: Rowman and Allanheld. 1986.
Keywords: valuation theory and methods

Danzon, P.M. and Lillard. "Settlement Out of Court: The Disposition of Medical Malpractice Claims." *Journal of Legal Studies* 12: 345-357. 1983.

Dardis, R. "The Value of Life: New Evidence From the Marketplace." *The American Economic Review* 70(5): 1077-1082. December 1980.

Davis, R.K. *The Value of Outdoor Recreation: An Economic Study of the Maine Woods*. Ph.D. Dissertation. Harvard University, Cambridge, MA. 1963.
Keywords: applications: AB, CV, COI

Department of Health and Human Services, Food and Drug Administration. "Regulations Restricting the Sale and Distribution of Cigarettes and Smokeless Tobacco to Protect Children and Adolescents, Final Rule." 61 FR 44395. August 28, 1996.
Keywords: regulatory support document

Desvousges, William H. et al. *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method*. Edward Elgar: UK. 1998.
Keywords: benefits transfer

Desvousges, W.H., F.R. Johnson, and H.S. Banzhaf. *Assessing Environmental Externality Costs for Electricity Generation*. Prepared for Northern States Power Company by Triangle Economic Research. December 1994.
Keywords: general applications

Diamond, P.A. and Hausman, J.A. "Contingent Valuation: Is Some Number Better Than No Number?" *Journal of Economic Perspectives* 8(4): 45-64. Fall 1994.
Keywords: valuation theory and methods

Dickie, M. and S. Gerking. "Valuing Reduced Morbidity: A Household Production Approach."
Southern Economic Journal 57(3): 690-702. 1991a.
Keywords: valuation theory and methods

Dickie, M. and S. Gerking. "Willingness to Pay for Ozone Control: Inferences from the Demand for
Medical Care." *Journal of Environmental Economics and Management* 21(1): 1-16. July 1991b.
*Keywords: general application*s

Dickie, M., S. Gerking, W. Schulze, A. Coulson, and D. Tashkin. *Improving Accuracy and Reducing
Costs of Environmental Benefit Assessments: Value of Symptoms of Ozone Exposure: An
Application of the Averting-Behavior Method.* Draft Report to the Office of Policy, Planning and
Evaluation, US Environmental Protection Agency. September 1986.
Keywords: applications: AB, CV, COI

Dickie, M., S. Gerking, D. Brookshire, D. Coursey, W. Schulze, A. Coulson, and D. Tashkin.
*Improving Accuracy and Reducing Costs of Environmental Benefit Assessments: Reconciling
Averting Behavior and Contingent Valuation Benefit Estimates of Reducing Symptoms of Ozone
Exposure.* Draft Report to the Office of Policy, Planning and Evaluation, US Environmental
Protection Agency. September 1987.
Keywords: applications: AB, CV, COI

Dolan, P., C. Gudex, P. Kind, A. Williams. "Valuing Health States: A Comparison of Methods."
Journal of Health Economics 15: 209-231. 1996.
Keywords: valuation theory and methods

Dor, A, P.J. Held, and M.V. Pauly. "The Medicare Costs of Renal Dialysis - Evidence from a
Statistical Cost Function." *Medical Care* 30(10): 879-891. 1992.
Keywords: applications: AB, CV, COI

Doyle, J.K., G.H. Mclelland, W.D. Schulze, S.R. Elliott and G.W. Russell. "Protective Responses
to Household Risk: A Case Study of Radon Mitigation." *Risk Analysis.* 11(1): 121-134. March 1991.
Keywords: applications: AB, CV, COI

Elixhauser, A., R.M. Andrews, and S. Fox. *Clinical Classifications for Health Policy Research:
Discharge Statistics By Principle Diagnosis and Procedure.* Agency for Health Care Policy and
Research (AHCPR), Center For General Health Services Intramural Research, US Department of
Health and Human Services.1994.

Epple, D. "Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for
Differentiated Products." *Journal of Political Economy* 95(1): 59-80. 1987.
Keywords: valuation theory and methods

Evans, R.W. et al. "The Quality of Life of Patients with End-Stage Renal Disease." *New England Journal of Medicine* 312(9): 553-559. February 1985.
*Keywords: general application*s

Evans, W.N. and W.K. Viscusi. "Estimation of State-Dependent Utility Functions Using Survey Data." *The Review of Economics and Statistics:* 94-104. 1991.
Keywords: valuation theory and methods

Federal Highway Administration (FHWA). "Alternative Approaches to Accident Cost Concepts." Report No. FHWA-RD-83-079. Federal Highway Administration, Washington, DC. January 1984.

Fisher, W.L., L. Chestnut, and D.M. Violette. "The Value of Reducing Risks of Death: A Note on New Evidence." *Journal of Policy Analysis and Management* 8(1): 88-100. 1989.
Keywords: valuation theory and methods

Fischoff, B. et al. "How Safe is Safe Enough? A Psychometric Study of Attitudes Towards Technological Risks and Benefits." *Policy Sciences* 9: 127-152. 1978.

Fisher, A., L.G. Chestnut, and D.M. Violette. "The Value of Reducing Risks of Death: A Note on New Evidence." *Journal of Policy Analysis and Management* 8(1): 88-100. Winter 1989.
Keywords: valuation of mortality risk

Freeman, A.M. III. "*Ex Ante* and *Ex Post* Values for Changes in Risks." *Risk Analysis* 9(3): 309-317. 1989.
Keywords: valuation theory and methods

Freeman, A.M. III. *The Measurement of Environmental and Resource Values: Theory and Methods.* Washington, DC: Resources for the Future. 1993.
Keywords: valuation theory and methods

Freeman, A.M. III. "Supply Uncertainty, Option Price, and Option Value." *Land Economics* 61(2): 176-181. May 1985.
Keywords: valuation theory and methods

French, M.T. and J.A. Mauskopf. "A Quality-of-Life Method for Estimating the Value of Avoided Morbidity." *American Journal of Public Health* 82(11): 1553-1555. November 1992.
Keywords: valuation theory and methods

French, M.T., J.A. Mauskopf, J.L. Teague, E.J. Roland. "Estimating the Dollar Value of Health Outcomes from Drug-Abuse Interventions." *Medical Care* 34(9): 890-910. 1996.
Keywords: valuation theory and methods

Furby, L. and B. Fischhoff. *Specifying Subjective Evaluations: A Critique of Dickie et al.'s Interpretation of their Contingent Valuation Results for Reduced Minor Health Symptoms*. Report to the Office of Policy, Planning, and Evaluation, US Environmental Protection Agency. Eugene Research Institute, OR. June 1988.
Keywords: valuation theory and methods

Garner, T.I. *Economic Analysis of End-Stage Renal Disease Treatments*. Dissertation, University of Maryland. Volume 46/01-A of Dissertation Abstracts International: 210. 1984.
Keywords: applications: AB, CV, COI

Garner, T.I. and R. Dardis. "Cost-Effectiveness Analysis of End-Stage Renal Disease Treatments." *Medical Care* 1: 25-34. Janurary 1987.
Keywords: applications: AB, CV, COI

Geistfeld, M. "Placing a price on pain and suffering: A Method for Helping Juries Determine Tort Damages for Nonmonetary Injuries." *California Law Review* 83: 773-851. May 1985.

Gerking, S. and L.R. Stanley. "An Economic Analysis of Air Pollution and Health: The Case of St. Louis." *The Review of Economics and Statistics* 68(1): 115-121. February 1986.
Keywords: valuation theory and methods

Green, A. et al. *An Interdisciplinary Study of the Health, Social and Environmental Economics of Sulfur Oxide Pollution in Florida*. Report to the Florida Sulfur Oxides Study Inc. Interdisciplinary Center for Aeronomy and Atmospheric Sciences, University of Florida, Gainesville, FL. February 1978.
Keywords: general applications

Grossman, C., W. Morton, and R. Nussbaum. "Hypothyroidism and Spontaneous Abortions Among Hanford, Washington Downwinders." *Archives of Environmental Health* 51(3): 175-176. May/June 1996.

Gudex, C.M. "Health-Related Quality-of-Life in End-Stage Renal-Failure." *Quality of Life Research* 4(4): 359-366. 1995.
Keywords: general applications

Hall, J.V. et al. *Economic Assessment of the Health Benefits from Improvements in Air Quality in the South Coast Air Basin*. Final Report to the South Coast Air Quality Management District. California State University Fullerton Foundation, CA. June 1989.
Keywords: applications

Hammitt, J.K. *Automobile Accident Compensation, Volume II: Payments by Auto Insurers*. Santa Monica, California: The Rand Corporation. 1985.

Hanemann, W.M. "Valuing the Environment through Contingent Valuation." *Journal of Economic Perspectives* 8(4): 19-43. Fall 1994.
Keywords: valuation theory and methods

Hanley, N. and C. Spash. *Cost-Benefit Analysis and the Environment*. Brookfield, VT: Edward Elgar Publishing. 1993.
Keywords: valuation theory and methods

Harrington, W., and P.R. Portney. "Valuing the Benefits of Health and Safety Regulation." *Journal of Urban Economics* 22: 101-112. 1987.
Keywords: valuation theory and methods

Harrington, W., A.J. Krupnick and W.O. Spofford, Jr. "The Economic Losses of a Waterborne Disease Outbreak." *Journal of Urban Economics* 25(1): 116-137. January 1989.
Keywords: applications: AB, CV, COI

Hartunian, N.S., C.N. Smart, M.S. Thompson. *The Incidence and Economic Costs of Major Health Impairments*. Lexington, MA: Lexington Books. 1981.
Keywords: applications: AB, CV, COI

Haveman, R. and B. Wolfe. "The Economic Well-Being of the Disabled: 1962-84." *Journal of Human Resources* 25(1): 32-54. Winter 1990.
Keywords: general applications

Held, P.J., et al. *Cost Effectiveness of ESRD Treatment Modalities*. The Urban Institute, Washington, DC. Final Report to Health Care Financing Administration. April 30, 1992.
Keywords: applications: AB, CV, COI

Hensler, D.R., M.S. Marquis, A.F. Abrahamse, S.H. Berry, P.A Ebener, E.G. Lewis, E.A. Lind, R.J. MacCoun, W.G. Manning, J.A. Rogowski, M.E. Viana. *Compensation for Accidental Injuries in the United States.* Santa Monica, California: RAND. 1991.

Hoffman, C., D. Rice, and H.S. Sung. "Persons with Chronic Conditions: Their Prevalence and Costs" *JAMA* 276(18): 1473-1479. November 13, 1996.
Keywords: applications: AB, CV, COI

Hori, H. "Revealed Preferences for Public Goods." *American Economics Review* 65: 978-991. 1975.

Hu, T., and F.H. Sandifer. *Synthesis of Cost-of-Illness Methodology: Part I.* Report to the National Center for Health Services Research, Department of Health and Human Services. 1981.
Keywords: valuation theory and methods

Ivanov, V.K., and A.F. Tsyb, "Chernobyl Radiation Risks: Assessments of Morbidity, Mortality, and Disability Rates According to the Data of the National Radiation and Epidemiological Registry, 1995." in *Nagasaki Symposium: Radiation and Human Health*, edited by S. Nagataki and S. Yamashita. New York: Elsevier Science Publishers B.V.: 1996.

Johansson, P. *The Economic Theory and Measurement of Environmental Benefits*. Cambridge, England: Cambridge University Press. 1987.
Keywords: valuation theory and methods

Johansson, P. *Evaluating Health Risks: An Economic Approach*. Cambridge, England: Cambridge University Press. 1995.
Keywords: valuation theory and methods

Johnson, R.F., M.C. Ruby, W.H. Desvousges, A.R. Gable, P. De Civita, and D. Steib. *Using Stated Preferences and Health-State Classifications to Value the Health Benefits of Air Quality Programs.* Public Works and Government Services Canada. August 1997.

Johnson, W.G. and J. Lambrinos. "Wage Discrimination Against Handicapped Men and Women." *The Journal of Human Resources* 20(2): 264-277. Spring 1985.
Keywords: general applications

Jones-Lee, M.W. "Altruism and the Value of Other People's Safety." *Journal of Risk and Uncertainty* 4: 213-219. April 1991.
Keywords: valuation theory and methods

Jones-Lee, M.W. "Paternalistic Altruism and the Value of a Statistical Life." *The Economic Journal* 102: 80-90. January 1992.
Keywords: valuation theory and methods

Jones-Lee, M.W., M. Hammerton, and P.R. Phillips. "The Value of Safety: Results of a National Sample Survey," *The Economic Journal* 95: 49-72. March 1985.
Keywords: applications: AB, CV, COI

Joyce, T.J., M. Grossman, and F. Goldman. "An Assessment of the Benefits of Pollution Control: The Case of Infant Health." *Journal of Urban Economics* 25(1): 32-51. January 1989.
Keywords: applications: AB

Kakalik, J., et al. *The Cost of Special Education*. Rand Corporation Report N-1791-ED.1981.

Kelly, A.E., A.C. Haddix, K.S. Scanlon, C.G. Helmick, and J. Mulinare. "Appendix B: Cost-Effectiveness of Strategies to Prevent Neural Tube Defects" in *Cost-Effectiveness in Health and Medicine* edited by M.R. Gold, L.B. Russell, J.E. Siegel, M.C. Weinstein. Oxford University Press. 1996.

Kopp, R.J. "Why Existence Value Should be Used in Cost-Benefit Analysis." *Journal of Policy Analysis and Management* 11(1): 123-130. 1992.
Keywords: valuation theory and methods

Krupnick, A.J. *Benefit Estimation and Environmental Policy: Setting the NAAQS for Photochemical Oxidants*. Resources for the Future, Washington, DC. December 1986.
Keywords: valuation theory and methods

Krupnick, A.J. and M.L. Cropper. "The Effect of Information on Health Risk Valuations." *Journal of Risk and Uncertainty* 5: 29-48. 1992.
Keywords: applications: AB, CV, COI

Krupnick, A.J. and M.L. Cropper. *Valuing Chronic Morbidity Damages: Medical Costs, Labor Market Effects, and Individual Valuations*. Report to the Office of Policy, Planning, and Evaluation, US Environmental Protection Agency. Resources for the Future, Washington, DC. February 1989.
Keywords: applications: AB, CV, COI

Krupnick, A.J. and R.J. Kopp. *The Health and Agricultural Benefits of Reductions in Ambient Ozone in the United States*. Resources for the Future, Washington, DC. August 1988.
Keywords: general applications

Krupnick, A.J., and W. Harrington, and B. Ostro. "Ambient Ozone and Acute Health Effects: Evidence from Daily Data." *Journal of Environmental Economics and Management* 18: 1-18. 1990.
*Keywords: general application*s

Kuik, O.J., F.H. Oosterhuis, H.M.A. Jansen. *European Communities Environmental Policy Series: Assessment of Benefits of Environmental Measures*. London, England: Graham & Trotman. 1992.
Keywords: valuation theory and methods

Landefeld, J. and E.P. Seskin. "The Economic Value of Life: Linking Theory to Practice." *American Journal of Public Health* 72(6): 555-566. June 1982.
Keywords: valuation theory and methods

Lang, C., G. Yarwood, R. Laconde, and R. Bloxam. *Environmental and Health Benefits of Cleaner Vehicles and Fuels*. Prepared for Canadian Council of Ministers of the Environmental Task Force on Cleaner Vehicles and Fuels. October 1995.
Keywords: application

Leebron, D.W. "Final Moments: Damages for Pain and Suffering Prior to Death." *New York University Law Review* 64: 256-360. May 1989.

Levin, F.S. "Pain and Suffering Guidelines: A Cure for Damages Measurement 'Anomie'," *University of Michigan Law Review* 22: 303-332. Winter 1989.

Link, A.N. *Evaluating Economic Damages: A Handbook for Attorneys*. Westport, Conn: Quorum Books. 1992.
Keywords: valuation theory and methods

Litai, D. "A Risk Comparison Methodology for the Assessment of Acceptable Risk." MIT Dissertation. 1980.

Loehman, E.T. et al. "Distributional Analysis of Regional Benefits and Cost of Air Quality Control." *Journal of Environmental Economics and Management* 6: 222-243. 1979.
Keywords: general applications

Loehman, E.T. et al. *An Interdisciplinary Study of the Health, Social and Environmental Economics of Sulfur Oxide Pollution in Florida*. Report to the Florida Sulfur Oxides Study, Inc. Interdisciplinary Center for Aeronomy and (other) Atmospheric Sciences, University of Florida, Gainesville, FL. 1978.
Keywords: applications: AB, CV, COI

Loehman, E.T. and V.H. De. "Application of Stochastic Choice Modeling to Policy Analysis of Public Goods: A Case Study of Air Quality Improvements." *The Review of Economics and Statistics* 64(3): 474-480. 1982.
Keywords: applications: AB, CV, COI

Loomis, J.B. "The Evolution of A More Rigorous Approach to Benefit Transfer: Benefit Function Transfer." *Water Resources Research* 28(3): 701-705. March 1992.
Keywords: benefits transfer

Lopez, A., R.N. Dexter, J.C. Reinert. "Valuation of Developmental Toxicity Outcomes." *The Environmental Professional* 17: 186-192. 1995.
Keywords: general applications

Lybarger, J.A., R. Lee, D.P. Vogt, R.M. Perhac, R.F. Spengler, and D.R. Brown. "Medical Costs and Lost Productivity from Health Conditions at Volatile Organic Compound Contaminated Superfund Sites." *Environmental Research*. (in press).

Magat, W.A., W.K. Viscusi, and J. Huber. "Paired Comparison and Contingent Valuation Approaches to Morbidity Risk Valuation." *Journal of Environmental Economics and Management* 15: 395-411. 1988.
Keywords: applications: AB, CV, COI

Mauskopf, J.A., and M.T. French. "Estimating the Value of Avoiding Morbidity and Mortality from Foodborne Illnesses." *Risk Analysis* 11(4): 619-631. 1991.
Keywords: applications: AB, CV, COI

McDonnell, W.F., K.E. Muller, P.A. Bromberg, and C.M. Shy. "Predictors of Individual Differences in Acute Responses to Ozone Exposure." *American Review of Respiratory Disorders* 147(4): 818-825. April 1993.
Keywords: general applications

Miller, T.R. "Injury Cost Estimation: A Pain in the Neck." mimeo, 1997.

Miller, T.R. "The Plausible Range for the Value of Life: Red Herrings Among the Mackerel." *Journal of Forensic Economics* 3(3): 17-39. 1990.
Keywords: valuation of mortality risk

Miller, T.R. "Willingness-to-Pay Comes of Age: Will the System Survive?" *Northwestern University Law Review* 83: 876-907. Summer 1989.

Miller, T.R., C.P. Brinkman, and S. Luchter. "Crash Costs and Safety Investment." Proceedings of the 32nd Annual Conference, Association for the Advancement of Automotive Medicine, Des Plaines, IL. 1988.

Miller, T.R., S. Luchter, and C. P. Brinkman. "Crash Costs and Safety Investment." *Accident Analysis and Prevention* 21(4): 303-315. 1989.

Mishan, Edward J. *Cost-Benefit Analysis*. Fourth Edition. New York: Praeger. 1988.
Keywords: valuation theory and methods

Mitchell, R. and R.T. Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington, DC: Resources for the Future. 1989.
Keywords: valuation theory and methods

Morgan, M.G. and M. Henrion. *Uncertainty, A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Anlaysis*. New York, NY: Cambridge University Press. 1990.

Murdoch, J.C. and M.A. Thayer. "The Benefits of Reducing the Incidence of Nonmelanoma Skin Cancers: A Defensive Expenditures Approach." *Journal of Environmental Economics and Management* 18(2) Part 1: 107-119. March 1990.
Keywords: applications: AB, CV, COI

National Center for Health Statistics (NCHS). *Current Estimates from the National Health Interview Survey, 1987*. Series 10 (149). Washington, DC: US GPO. 1988.

National Institutes of Health (NIH). National Heart, Lung, and Blood Institute. *National Asthma Education and Prevention Program Task Force on the Cost Effectiveness, Quality of Care, and Financing of Asthma Care*. NIH publication no. 55-807, September, 1996.

National Oceanic and Atmospheric Administration (NOAA). *Natural Resource Damage Assessments Under the Oil Pollution Act of 1990. Appendix I: Report of the NOAA Panel on Contingent Valuation.* 58 FR 4601-4614. January 15, 1993.
Keywords: valuation theory and methods

National Research Council (NRC). *Health Effects of Exposure to Low Levels of Ionizing Radiation (BIER V).* Committee on the Biological Effects of Ionizing Radiations, Board of Radiation Effects Research, Commission on Life Sciences, National Academy Press, Washington, DC. 1990.

Neumann, J.E., M.T. Dickie, and R.E. Unsworth. Industrial Economics, Incorporated. Memorandum to Jim DeMocker, US Environmental Protection Agency, Office of Air and Radiation. Linkage Between Health Effects Estimation and Morbidity Valuation in the Section 812 Analysis - Draft Valuation Document. March 31, 1994.

O'Connell, J. and K. Carpenter. "Payment for Pain and Suffering Through History." *Insurance Council Journal*. July 1983.

Ostro, B.D. and L.G. Chestnut. "Assessing the Health Benefits of Reducing Particulate Matter Air Pollution in the United States." *Environmental Research* 76(2): 94-106. February 1998.
Keywords: application

Ostro, B., J.M. Sanchez, C.A. and G.S. Eskeland. *Air Pollution and Mortality: Results from Santiago, Chile*. The World Bank. 1995.

Pearce, D.W. and R.K. Turner. *Economics of Natural Resources and the Environment*. Maryland: Johns Hopkins University. 1990.
Keywords: valuation theory and methods

Pfennigstorf, W. and D.G. Gifford. *A Comparative Study of Liability Law and Compensation Schemes in Ten Countries and the United States.* Oak Brook, Illinois: Insurance Research Council. 1991.

Pope, C.A. et al. "Particulate Air Pollution as a Predicator of Mortality in a Prospective Study of U.S. Adults." *American Journal of Respiratory & Critical Care Medicine* 151: 669-674. 1995.

Portney, P.R. "Trouble in Happyville." *Journal of Policy Analysis and Management* 11(1): 131-132. 1992.

Prahl, R.J. and S.M. Ultrata. *Liability Claim Concepts and Practices.* Malvern, Pennsylvania: Insurance Institute of America. 1985.

Pratt, J.W. and R.J. Zeckhauser. "Willingness to Pay and the Distribution of Risk and Wealth." *Journal of Political Economy* 104(4): 747-763. 1996.

Priest, G.L. and B. Klein. "The Selection of Disputes for Litigation." *Journal of Legal Studies* 13: 1-56. 1984.

Ransom, M.R. and C.A. Pope. "Elementary-School Absences and PM(10) Pollution in Utah Valley." *Environmental Research* 58(2): 204-219. August 1992.
Keywords: general applications

Reinert, J.C., S.G. Slotnick and D.J. Viviani. "A Discussion of the Methodologies Used in Pesticide Risk-Benefit Analysis." *The Environmental Professional* 12: 94-100. 1990.
Keywords: valuation theory and methods

Rice, D.P. "Estimating the Cost of Illness." *Health Economics Series*. Public Health Service, Washington, DC. May 1966.
Keywords: applications: AB, CV, COI

Rice, D.P., E. MacKenzie and Associates. "Cost of Injury in the United States: A Report to Congress." University of California, San Francisco and Johns Hopkins University. 1989.

Rice, D.P., T.A. Hodgson and A.N. Kopstein. "The Economic Cost of Illness: A Replication and Update." *Health Care Financing Review* 39: 61-81. 1985.
Keywords: applications: AB, CV, COI

Rodgers, G.B. "Estimating Jury Compensation for Pain and Suffering in Product Liability Cases Involving Nonfatal Personal Injury." *Journal of Forensic Economics* 6(3): 251-262. 1993.

Rosen, S. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 81(1): 34-55. January-February 1974.

Rosenthal, D.H. and R.H. Nelson. *Why Existence Value Should Not be Used in Cost-Benefit Analysis*. Paper. June 1991.
Keywords: valuation theory and methods

Rowe, R.D. et al. *Benefits of Air Pollution Control in California*. Volume 2. Report to the California State Air Resources Board. Energy and Resource Consultants, Inc., Boulder, CO. December 1986.
Keywords: regulatory support document

Rowe, R.D., et al. *The New York Electricity Externality Study*. Oceana Publications, Inc. Dobbs Ferry, NY. 1995.

Rowe, R.D. and L.G. Chestnut. *Oxidants and Asthmatics in Los Angeles: A Benefits Analysis*. Report to the Office of Policy Analysis, US Environmental Protection Agency. Energy and Resource Consultants, Inc., Boulder, CO. March 1985.
Keywords: applications: AB, CV, COI

Rowe, R.D. and L.G. Chestnut. *Valuing Changes in Morbidity: WTP Versus COI Measures*. Boulder, CO: Resources for the Future. Paper presented at the American Economic Association annual meeting, Dallas, Texas. Energy and Resource Consultants, Inc., Boulder, CO. December 1986.
Keywords: applications: AB, CV, COI

Salkever, D. "Updated Estimates of Earnings Benefits from Reduced Exposure of Children To Environmental Lead." *Environmental Research* 70: 1-6. 1995.

Sargeant, K.A. *Health Benefits Assessment in EPA and Other Federal Agencies*. Report to Economics and Technology Division, Office of Pesticides and Toxic Substances, US Environmental Protection Agency. August 1989.
Keywords: valuation theory and methods

Schwab C., N.G. Christie and N.C. Soguel. "The Pain of Rode Accident Victims and the Bereavement of their Relatives: A Contingent Valuation Experiment." *Journal of Risk and Uncertainty* 13: 277-291. 1996.

Schwartz, J. "Societal Benefits of Reducing Lead Exposure." *Environmental Research* 70: 1-6. 1994.

Seskin, E.P. "An Analysis of Some Short-Term Health Effects of Air Pollution in the Washington, DC Metropolitan Area." *Journal of Urban Economics* 6: 275-291. 1979.
Keywords: general applications

Shogren, Jason. "Valuing Indirect Effects from Environmental hazards on a Child's Life Chances." Prepared for the Office of Policy and Office of Health Protection, US Environmental Protection Agency. February 1999.
Keywords: valuation theory and methods

Showstack, J. *Service Use and Cost Associated with Kidney Transplant*. Report to the Agency for Health Care Policy and Research, Rockville, MD. Center for Research Dissemination and Liaison. May 1989.
Keywords: applications: AB, CV, COI

Slovic, Paul. "Perception of Risk." *Science*, 30(4): 423-439. 1987.

Slovic, P., B. Fischhoff and S. Lichtenstein. "Rating the Risks." *Chemtech* 9 (12): 738-744. 1979.

Smith, D.H., D.C. Malone, K.A. Lawson, L.J. Okamoto, C. Battista, and W.B. Saunders. "A National Estimate of the Economic Costs of Asthma." *American Journal of Respiratory and Critical Care Medicine* 156: 787-793. September 1997.
Keywords: application: COI

Smith, V.K. "On Separating Defensible Benefit Transfers from 'Smoke and Mirrors.'" *Water Resources Research* 28(3): 685-694. March 1992.
Keywords: benefits transfer

Smith, V.K. "Pricing What Is Priceless: A Status Report on Non-Market Valuation of Environmental Resources." in *The International Yearbook of Environmental and Resource Economics 1997/1998: A Survey of Current Issues* edited by H. Folmeer and T. Tietenberg. Brookfield, VT: Edward Elgar. 1997.

Smith V.K. and W. Desvousges. "Asymmetries in the Valuation of Risk and the Siting of Hazardous Waste Disposal Facilities." *American Economic Association Papers and Proceedings* 76(2): 291-294. 1986.
Keywords: applications: AB, CV, COI

Smith, V.K., and W.H. Desvousges. "An Empirical Analysis of the Economic Value of Risk Changes." *Journal of Political Economy* 95(1): 89-114. February 1987.
Keywords: application: CV

Smith, V.K. and W.H. Desvousges. "The Generalized Travel Cost Model and Water Quality Benefits: A Reconsideration." *Southern Economic Journal* 52: 371-381. 1985.
Keywords: valuation theory and methods

Smith, V.K., W.H. Desvousges, J.W., Payne. "Do Risk Information Programs Promote Mitigating Behavior?" *Journal of Risk and Uncertainty* 10(3): 203-221. May 1995.
Keywords: applications: AB, CV, COI

Snell, E.W., R.E. Unsworth, and M. Dickie. *The Applicability of Benefits Transfer Approach to Assess the Economic Benefits of Reduced Air Toxics Emissions Under the Clean Air Act.* Report to the Office of Policy Analysis and Review, US Environmental Protection Agency. 1993.

Strauss, M.J. et al. "Cost and Outcome of Care for Patients with Chronic Obstructive Lung Disease." *Medical Care* 24(10): 915-924. October 1986.
Keywords: applications: AB, CV, COI

Taylor, D.C. "Your Money or Your Life? Thinking About the Use of Willingness-to-Pay Studies to Calculate Hedonic Damages." *Washington and Lee Law Review* 51: 1519-1556. Fall 1994.

Taylor, T.N., P.H. Davis, J.C. Torner, J. Holmes, J.W. Meyer, and M.F. Jacobson. "Lifetime Cost of Stroke in the United States." Stroke 29(9): 1459-1466. 1996.

Thompson, M.S. "Willingness to Pay and Accept Risks to Cure Chronic Disease." *American Journal of Public Health* 76(4): 392-396. April 1986.
Keywords: applications: AB, CV, COI

Tolley, G., et al. *Valuation of Reductions in Human Health Symptoms and Risks*. Volumes 1-4. Final Report to the US Environmental Protection Agency. University of Chicago, Chicago, IL. January 1986.
Keywords: valuation theory and methods

Tolley, G., D. Kenkel, R. Fabian, eds. *Valuing Health for Policy: An Economic Approach*. Chicago: University of Chicago Press. 1994.
Keywords: valuation theory and methods

The Urban Institute. "The Costs of Highway Crashes." Federal Highway Administration Research Report Number FHWA-RD-91-055, Washington, D.C. October 1991.

US Department of Commerce (USDOC). Economics and Statistics Administration. Statistical Abstract of the United States, The National Data Book. 112th edition, Washington, D.C. 1992.

US Department of Transportation (USDOT). "Motor Vehicle Accident Costs." Federal Highway Administration Technical Advisory. October 31, 1994.

US Environmental Protection Agency. *Air Quality Criteria for Particulate Matter*, vol. 3, Office of Research and Development. April 1996.

US Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act, 1970 to 1990*. Report to the United States Congress, Washington, DC. October 1997a.
Keywords: regulatory support document

US Environmental Protection Agency. *The Children's Health Valuation Handbook*. Prepared for the Office of Children's Health Protection. Forthcoming.
Keywords: valuation theory and methods

US Environmental Protection Agency. *Cost of Illness Handbook,* Prepared for Office of Pollution Prevention and Toxics by Abt Associates. Prepared by Abt Associates. 2000b.
Keywords: applications: AB, CV, COI

US Environmental Protection Agency. *Costs and Benefits of Reducing Lead in Gasoline: Final Regulatory Impact Analysis*. Office of Policy Analysis, Washington, DC. February 1985.
Keywords: regulatory support document

US Environmental Protection Agency. *Estimating and Valuing Morbidity in a Policy Context: Proceedings of June 1989 Association of Environmental and Resource Economists Workshop*. Research Triangle Park, N.C. June 1989b.
Keywords: regulatory support document

US Environmental Protection Agency. *Guidelines for Preparing Economic Analysis*. Final Draft. 2000a.

US Environmental Protection Agency. *The Medical Costs of Five Illnesses Related to Exposure to Pollutants*. Report to Nicolaas Bouwes, Regulatory Impacts Branch, Economics and Technology Division, Office of Pollution Prevention and Toxics, US Environmental Protection Agency. Prepared by Abt Associates, Incorporated. June 1992.
Keywords: applications: AB, CV, COI

US Environmental Protection Agency. *National Primary Drinking Water Regulations, Contaminant Specific Fact Sheets*, Office of Water. October 1995.
Keywords: regulatory support document

US Environmental Protection Agency. *Regulatory Impact Analysis: Benefits and Costs of Final Surface Water Treatment Rule*. Office of Drinking Water, Washington, DC. February 1989.
Keywords: regulatory support document

US Environmental Protection Agency. *Regulatory Impact Analysis: Benefits and Costs of Proposed National Primary Drinking Water Regulations for Inorganic Chemicals*. Office of Drinking Water, Washington, DC. March 1989a.
Keywords: regulatory support document

US Environmental Protection Agency. *Regulatory Impact Analysis for the Proposed Rulemaking on Corrective Action for Solid Waste Management Units*. Prepared for the Office of Solid Waste, US Environmental Protection Agency. Prepared by ICF, Incorporated. June 25, 1990.
Keywords: regulatory support document

US Environmental Protection Agency. *Regulatory Impact Analysis: Protection of Stratospheric Ozone*. Volumes 1-2. Stratospheric Protection Program, Office of Program Development, Office of Air and Radiation, Washington, DC. December 1987.
Keywords: regulatory support document

US Environmental Protection Agency. *Review of the National Ambient Air Quality Standards for Ozone: Assessment of Scientific and Technical Information*. Air Quality Management Division, Office of Air Quality Planning and Standards, Washington, DC. June 1989c.
Keywords: regulatory support document

US Environmental Protection Agency. *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part A)*. December 1989d.

US Environmental Protection Agency. *The Use of the Benchmark Dose Approach in Health Risk Assessment*. Office of Research and Development. 1995.

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.

US Renal Data System (USRDS). *US Renal Data System: 1995 Annual Data Report*. Report to the National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, MD. April 1995.
Keywords: applications: AB, CV, COI

Viscusi, W.K. *Fatal Tradeoffs: Public and Private Responsibilities for Risk*. New York: Oxford University Press. 1992.
Keywords: valuation of mortality risk

Viscusi, W.K. "Pain and Suffering in Product Liability Cases: Systematic Compensation or Capricious Awards?" *International Review of Law and Economics* 8: 203-220. 1988.

Viscusi, W.K. "The Value of Risks to Life and Health." *Journal of Economic Literature* 31: 1912-1946. December 1993.
Keywords: valuation theory and methods

Viscusi, W.K., and W. Evans. "Utility Functions that Depend on Health Status: Estimates and Economic Implications." *The American Economic Review* 80(3): 353-374. June 1990.
Keywords: valuation theory and methods

Viscusi, W.K. and M.J. Moore. "Rates of Time Preference and Valuations of the Duration of Life." *Journal of Public Economies* 38: 297-317. 1989.
Keywords: valuation theory and methods

Viscusi, W.K., W.A. Magat and A. Forrest. "Altruistic and Private Valuations of Risk Reduction." *Journal of Policy Analysis and Management* 7(2): 227-245. Winter 1988.
Keywords: application, CV

Viscusi, W.K., W.A. Magat and J. Huber. "An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks." *RAND Journal of Economics* 18(4): 465-479. Winter 1987.
Keywords: application, CV

Viscusi, W.K., W. Magat and J. Huber. "Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk-Dollar Trade-offs for Chronic Bronchitis." *Journal of Environmental Economics and Management* 21(1): 32-51. 1991.
Keywords: application, CV

Von Schirnding, Y.E.R., and R.I. Ehrlich. "Environmental Health Risks of Toxic Waste Site Exposures — An Epidemiological Perspective." *South African Medical Journal* 81(11): 546-569. 1992.

Waitzman, N.J. and R.M. Scheffler and P.S. Romano. *The Costs of Birth Defects.* Lanham, Maryland: University Press of America, Inc. 1996.
Keywords: applications: AB, CV, COI

Weinstein, M.C. and R.J. Quinn. *Psychological Considerations in Valuing Health Risk Reductions.* Harvard School of Public Health, Cambridge, MA. January 31, 1983.
Keywords: valuation theory and methods

Weiss, K.B., P.J. Gergen, and T.A. Hodgson. "An Economic Evaluation of Asthma in the United States." Special Article. *The New England Journal of Medicine* 326(13): 862-866. 1992.
Keywords: applications: AB, CV, COI

Weitzel, D.L. *Economic Valuation of Environmental Health Benefits: A Review of the Literature.* Report to the Washington State Department of Ecology. National Economic Research Associates, Inc., Seattle, WA. December 31, 1990.
Keywords: applications: AB, CV, COI

Wittels, E., J.W. Hay and A.M. Gotto, Jr. "Medical Costs of Coronary Artery Disease in the United States." *The American Journal of Cardiology* 65: 432-440. February 1990.
Keywords: applications: AB, CV, COI

Zeckhauser, R. "The Economics of Catastrophes." *Journal of Risk and Uncertainty* 12: 2-3. 1996.
Keywords: valuation theory and methods

APPENDIX A

ANNOTATED BIBLIOGRAPHY

Guide to Using the Annotated Bibliography

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 in the following categories:

1)   Valuation Theory and Methods
2)   General Applications
3)   Commonly Applied Methods: Averting-Behavior (AB), Contingent
            Valuation (CV), and Cost-of- Illness (COI)
4)   Benefits Transfer
5)   Valuation of Mortality Risk
6)   Regulatory Support Documents

These categories correspond to the *keywords* listed after each citation in the general bibliography and to the first *keyword* listed after each abstract in the annotated bibliography. Some abstracts list additional keywords because the articles are applicable to more than one category. For example, we place an article on contingent valuation (CV) methods in the "Valuation Theory and Methods" section, but also list CV as one of the keywords. These additional keywords include: *averting behavior (AB), contingent valuation (CV), cost of illness (COI), benefits transfer, and valuation of mortality risk.*

Table of Contents

Valuation Theory and Methods

Arthur, W.B. "The Economics of Risks to Life." *American Economic Review* 71(1): 54-64. March 1981.

This paper derives expressions for the value of activities that alter the mortality schedule and for the cost of premature loss of life. The method described is actuarial because it uses full age-specific accounting to evaluate changes in mortality. It is also based on welfare theory and accounts for economic transfers across society. The author concludes that valuation of risks to life largely depends on age and social support costs. Age is important because under the welfare criterion, a life lost at a younger age forfeits more than one at an older age. Societal social costs also play a large role in estimating the valuation of risks to life because the costs of additional consumption can offset the value of staying alive longer.

Keywords: valuation theory and methods

Atkinson, S., T. Crocker, and J. Shogren. "Bayesian Exchangeability, Benefit Transfer, and Research Efficiency." *Water Resources Research* 28(3): 715-722. March 1992.

When deriving benefit estimates, economic policy-makers can either fund primary research or conduct a benefits transfer. To help policy-makers make this decision, the authors propose a methodology for evaluating the applicability of benefits estimates from one site to another. The authors suggest that Bayes estimators, which are random coefficient estimators, can be used to extrapolate the results of a benefits assessment from one study to another. This proposal rests upon the Bayesian concept of exchangeability, in which sites having benefits in common are exchangeable because they share a common structure of benefit generation. This paper examines this method and employs a hedonic study of pollution control benefits to illustrate how Bayes estimators allow the hypothesis of exchangeability to be tested.

Keywords: valuation theory and methods

Baird, S.J., J.T. Cohen, J.D. Graham, A.I. Shlyakhter, and J.S. Evans. "Non-cancer Risk Assessment: A Probabilistic Alternative to Current Practice." *Human and Ecological Risk Assessment* 2(1): 79-102. March 1996.

This study proposes a probabilistic alternative to the USEPA's method for reporting chemical reference doses (RfDs) as a single number. The alternative method described in this article expresses the human population threshold as a probability distribution of values in order to account for major sources of scientific uncertainty. The authors illustrate this approach by using the same data that the USEPA uses to justify their current RfD procedure. This approach is also similar to the EPA's method in that it recognizes the four key extrapolations necessary to base the human population threshold based on animal data: animal to human, human heterogeneity, low observed adverse effect

level (LOAEL) to no observed adverse effect level (NOAEL), and subchronic to chronic. This approach differs from the EPA method in that it defines a probability distribution of adjustment factors rather than defining point estimates of uncertainty factors. The article also indicates that the initial uncertainty characterizations can be further refined when more robust data becomes available for a particular chemical. The authors conclude that this approach can help decision-makers understand how much extra control cost must be expended to achieve a specific increased in confidence that the human population threshold is not being exceeded.

Keyword: valuation theory and methods

Bartik, T.J. "The Estimation of Demand Parameters in Hedonic Price Models." *Journal of Political Economy* 95(1): 81-88. February 1987.

This article evaluates parameters used in developing hedonic price models. These models typically analyze the link between property prices and changing environmental conditions. As the authors note in the Conclusion, "the main point of this paper is that the problem of estimating hedonic demand parameters is caused not by demand-supply interaction but by the endogeneity of both marginal prices and quantities when households face a nonlinear budget constraint. Appropriate instrumental variables for this problem should exogenously shift the hedonic price function; previously proposed instruments do not do so. An instrumental variables solution to this problem is suggested using instruments that exogenously shift the budget constraint. The practical problem for empirical hedonic research is finding instruments whose exogeneity can be defended with some plausibility."

Keywords: valuation theory and methods

Bentkover, J.D., V.T. Covello and J. Mumpower. *Benefits Assessment: The State of the Art*. Holland: D. Reidel Publishing Company. 1986.

This books examines the state of the art from the mid-1980s in the theory and methods of benefit assessment. By discussing over 50 years of research, theoretical development and practice, it illustrates the complex nature of conducting benefits assessment. The book focuses on several key topics, including: US federal guidelines for benefits assessment; the implementation and interpretation of benefit-cost analyses; regulatory impact analyses; specific benefits assessments; alternative methods to benefits assessment; and practical techniques of benefits assessment.

Keywords: valuation theory and methods

Biddle, J.E. and G.A. Zarkin. "Worker Preferences and Market Compensation for Job Risk." *The Review of Economics and Statistics:* 660-667. 1988.

Although there is substantial evidence that workers are compensated for the risk of injury or death associated with their jobs, this article argues that workers optimally choose jobs on the basis of their taste for income versus job risk. The authors use the hedonic income equation to examine the market relationship between labor income and job risk, and the characteristics of individuals' tastes for income versus job risk. The paper concludes that valuations calculated from the hedonic income equation overstate the willingness of a worker to pay for a decrease in risk and understate the amount of income required to compensate a worker for an increase in risk.

Keywords: valuation theory and methods

Blodgett, J. *Health Benefits of Air Pollution Control: A Discussion*. CRS Report for Congress. Congressional Research Service, The Library of Congress. February 27, 1989.

This study analyzes proposed amendments to the Clean Air Act in order to assesses the health benefits of controlling air pollution. It presents a review of the literature and of benefit-cost analyses; six CRS-contracted assessments of current knowledge of and methods for estimating benefits; and a colloquium where authors and commentators discuss the studies and their implications. The report concludes that it is not currently feasible to unambiguously evaluate health benefits resulting from control of some air pollutant, even thought there is no doubt that significant benefits occur. It also concludes that only controls on ozone and acidic aerosols would provide general public health benefits; that numerical estimates of health benefits are only beneficial when underlying assumptions and methodological limitations are clearly presented; that specific estimates of adverse health effects are highly uncertain; and, that determining "net social benefit" by comparing existing monetized estimates of air pollution control benefits to existing monetized estimates of costs is rarely feasible.

Keywords: valuation theory and methods

Braden, J.B. and C.D. Kolstad, eds. *Measuring the Demand for Environmental Quality*. Netherlands: Elsevier Science Publishers BV. 1991.

This book assesses the state of the art for estimating the value of environmental goods and services and evaluates the relative strength of these methods. It discusses relevant theory and methods, including environmental demand theory, household production functions, and hedonic methods. It also examines methods for valuing classes of environmental effects, such as health effects, aesthetics, recreation and nonuse values.

Keywords: valuation theory and methods

Brennan, K.M. and R.M. Black III. *Methodology for Valuing Health Risks of Ambient Lead Exposure*. Report to the Ambient Studies Branch, Office of Air Quality Planning and Standards, US Environmental Protection Agency. Mathtech, Inc., NJ. December 1987.

This report is part of the Regulatory Impact Analysis for conducting a formal benefits analysis of several alternative lead National Ambient Air Quality Standards (NAAQS). The report discusses a methodology for valuing some of the improvements in health associated with a reduction in ambient lead concentrations. These benefits of additional NAAQS control include savings in short-term medical treatment costs, reduced blood lead-EP concentrations in children, an improvement in IQ levels of children, and hypertension-related benefits in adult males.

Keywords: valuation theory and methods

Bresnahan, B.W. and M. Dickie. "Averting Behavior and Policy Evaluation." *Journal of Environmental Economics and Management* 29(3) Part 1: 378-92. November 1995.

This article assesses information revealed by averting behavior to information required for policy evaluation. The authors discuss the theoretical underpinnings of the averting-behavior method and examine protective actions, which substitute for missing contingent claims markets by supporting transfers of income or health across states of nature. The article concludes that policy evaluations like benefits transfers require structural estimates of the protective technology.

Keywords: valuation theory and methods, AB, benefits transfer

Cambridge Economics, Inc. *Contingent Valuation: A Critical Assessment*. Report of a Symposium sponsored by Exxon Corporation. Cambridge, MA: Cambridge Economics, Inc. April 2 and 3, 1992.

This report argues that although contingent valuation is the only tool that exists for placing a price tag on "nonuse values," such as people's preferences for natural resources, it is not an advisable method. In this report, several authors review experiments conducted using contingent valuation methods. These authors include P. Diamond, J. Hausman, S. Shavell, M. Kemp, W. Desvousges, D. McFadden, P. Milgrom, J. Payne, D. Schkade, W. Mead, and J. Daum. They generally conclude that contingent valuation estimates of nonuse values are not good economic indicators because of

biases and errors associated with the survey procedures. Some authors recommend the use of other methods or argue that legislation is a more effective way to account for the values people place on natural resources.

Keywords: valuation theory and methods, CV, application

Conley, B.C. "The Value of Human Life in the Demand for Safety." *The American Economic Review* 66(1): 45-55. March 1976.

This article addresses the economics of safety by assessing the value of human life. The author examines values determined by the human capital approach and the willingness to pay approach. This study extends the traditional model of individual maximization to include the effects of choices associated with a change in the probability of living, and it determines the value of human life with reference to an individual's wealth and utility function characteristics. A deterministic model of individual optimization is developed and then applied to the demand for safety. The study concludes that for income above some undetermined low level, the value of life is larger than discounted earnings, and in early and middle adulthood, it is larger than discounted consumption.

Keywords: valuation theory and methods

Courant, P.N. and R.C. Porter. "Averting Expenditure and the Cost of Pollution." *Journal of Environmental Economics and Management* 8 (4): 321-329. December 1981.

"The paper considers the relationship between willingness to pay for environmental quality and averting expenditures - that is, the costs of measures undertaken in efforts to counteract the consequences of pollution. The models used assume perfect mobility among locations with different levels of environmental quality. The major results are: (1) averting expenditures are not in general a good measure of willingness to pay; (2) averting expenditures are not always even a lower bound on willingness to pay; (3) even when averting expenditures are a lower bound, the difference between the level of such expenditures and willingness to pay cannot be attributed to the unavertible "aesthetic" consequences of pollution." (Abstract, Courant and Porter 1981)

Keywords: valuation theory and methods, AB

Cropper, M.L. *Outline: Benefits Estimation Seminars: Valuing the Health Impacts of Water Pollution*. January 23, 1996.

This report is a compilation of presentation materials from the Benefits Estimation Seminar for Valuing the Health Impacts of Water Pollution. The topics covered for valuing mortality benefits include willingness to pay (WTP) for reductions in risk and empirical estimates of WTP by age and

income. Topics on valuing morbidity benefits include reduced risk of cancer, reduced risk of acute illness from shellfish, health benefits associated with lead reduction, and valuing other health endpoints. The report includes figures and equations, such as life expectancy tables, a hedonic model of the value of risks to life, and risk-risk tradeoff equations.

Keywords: valuation theory and methods

Cropper, M.L. "Measuring the Benefits from Reduced Morbidity." *American Economic Association Papers and Proceedings* 71(2): 235-240. May 1981.

This study presents a simple model of preventative health care and uses the model to determine what a person is willing to pay for a change in air quality. The model is based on the human capital theory which suggests that if people in polluted areas experience diminished resistance to disease, they will compensate at least partially by engaging in a healthier lifestyle; for example, they may exercise or sleep more. The human capital theory differs from the damage function approach, which ignores the effects of preventative health care on measurements of morbidity benefits of a reduction in pollution. The human capital theory does not assume that people are aware that pollution is the cause of their negative health effects. This study concludes that for acute illness, willingness-to-pay values for a change in air quality derived from the human capital theory-based model are greater than the values yielded by the damage function approach. This conclusion implies that the damage function approach understates the willingness to pay.

Keywords: valuation theory and methods

Cropper, M.L., and A.M. Freeman III. "Environmental Health Effects." *Measuring the Demand for Environmental Quality.* J.B. Braden and C.D. Kolstad (ed.) North-Holland, New York. 1991.

Also cited as:

Cropper, M.L. and A.M. Freeman III. *Valuing Environmental Health Effects*. Washington, DC: Resources for the Future. March 1990.

This paper assesses methods currently used to estimate monetary values to improvements in human health resulting from improved environmental quality. The benefits of a reduction in risk of mortality or morbidity are defined as the sum of what each affected person is willing to pay to decrease his own risk of death or illness, plus the sum of what society as a whole is willing to pay over and above this sum to decrease the risk of death or illness for any other exposed people. The authors use indirect and direct approaches to evaluate averting behavior and acknowledge that altruistic feelings or health insurance might influence the willingness-to-pay value. They conclude that: 1) models need to incorporate risk characteristics, like time and cause of death; 2) the use of medication should be

explored as a mitigating behavior; 3) perceptions of risk affect our decisions; 4) a systematic body of knowledge to determine socio-economic influence on willingness to pay should be developed; and 5) there is a need for a series of comparative studies using several methods to value the same policy output.

Keywords: valuation theory and methods, AB

Cropper, M. and A.M. Freeman. *Estimating Individuals' Values for Health Benefits.* CRS Report for Congress. Congress Research Service, The Library of Congress. January 1, 1989.

This paper describes and evaluates the currently available methods for assigning monetary values to improvements in human health that can be attributed to reduced air pollution. Information on monetary values of health improvements can be used in benefit-cost analysis of air pollution control. The authors examine how closely empirical methods capture the true willingness to pay for improvements in health and/or the reduced threat of disease or premature mortality. The authors conclude that empirical measures of health benefits would be strengthened if both the direct and indirect approaches produced similar results or if either approach produced similar results when applied to different groups of persons from the same population. The paper also notes that estimates of the costs of air pollution control are probably less reliable than commonly believed and that the difficulties in determining benefits are not substantially greater than those involved in assessing the costs.

Keywords: valuation theory and methods

Cropper, M.L. and F.G. Sussman. "Valuing Future Risks to Life." *Journal of Environmental Economics and Management* 19(3): 160-174. September 1990.

"Environmental policies that alter future mortality rates may affect both current and future generations. This paper examines willingness to pay for future risk reductions from the perspective of the current generation. The life cycle consumption/saving model implies that an individual discounts future risks to himself at the consumption rate of interest. If capital markets are perfect, the consumption rate equals the market rate of interest; otherwise, the consumption rate exceeds the market rate, and numerical results suggest that the implied discount factor may be substantial. The overlapping generations model implies that a member of the current generation discounts the value of risks to future generations at the rate at which current consumption is substituted for a bequest." (Abstract, Cropper and Sussman 1990)

Keywords: valuation theory and methods

Cummings, R.G., D.S. Brookshire, and W.D. Schulze, eds. *Valuing Environmental Goods: An Assessment of the Contingent Valuation Method.* New Jersey: Rowman and Allanheld. 1986.

This book examines the state of the art of the contingent valuation method, which uses surveys to determine values for public goods, especially environmental goods. In contingent valuation methods, individuals are not asked their opinions or attitudes, but their willingness to pay to either maintain or induce a positive effect or prevent a negative effect from occurring. The book discusses contingent valuation in terms of its structural and hypothetical biases, and provides suggestions for further research. The authors conclude that contingent valuation is generally a positive and accurate method.

Keywords: valuation theory and methods, CV

Diamond, P.A. and J.A. Hausman. "Contingent Valuation: Is Some Number Better Than No Number?" *Journal of Economic Perspectives* 8(4): 45-64. Fall 1994.

This paper evaluates the contingent valuation (CV) method by discussing the methodology of CV surveys. It focuses on the credibility, reliability, precision, and content of the surveys. The authors conclude that CV surveys do not measure the preferences they attempt to measure and that changes in survey methods are not likely to make the CV method more valid. The authors argue that reliance on CV surveys in damage assessments on government decision-making is misguided.

Keywords: valuation theory and methods, CV

Dickie, M. and S. Gerking. "Valuing Reduced Morbidity: A Household Production Approach." *Southern Economic Journal* 57(3): 690-702. 1991a.

This paper examines the household production approach, which is used to combine public and private goods in the production of non-market commodities for final consumption. The authors collect data using a special survey designed to implement the household production approach. They also estimate the technical relationships between health attributes, private goods, and air quality. The paper concludes that while it may be possible to estimate a common value for a broadly defined category of attributes, attempts to value detailed attributes of non-market home produced commodities may be ill-advised. In addition, the authors demonstrate that statistical tests support the hypothesis that individuals equate marginal rates of technical substitution in household production with relevant price ratios.

Keywords: valuation theory and methods

Dolan, P., C. Gudex, P. Kind, A. Williams. "Valuing Health States: A Comparison of Methods." *Journal of Health Economics* 15: 209-231. 1996.

"In eliciting health state valuations, two widely used methods are the standard gamble (SG) and the time trade-off (TTO). Both methods make assumptions about individual preferences that are too restrictive to allow them to act as perfect proxies for utility. Therefore, a choice between them might instead be made on empirical grounds. This paper reports on a study which compared a "props" (using specially-designed boards) and a "no props" (using self-completion booklets) variant of each method. The results suggested that both no props variants might be susceptible to framing effects and that TTO props outperformed SG props." (Abstract, Dolan et al. 1996)

Keywords: valuation theory and methods

Epple, D. "Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for Differentiated Products." *Journal of Political Economy* 95(1): 59-80. 1987.

"In choosing the level of quality to purchase, the buyer of a differentiated product also chooses a point on the marginal price schedule for that product. Hence, in general, the demand functions for product characteristics cannot be consistently estimated by ordinary least squares. Market equilibrium results in a matching of characteristics of demanders and suppliers. This matching restricts the use of buyer and seller characteristics as instruments when estimating demand and supply functions for product characteristics. The paper develops these issues. A stochastic structure for hedonic equilibrium models is then proposed, identification results are presented, and estimation procedures are outlined." (Abstract, Epple 1987)

Keywords: valuation theory and methods

Evans, W.N. and W.K. Viscusi. "Estimation of State-Dependent Utility Functions Using Survey Data." *The Review of Economics and Statistics:* 94-104. 1991.

"Surveys of individual's risk-dollar tradeoffs illuminate not only the local tradeoff rates but also can be used to address more fundamental questions about the structure of utility functions. This largely unexplored empirical area is investigated by developing an econometric technique to estimate utility functions based on survey data on risk-dollar tradeoffs for minor health effects. The empirical tests indicate that for all but one of the temporary health effects considered, consumers treat injuries as tantamount to a drop in income, implying that the health impact does not alter the structure of the utility function in a fundamental way." (Abstract, Evans and Viscusi 1990)

Keywords: valuation theory and methods

Fisher, W.L., L. Chestnut, and D.M. Violette. "The Value of Reducing Risks of Death: A Note on New Evidence." *Journal of Policy Analysis and Management* 8(1): 88-100. 1989.

"Government agencies face difficult resource-allocation decisions when confronted with projects that will reduce risks of fatality. Evidence from individual behavior helps determine society's values for reducing risks. The most credible evidence is based on individuals' willingness to pay (or willingness to accept compensation) for small changes in risks. Studies of consumer behavior are limited, but more evidence is available relating wages to job risks. Contingent valuation studies reinforce the wage-risk implications, leading to a range of values that can be compared with the costs of proposals to reduce fatal risks." (Abstract, Fisher et al. 1989)

Keywords: valuation theory and methods

Freeman, A.M. III. *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington, DC: Resources for the Future. 1993.

This book examines the relationship between benefits and environmental decision-making and the problems associated with measuring the values of environmental changes. An earlier edition of the book presented the state-of-the-art in 1979, and this book reanalyzes many of topics covered in the original book, including contingent valuation, valuing improved health, property value models, and the travel cost approach. It also discusses new topics including intertemporal welfare measures, the use of discrete choice models, the valuation of risk changes, hedonic wage models, nonuse values, and measurement of the cost of environmental policies.

Keywords: valuation theory and methods

Freeman, A.M. III. "*Ex Ante* and *Ex Post* Values for Changes in Risks." *Risk Analysis* 9(3): 309-317. 1989.

This article uses a simple model of individual preferences based on expected utility to examine two issues relating to the effects of public policies on the economic valuation of changes in individual risks: 1) the association between the values of risk prevention (i.e. reducing the probability of an adverse event); and 2) the relationship between *ex ante* and *ex post* measures of the value of changes in risk. The author assumes risk to mean a composite of the probability of an adverse event and the severity of the consequences of the event. The paper concludes that structural differences between measures of value for risk reduction and risk prevention exist. The author also notes that *ex post* measures of the value of risk reduction and risk prevention are likely to be poor and unreliable indicators of the desired *ex ante* willingness to pay.

Keywords: valuation theory and methods

Freeman, A.M. III. "Supply Uncertainty, Option Price, and Option Value." *Land Economics* 61(2): 176-181. May 1985.

The term "option value" is applied to the case where an individual who is uncertain as to whether s/he will demand a good in the future is faced with the uncertainty in the supply or availability of that good. Option value is the excess of option price, or the maximum willingness to pay for a project which preserves the option to consume the good in the future, over the expected consumer surplus. This paper demonstrates that the "supply-side option value" is greater than zero for the risk averse individual when supply-side uncertainty is involved, and is indeterminate for more general cases of supply uncertainty. The author examines supply-side uncertainty, the relationship between option price and expected consumer surplus, and the implications of introducing demand uncertainty into a model. The author concludes that nothing definite can be said about the relationship between option price and the increase in expected surplus and that no simple generalizations can be made.

Keywords: valuation theory and methods

French, M.T. and J.A. Mauskopf. "A Quality-of-Life Method for Estimating the Value of Avoided Morbidity." *American Journal of Public Health* 82(11): 1553-1555. November 1992.

This article describes a quality-of-life method developed to value changes in health status. The model evaluates changes in health attributes for various illnesses and then estimates the dollar value of the associated welfare losses. The willingness to pay to avoid asthma, a headache, a cough, bronchitis, and arthritis were determined using the quality of life approach. The authors state that these estimated values correspond reasonably well to those obtained from more expensive and restrictive traditional models (e.g. contingent valuation studies).

Keywords: valuation theory and methods

French, M.T., J.A. Mauskopf, J.L. Teague, E.J. Roland. "Estimating the Dollar Value of Health Outcomes from Drug-Abuse Interventions." *Medical Care* 34(9): 890-910. 1996.

This article proposes a methodology for estimating the health-related costs of drug abuse and demonstrates this methodology by estimating the potential dollar value of avoiding adverse health consequences through successful drug-abuse interventions. The dollar value of avoiding a variety of diseases, including acute hepatitis B, and HIV/AIDS, is estimated for a white male aged 32 years. The results indicate that estimated avoided drug-related morbidity values can vary significantly; for example, the value of avoiding only the morbidity associated with a single case of HIV/AIDS is approximately $157,811 for the period beginning with transmission and ending just before death. This method can be used to calculate benefit estimates that are used in benefit-cost analyses of drug-abuse interventions.

Keywords: valuation theory and methods

Furby, L. and B. Fischhoff. *Specifying Subjective Evaluations: A Critique of Dickie et al.'s Interpretation of their Contingent Valuation Results for Reduced Minor Health Symptoms*. Report to the Office of Policy, Planning, and Evaluation, US Environmental Protection Agency. Eugene Research Institute, OR. June 1988.

This report critically examines the report by Dickie et al. (1987) titled *Improving Accuracy and Reducing Costs of Environmental Benefit Assessment. Vol.1 Valuating Morbidity: An Overview and State of the Art Assessment*, which analyzes the valuation of minor heath symptoms due to air pollution exposure. The study by Dickie et al. described a large discrepancy in valuation results depending on whether the respondents were asked to value the elimination of a single symptom incident or to value the elimination of symptom incidences every month. This study finds that the process used by Dickie et al., which involves an "editing" phase followed by an "anchoring and adjusting" phase to assign monetary values to non-market goods, is inconsistent with their use in

psychological literature. This report addresses the weaknesses in the survey design used by Dickie et al. and proposes alternative accounts of the results. In addition, a comprehensive analysis of the contingent markets that reveals alternative explanations for results is presented. The report also provides an evaluation of and suggestions for contingent valuation surveys.

Keywords: valuation theory and methods, CV

Gerking, S. and L.R. Stanley. "An Economic Analysis of Air Pollution and Health: The Case of St. Louis." *The Review of Economics and Statistics* 68(1): 115-121. February 1986.

Individuals produce health capital and are able to adjust their consumption of medical care to defend against reductions in air quality. This article measures these adjustments through a compensating variation type of marginal willingness-to-pay expression for improved air quality. The model is tested using cross-sectional data on employed adult residents of St. Louis, Missouri. Estimates are derived for a 30 percent reduction in ozone. The authors conclude that the marginal willingness-to-pay values range from $18.45 to $24.48 per year.

Keywords: valuation theory and methods

Hanemann, W.M. "Valuing the Environment through Contingent Valuation." *Journal of Economic Perspectives* 8(4): 19-43. Fall 1994.

This article focuses on contingent valuation and describes how researchers make such surveys reliable. The author covers topics such as recent innovations in sampling, questionnaire design, and data analysis. Arguments that contingent valuation results are not validated by the economic theory are also examined. The author concludes that contingent valuation is an acceptable method for assessing demand for a good not traded through markets.

Keywords: valuation theory and methods, CV

Hanley, N. and C. Spash. *Cost-Benefit Analysis and the Environment*. Brookfield, VT: Edward Elgar Publishing. 1993.

This book is a guide to the theory and practice of cost-benefit analysis as applied to environmental management. It is divided into two parts. Part I focuses on the theory and methods of cost-benefit analysis and covers topics such as the welfare foundations of cost-benefit analysis, the contingent valuation method, the hedonic pricing method, the travel cost method, production function approaches, and discounting. Part II is a compilation of case studies and includes subjects such as

tropospheric ozone damage to agricultural crops, costs and benefits of controlling nitrate pollution, valuing habitat protection, and the greenhouse effect. The authors present both the positive and negative aspects of cost-benefit analysis but conclude that it is a useful method for presenting the effects of a project on the environment.

Keywords: valuation theory and methods

Harrington, W., and P.R. Portney. "Valuing the Benefits of Health and Safety Regulation." *Journal of Urban Economics* 22: 101-112. 1987.

Evaluating the benefits of public regulatory programs designed to improve human health is difficult. The cost-of-illness (COI) and averting-expenditures methods are often used to assess the benefits of health regulations, but both approaches may under- or over-state the benefits. As the Introduction notes, this study addresses the following question: "If data were available for both the direct and indirect costs of illness or injury as well as the averting measures, what would be the relationship between their sum and true willingness to pay?." This paper uses a simple static model of individual utility maximization in order to assess the results. The authors conclude that the COI plus defensive expenditures normally underestimate the "true" willingness to pay.

Keywords: valuation theory and methods, COI, AB

Hu, T., and F.H. Sandifer. *Synthesis of Cost-of-Illness Methodology: Part I.* Report to the National Center for Health Services Research, Department of Health and Human Services. 1981.

This report discusses the economic burdens of illness to society by investigating a variety of methods used to estimate or conceptualize the cost of illness. "Cost of illness" often represents a standard term for valuation studies related to health, regardless of the method applied. The report concludes that the current procedures used for cost of illness are adequate, but the use of assumptions and data need to be improved. It also contains an extensive appendix that reviews the cost of illness of major diseases. The Appendices are: A - Infective Diseases; B - Neoplasms; C - Endocrine, Nutritional, and Metabolic Diseases; D - Mental Disorders; E - Diseases of the Nervous System and Sense Organs; F - Diseases of the Circulatory System; G - Diseases of the Respiratory System; H - Diseases of the Digestive System ; I - Diseases of the Genitourinary System; J - Diseases of the Musculoskeletal System and Connective Tissue; K - Congenital Anomalies; L - Perinatal Morbidity and Mortality; and, M - Accidents, Poisonings, and Violence.

Keywords: valuation theory and methods, COI, application

Johansson, P. *Evaluating Health Risks: An Economic Approach*. Cambridge, England: Cambridge University Press. 1995.

Health economics has mainly focused on cost-effective analysis based on quality-adjusted life-years and healthy-years, rather than willingness to pay. The main purpose of this book is to define and estimate willingness-to-pay measures for changes in health risks. As the introduction states, "the main part of the book is concerned with the economic theory of health benefits: for example, what is meant by a money measure of the utility change caused by a health change in a certain world and a risky world, respectively, and what properties such measures possess. However, two chapters are devoted to empirical issues. One of these (chapter 5) briefly surveys the methods that can be used to assess changes in health and the available empirical evidence, for example, with respect to the value of a statistical life. The other (chapter 6) presents in more detail a particular empirical method, the contingent valuation methods, and discusses with reference to actual studies of medical treatments many of the steps in an empirical valuation study based on the survey method." The book concludes that cost-effective analysis and cost-benefit analysis are complementary rather than mutually exclusive methods.

Keywords: valuation theory and methods

Johansson, P. *The Economic Theory and Measurement of Environmental Benefits*. Cambridge, England: Cambridge University Press. 1987

This book discusses consumer surplus measures, with an emphasis on the circumstances in which a money measure correctly ranks/measures the underlying utility change. The author focuses on four major case studies: unrationed private goods, rationed private goods, public goods or 'bads' (externalities), and discrete choices. The book reviews practical methodologies in order to calculate the consumer's surplus for these classes of goods. In the second part of the book, the author discusses intertemporal issues. Consumer surplus measures are derived and practical methodologies to be used when the consumer faces a risky future are presented. The book concludes with remarks on the choice of money measures in a risky world and suggests future research topics.

Keywords: valuation theory and methods

Jones-Lee, M.W. "Paternalistic Altruism and the Value of a Statistical Life." *The Economic Journal* 102: 80-90. January 1992.

The value of a statistical life for three special cases of pure self interest, pure altruism, and safety focused altruism is given by the population mean marginal rate of substitution of own wealth for own safety. The value of a statistical life must be determined for other cases because the assumption of universal pure self-interest is unwarranted, and because altruistic concern usually manifests itself as paternalistic altruism. As the Introduction states, "the main aim of this paper is therefore to establish

how the value of a statistical life should be defined for a rather comprehensive range of degrees and types of altruism than has so far been considered in the literature. From this more general definition it is then possible to determine the way in which the value of statistical life will vary over the spectrum of altruistic concern on which pure self-interest, pure altruism and safety-focused altruism are all located as special cases." Pure paternalism is another special case that also entails a value of statistical life equal to that implied by pure self-interest.

Keywords: valuation theory and methods

Jones-Lee, M.W. "Altruism and the Value of Other People's Safety." *Journal of Risk and Uncertainty* 4: 213-219. April 1991.

"This article considers the manner in which people's altruistic concern for other people's safety should be incorporated in willingness-to-pay based values of statistical life and safety. It is shown that, within a utilitarian framework, the traditional prescription that such values should take full account of people's willingness to pay for others' safety is valid *if and only if* altruism is exclusively *safety-focused*, in the sense that while *i* is concerned for *j'*s safety, he is quite indifferent to other determinants of *j'*s utility. " (Abstract, Jones-Lee 1991)

Keywords: valuation theory and methods

Kopp, R.J. "Why Existence Value Should be Used in Cost-Benefit Analysis." *Journal of Policy Analysis and Management* 11(1): 123-130. 1992.

This article refutes the article by Rosenthal and Nelson (1992), titled "Why Existence Value Should Not Be Used in Cost-Benefit Analysis," by arguing for the need to quantify existence values. Existences values are discussed in the context of neoclassical welfare theory in order to address definitional problems. The article concludes that excluding existence values from cost-benefit studies necessities that all pure public goods be similarly excluded.

Keywords: valuation theory and methods

Krupnick, A.J. *Benefit Estimation and Environmental Policy: Setting the NAAQS for Photochemical Oxidants*. Resources for the Future, Washington, DC. December 1986.

This paper discusses important methodological issues concerning benefit-cost analysis of major regulations by examining the process of setting the National Ambient Air Quality Standards (NAAQS) for photochemical oxidants. As the Introduction notes, "four major issues are discussed: (1) the choice of approaches to modeling policy-induced changes in air pollution; (2) difficulties in

using clinical and epidemiological studies in a benefit analysis; (3) difficulties in applying dollar (unit) values to morbidity end-points; and (4) problems in aggregating benefit across health effects categories into an estimate of overall health benefits." The paper concludes that the size of morbidity benefits of ozone control is sensitive to analysis procedures and that the costs of attaining the current 0.12 parts per million standard ranges between $11 and $20 billion.

Keywords: valuation theory and methods

Kuik, O.J., F.H. Oosterhuis, H.M.A. Jansen. *European Communities Environmental Policy Series: Assessment of Benefits of Environmental Measures*. London, England: Graham & Trotman. 1992.

The purpose of this study is to prepare guidelines for the Commission of the European Communities regarding the assessment of the potential benefits of environmental measures. The results of this study will contribute to the implementation of the Single European Act, which requires that European Community (EC) environmental policy assess the "potential benefits and costs of action or lack of action" (Article 130 R). This book describes the methodology of benefits assessment, policy-makers' views on benefits assessment, an inventory of case studies, and an application of benefits assessment for the EC-Commission. The author concludes that benefit assessment of environmental measures improves the process of decision-making; that decision-makers prefer hard estimates of benefits; that more comprehensive benefits assessment can be achieved by softer valuation methods, such as contingent valuation, and hedonic price; that reliable monetary benefit assessment and dose-effect relationships are not always possible; that transboundary benefits are important; that macroeconomic effects of environmental measures are often small; and that limitations to benefit assessment exist.

Keywords: valuation theory and methods

Landefeld, J. and E.P. Seskin. "The Economic Value of Life: Linking Theory to Practice." *American Journal of Public Health* 72 (6): 555-566. June 1982.

Cost-benefit analyses of health programs generally rely on human capital estimates of the economic value of life. However, most economists agree that cost-benefit analyses should be based on individuals' willingness to pay for small changes in their probability of survival, though this value is difficult to measure. The willingness to pay to avoid the expected economic losses associated with death is often used as a lower bound for valuing risks to life. Human capital estimates cannot be

linked to willingness to pay approaches unless they are reformulated. This paper concludes that the only clear, consistent and objective values for use in cost-benefit analyses of policies affecting risks to life are based on a human capital approach that is reformulated using a willingness-to-pay criterion.

Keywords: valuation theory and methods

Link, A.N. *Evaluating Economic Damages: A Handbook for Attorneys*. Westport, Conn: Quorum Books. 1992.

This book presents the basic elements involved in the evaluation of the economic damages associated with wrong death cases and personal injury cases. The information presented is based on a mail survey of 30 members of the National Association of Forensic Economists, who have over eight years of experience consulting as forensic economists for attorneys. The author notes that an understanding of forensic economics allows plaintiff and defense attorneys to advise clients on the importance of using a forensic economist; to help the forensic expert obtain relevant information; and to critique the analyses other forensic experts prepare. The author divides the book into two sections: economic losses in wrongful death cases, and economic losses in personal injury cases. The major themes covered in the former category include estimating future earnings, life expectancy, work-life and probability of employment, future tax liabilities, choosing a discount rate, and non-market economic losses. The latter section covers permanent total disability and permanent partial disability.

Keywords: valuation theory and methods

Mishan, E.J. *Cost-Benefit Analysis*. Fourth Edition. New York: Praeger. 1988.

This book presents the various aspects associated with cost-benefit analysis. It provides examples of cost-benefit studies; describes economic concepts of costs and benefits, such as consumers' surplus and opportunity cost; examines external effect and investment criteria; highlights particular problems in project evaluation; and discusses uncertainty.

Keywords: valuation theory and methods

Mitchell, R. and R.T. Carson. *Using Surveys to Value Public Goods: The Contingent Valuation Method*. Washington, DC: Resources for the Future. 1989.

This book examines contingent valuation (CV) and argues that this method offers the best approach for assessing public willingness to pay for many public goods. The authors place CV in the larger context of welfare theory in order to explore issues such as willingness-to-pay versus willingness-to-accept measures, existence values, and the role of uncertainty in benefits valuation. The authors

conclude that the CV method can yield valid information on willingness to pay for public goods if it is applied in a way that addresses potential error bias. A list of guidelines, sample questions and general recommendations for the conduct of CV are included at the end of the book.

Keywords: valuation theory and methods, CV

National Oceanic and Atmospheric Administration (NOAA). *Natural Resource Damage Assessments Under the Oil Pollution Act of 1990. Appendix I: Report of the NOAA Panel on Contingent Valuation.* 58 FR 4601-4614. January 15, 1993.

This report evaluates the use of contingent valuation (CV) methods in determining non-use values for assessing damages of natural resources resulting from a discharge of oil under the Oil Pollution Act of 1990. While lost 'use values' refer to the losses experienced by those who make active use of a resource, 'non-use' values, otherwise known as 'existence' or 'passive-use' values, refer to the losses experienced by those who do not actively use the resource, but derive satisfaction from its mere existence. The authors of this report assert that while CV techniques can be used to elicit non-use values, the method has certain limitations. The report examines the limitations of CV and provides guidelines for what they consider to be an ideal CV survey.

Keywords: valuation theory and methods, CV

Pearce, D.W. and R.K. Turner. *Economics of Natural Resources and the Environment*. Maryland: Johns Hopkins University. 1990.

This book synthesizes various approaches of natural resource economics and environmental economics to highlight key issues relating to national, international, and global environmental problems. The authors focus on the idea of "sustainable development," emphasize a mainstream approach, and stress economic efficiency. The topics covered in the book include the historical development of environmental economics, environmental ethics, pollution control policy, mixed market, and centrally planned economies. In addition, the book addresses issues such as the destruction of the ozone layer and problems of the Third World, from an economic perspective.

Keywords: valuation theory and methods

Reinert, J.C., S.G. Slotnick and D.J. Viviani. "A Discussion of the Methodologies Used in Pesticide Risk-Benefit Analysis." *The Environmental Professional* 12: 94-100. 1990.

This article describes three interrelated facets of the risk-benefit balancing analysis used in pesticide regulation: individual and aggregate risks, risk trade-offs, and cost-effectiveness analysis. Aggregate risks are useful because benefits of pesticide reduction are calculated for the nation as a whole. The use of other pesticides often increases when one is taken off the market. The authors conclude that pesticide regulatory options need to consider cost-effectiveness, which depends on the calculation of net risk reduction, and risk trade-offs, which are based on aggregate risk estimations.

Keywords: valuation theory and methods

Rosenthal, D.H. and R.H. Nelson. *Why Existence Value Should Not be Used in Cost-Benefit Analysis*. Paper. June 1991.

This paper argues that economists should stop trying to quantify the concept of existence values. Existence values refer to any nonuse related change in the world, and there is no basis for deciding which existence values to quantify. The authors conclude that because economists are likely to analyze values that reflect their own beliefs, existence values are biased attempts to decide social ideologies by means of cost-benefit analysis.

Keywords: valuation theory and methods

Sargeant, K.A. *Health Benefits Assessment in EPA and Other Federal Agencies*. Report to Economics and Technology Division, Office of Pesticides and Toxic Substances, US Environmental Protection Agency. August 1989.

This report provides an overview of the different health benefits assessment analyses conducted by Federal Agencies. The EPA's regulatory impact analyses (RIAs) cover topics that include monetization of the health effects of lead and various chemical contaminants. The EPA focuses mainly on cancer mortality, though it conducts a few morbidity valuation activities. The Consumer Product Safety Commission and the Department of Transportation monetize reductions in fatalities and injuries. Reductions in work-related injuries and illnesses are monetized by the Occupational Safety and Health Administration. The US Department of Agriculture's Economic Research Service and the Food and Drug Administration monetize benefits of decreases in foodborne microbial and parasitic diseases. The Army Corps of Engineers has a method to monetize the human health and welfare benefits of flood control. The Department of the Interior monetizes ecosystem damages.

Keywords: valuation theory and methods

Shogren, Jason. "Valuing Indirect Effects from Environmental hazards on a Child's Life Chances." Prepared for the Office of Policy and Office of Health Protection, US Environmental Protection Agency. February 1999.

Abstract currently unavailable.

Keywords: valuation theory and methods

Smith, V.K. and W. Desvousges. "The Generalized Travel Cost Model and Water Quality Benefits: A Reconsideration." *Southern Economic Journal* 52: 371-381. 1985.

This paper describes a revised version of a generalized travel cost demand model described by Smith and Desvousges in "Estimating Water Quality Benefits: An Econometric Analysis." This model provides a basis for taking account of both site and individual characteristics in the estimation of the benefits associated with changes in site attributes, e.g. water quality. This paper highlights the importance of the revisions to this model for estimating benefits of improved water quality. The study indicates that the original model generally implied estimated benefits from three to over thirty times as large as the revised model. The rational for the revisions and new estimates are discussed. A comparison of the two models' benefit estimates for water quality improvements is also provided.
Keywords: valuation theory and methods

Tolley, G., D. Kenkel, R. Fabian, eds. *Valuing Health for Policy: An Economic Approach*. Chicago: University of Chicago Press. 1994.

The authors argue that lack of adequate framework, data shortcomings, and econometric estimation problems have impeded progress in valuing health. Given the need for state-of-the art estimates, this book provides an assessment of approaches to valuing morbidity and mortality. It also examines new efforts to estimate the benefits of reducing health risks. The book addresses four major subjects: a comparative analysis of approaches used to value health; problems in valuing widespread light symptoms illnesses, including coughs, headaches, and angina pectoris; the development of approaches for valuing life-threatening illnesses; and an application of findings to policy problems.

Keywords: valuation theory and methods

Tolley, G., et al. *Valuation of Reductions in Human Health Symptoms and Risks*. Volumes 1-4. Final Report to the US Environmental Protection Agency. University of Chicago, Chicago, IL. January 1986.

This report assesses attempts to value reductions in human health risks and develops new methods and estimates for these values. The report consists of four volumes. Volume 1 provides an executive summary of the report. Volume 2 provides a comparative assessment of work on valuing health risks and determines morbidity and mortality values applicable to effects of criteria air pollutants. Volume 3 describes a contingent valuation study, based on group experimentation and systematic household sampling, that estimates the benefits of light symptom reductions and angina relief. Volume 4 analyzes health valuation for serious or life threatening illnesses.

Keywords: valuation theory and methods, CV, application

US Environmental Protection Agency. *Children's Health Valuation Handbook.* Prepared for the Office of Children's Health Protection. Forthcoming.

Provides suggestions for valuing benefits of environmental regulations that affect children's health. Document is currently in draft form, under review. Contact staff at EPA's National Center for Environmental Economics for more information.

Keywords: valuation theory and methods

Viscusi, W.K. "The Value of Risks to Life and Health." *Journal of Economic Literature* 31: 1912-1946. December 1993.

This paper examines different approaches for determining appropriate economic values for risks to life and health. These values can be estimated by establishing risk reduction priorities according to the magnitude of the hazard, by measuring the value society places on risk reduction, or by determining the value individuals bearing the risk place on improved safety. Labor market data on worker wages for risky jobs are often used to infer attitudes toward risk and obtain estimates of the risk-dollar tradeoff. Valuation of health risks varies between individuals who take risks voluntarily and those who do not. It also changes on a temporal level, because health risks to future generations often assume a greater policy importance. The author argues that an appropriate schedule of values of life that is pertinent for different populations at risk needs to be established to help guide government policy.

Keywords: valuation theory and methods

Viscusi, W.K., and W. Evans. "Utility Functions that Depend on Health Status: Estimates and Economic Implications." *The American Economic Review* 80(3): 353-374. June 1990.

The objective of this article is to assess individuals' utility functions for good health and ill health. The two approaches used - a Taylor's series expansion and a logarithmic utility function - both indicate that the an individual's utility and his/her marginal utility at a given level of income is greater when healthy than when injured. This result has implications for the optimal level of insurance. In addition, income elasticity of the value of avoiding injury ranges from 0.67 (Taylor's series) to 1.0 (logarithmic case). The authors conclude that injury value figures used for deferred risk reductions should account for the income growth of those affected by regulations. The change in the implicit value of an injury with the magnitude of any non-incremental risk change is also discussed.

Keywords: valuation theory and methods

Viscusi, W.K. and M.J. Moore. "Rates of Time Preference and Valuations of the Duration of Life." *Journal of Public Economies* 38: 297-317. 1989.

"This paper develops a multi-period Markov model of the lifetime choice of occupational fatality risks. The empirical model analyzes the wage effects of job risks using the 1982 University of Michigan Panel Study of Income Dynamics in conjunction with death statistics from the US National Traumatic Occupational Fatality Survey. Evidence regarding workers' intertemporal choices with respect to risks with long-term implications is broadly consistent with rational behavior. Workers' implicit real rate of time preference with respect to future life years equals approximately 11 percent. This rate of time preference decreases with education." (Abstract, Viscusi and Moore 1989)

Keywords: valuation theory and methods

Weinstein, M.C. and R.J. Quinn. *Psychological Considerations in Valuing Health Risk Reductions*. Harvard School of Public Health, Cambridge, MA. January 31, 1983.

"A growing body of evidence indicates that the amounts people are willing to pay to reduce health risks are far greater in some contexts than in others. In seeking to account for these discrepancies, this paper examines the ways in which psychological concerns not normally considered by cost-benefit analysis may lead to normative criteria for resource allocation other than cost per life saved. Findings from psychological research suggest that behavioral violations of normative models of decision making are due in part to the influence of psychological consequences not considered by those models. Hypothetical, psychological consequences (such as social "blame" and "credit" for health effects) may be incorporated into extended utility models, reflecting the hypothesis that they are

normative carriers of utility. The implication of the psychological research and these extended models for both environmental health policy and normative decision theory are discussed." (Abstract, Weinstein and Quinn 1983)

Keywords: valuation theory and methods

Zeckhauser, R. "The Economics of Catastrophes." *Journal of Risk and Uncertainty* 12: 2-3. 1996.

"Catastrophes can profitably be thought of as economic events. This essay begins by considering the consumption of catastrophes, stressing the way that we disseminate information about them, and respond, possibly on a nonrational basis. Catastrophes are produced through a combination of actions by nature and humans. Due to inappropriate incentives, human actions often exacerbate outcomes. This is particularly true in"micromotive" situations, such as the AIDS epidemic, where actions by many players produce a collectively bad outcome. Mechanisms to prevent or ameliorate catastrophes - liability, insurance, and government regulation - are considered." (Abstract, American Economic Association)

Keywords: valuation theory and methods

General Applications

Alberini, A., G.S. Eskeland, A.J. Krupnick, and G. McGranahan. "Determinants of diarrheal disease in Jakarta." *Water Resources Research* 32(7): 2259-2269. July 1996.

This article explores the determinants of diarrheal disease in Jakarta through the use of data obtained by the Stockholm Environmental Institute in 1991. The variables that are examined include socioeconomic and demographic circumstances, local environmental conditions and practices, and the health of those household members most likely to be adversely affected by the household environment. The study also surveys defensive behavior such as washing hands after the toilet. These variables are used to model household defensive behavior and illness. The paper concludes that it is not the quality of water that appears to be associated with diarrheal disease, but the quantity. Interruptions in water supply are found to reduce defensive behavior and increase diarrheal illness. The effect of income on diarrhea is found to be weak while the availability of a washbasin is found to significantly increase defensive behavior and reduce the risk of diarrheal illness. It should be noted that the study participants are largely homogeneous and a relatively small percentage of respondents had suffered from diarrheal disease.

Keywords: application

Barron, W.F., J. Liu, T.H. Lam, C.M. Wong, J. Peters, and A. Hedley. "Costs and Benefits of Air Quality Improvement in Hong Kong." *Contemporary Economic Policy* 8: 105-117. 1995.

This article examines results from a respiratory health survey (RHS) conducted in Hong Kong in 1989 and a 1991 follow-up respiratory health survey performed after a 1990 ban on the use of high sulphur fuels. The study includes children aged eight to 11 residing both in an industrial area with poor ambient air quality as well as in a relatively clean area. The follow-up RHS found significant improvements in the health of the children living in the industrial area compared to those in the control area. The costs of the ban on high sulphur fuel and the resulting economic benefits are reviewed in this report. The conclusion of this retrospective analysis suggests that, as stated by the authors, "the avoided costs of doctor consultations alone offsets a moderate fraction of the costs of air quality improvement" and including long term health benefits, related productivity benefits, and willingness to pay for avoiding related illness, the total benefits far outweigh the costs.

Keywords: application

Brajer, V., J.V. Hall and R. Rowe. "The Value of Cleaner Air: An Integrated Approach." *Contemporary Policy Issues* 9: 81-91. April 1991.

The aggregate costs of strict environmental programs are rising and impacting previously untouched economic sectors. This study evaluates the economic benefits of air pollution controls by estimating the benefits of reducing ozone and fine particulate matter concentrations in the nation's most polluted area - the South Coast Air Basin, which centers on Los Angeles. This article examines the economic methodologies and results of this study. It also describes how health and atmospheric sciences informed the economic assessment. The authors conclude that in addition to providing estimates of the value of reducing pollutant-related health effects, this study makes significant advances in several areas, including human exposure modeling. It also illustrates the value of an integrated multi-disciplinary approach.

Keywords: application

Chestnut, L.G. *Human Health Benefits from Sulfate Reductions Under Title 4 of the 1990 Clean Air Act Amendments.* Final Report to the Office of Air and Radiation, US Environmental Protection Agency. 1995.

Abstract currently unavailable.

Keywords: application

Cifuentes, L.A. and L.B. Lave. "Economic Valuation of Air Pollution Abatement: Benefits from Health Effects." *Annual Review of Energy and the Environment* 18: 319-342. 1993.

This article examines the state of the art of benefits estimation for air pollution abatement, and proposes national average estimates for the benefits of abatement for several air pollutants. The study uses the direct or damage function approach to estimate the marginal benefits of air-pollution abatement of important pollutants, including sulfur dioxide, nitrogen dioxide, and ozone. Since the 1960s, air quality, except for ozone levels, has improved as the methods for controlling pollution have improved. In the 1990s, the importance and magnitude of health-related pollution effects are uncertain. The authors conclude that reducing this uncertainty requires better measures of air-pollution dose, standardized measures of morbidity, control for factors affecting health measure or randomization, and large sample sizes to isolate possible subtle effects.

Keywords: application

Desvousges, W.H., F.R. Johnson, and H.S. Banzhaf. *Assessing Environmental Externality Costs for Electricity Generation*. Prepared for Northern States Power Company by Triangle Economic Research. December 1994.

This report describes the basic methodology and results of an environmental cost study sponsored by Northern States Power Company (NSP). The NSP externality cost study applied the damage-cost approach to estimate the range of potential externality costs used in resource planning. The damages per ton of pollutants were estimated for three scenarios: rural, metropolitan, and urban. The pollutant with the largest potential per-ton damages was particulate matter followed by lead and nitrogen oxides with ozone. Urban settings had the highest per-ton potential damages, followed by the metropolitan fringe and rural scenarios.

Keywords: application

Dickie, M. and S. Gerking. "Willingness to Pay for Ozone Control: Inferences from the Demand for Medical Care." *Journal of Environmental Economics and Management* 21(1): 1-16. July 1991b.

"This paper applies a discrete choice version of the household production approach to the valuation of non-market goods. Willingness to pay for tropospheric ozone control is estimated using medical care demand... In example calculations, individuals living in high ozone areas are willingness to pay over $170 annually for an environment in which ozone concentrations never exceed 12 parts per million. Willingness to pay figures are two to four times larger than medical expenses savings caused by the same ozone reductions. Estimates obtained are compared with results of previous studies and proposed ozone control measures are discussed." (Abstract, Dickie and Gerking 1991).

Keywords: application

Evans, R.W. et al. "The Quality of Life of Patients with End-Stage Renal Disease." *New England Journal of Medicine* 312(9): 553-559. February 1985.

"We assessed the quality of life of 859 patients undergoing dialysis or transplantation, with the goal of ascertaining whether objective and subjective measures of the quality of life were influenced by case mix or treatment. We found that 79.1 percent of the transplant recipients were able to function at nearly normal levels, as compared with between 47.5 and 59.1 percent of the patients treated with dialysis (depending on the type). Nearly 75 percent of the transplant recipients were able to work, as compared with between 24.7 and 59.3 percent of the patients undergoing dialysis. On three subjective measures (life satisfaction, well-being, and psychological affect) transplant recipients had a higher quality of life than patients on dialysis. Among the patients treated with dialysis, those undergoing treatment at home had the highest quality of life...The quality of life of transplant

recipients compared well with that of the general population, but despite favorable subjective assessments, patients undergoing dialysis did not work or function at the same level as people in the general population." (Abstract, Evans et. al. 1995).

Keywords: application

Green, A. et al. *An Interdisciplinary Study of the Health, Social and Environmental Economics of Sulfur Oxide Pollution in Florida*. Report to the Florida Sulfur Oxides Study Inc. Interdisciplinary Center for Aeronomy and Atmospheric Sciences, University of Florida, Gainesville, FL. February 1978.

This report describes the health, social and environmental consequences of sulfur oxide pollution in Florida by modeling of dose-response relationships for sulfur oxide related pollutants, conducting risk-benefit analysis, and modeling of decisions and policy alternatives. The report also examines Disaggregated Benefit/Cost (DB/CA) analysis, which out of sixteen regulatory scenarios, yielded ten that had Benefit/Cost ratios substantially greater than one, and five with values smaller but comparable to one. The authors use a Quantified Acceptable Level of Risk (QALR) which yields results that support the conclusions of the DB/CA analysis. The report concludes that the State of Florida maintain its historic practice of employing more strict regulations than those required by the Federal government. It also recommends the use of the DB/CA and QALR to routinely assess air pollution problems.

Keywords: application

Gudex, C.M. "Health-Related Quality-of-Life in End-Stage Renal-Failure." *Quality of Life Research* 4(4): 359-366. 1995.

This study describes the health-related quality of life (HRQOL) of patients on different forms of treatment for endstage renal failure as part of a cost-utility analysis of renal failure treatment in Britain. Randomly selected adult dialysis and transplant patients were chosen from 24 British renal units using the European Dialysis and Transplant (EDTA) Registry Database through a Health Measurement Questionnaire. The study found that compared to the general population, patients with endstage renal failure experienced a lower quality of life, which was largely due to feelings of uncertainty about the future and lack of energy. In addition, transplant recipients reported better

HRQOL than dialysis patients and had fewer problems with physical mobility, self-care, social and personal relationships, and usual activities. On the other hand, dialysis patients experienced more distress, reported problems with depression, anxiety, pain and uncertainty about the future.

Keywords: application

Hall, J.V. et al. *Economic Assessment of the Health Benefits from Improvements in Air Quality in the South Coast Air Basin*. Final Report to the South Coast Air Quality Management District. California State University Fullerton Foundation, CA. June 1989.

This report discusses the economic assessment of health benefits in the South Coast Air Basin (SoCAB) resulting from improvements in air quality as pollution concentrations were nearing the state and Federal standards prevailing in the late 1980s. The human exposure model (REHEX) was used to statistically summarize air pollutant concentration distributions across the SoCAB and to quantify the number of individuals exposed. The study focused on health effects that could be quantified with dose-response relationships and that could be given an economic value derived from the literature, using cost-of-illness, contingent valuation, and hedonic wage studies. The results indicate that the annual benefits in the SoCAB of meeting the Federal ozone and PM-10 standards range from $4.8 billion to $20.4 billion, while benefits from meeting the California ozone and PM-10 standards range from $7.4 billion to $31.1 billion.

Keywords: application

Haveman, R. and B. Wolfe. "The Economic Well-Being of the Disabled: 1962-84." *Journal of Human Resources* 25(1): 32-54. Winter 1990.

This study examines the disabled working-age population with respect to changes in their labor market performance, their receipt of public income transfers, and their economic well-being from 1962-1984. The authors compare these variations over time with those of the non-disabled population. From the 1960s to the mid-1970s, the disabled improved their performance in the labor market and their real earnings increased both absolutely and relatively. In addition, the economic well-being of males increased. The earning of the disabled population decreased in the latter half of the 1970s, but this fall was cushioned by the transfer income. The decline in the well-being of the disabled population worsened after 1980 because of the retrenchment in disability benefit programs.

Keywords: application

Johnson, W.G. and J. Lambrinos. "Wage Discrimination Against Handicapped Men and Women." *The Journal of Human Resources* 20(2): 264-277. Spring 1985.

"The extent of discrimination against handicapped men and women is estimated in this paper. Observed wage differentials are corrected for selectivity bias. The results indicate that almost one-third of the wage differential for men and close to one-half for women can be attributed to discrimination. Interestingly, handicapped women are also subjected to sex discrimination." (Abstract, Johnson and Lambrinos 1985).

Keywords: application

Krupnick, A.J., and W. Harrington, and B. Ostro. "Ambient Ozone and Acute Health Effects: Evidence from Daily Data." *Journal of Environmental Economics and Management* 18: 1-18. 1990.

This study presents the results of a detailed epidemiological investigation of daily acute health effects associated with daily exposure to ozone and other pollutants. The authors use a Markov process model of health effects to estimate a statistically significant relationship between ambient ozone concentrations and daily reported respiratory symptoms among healthy non-smoking adults. No statistically significant effect is found for smokers or children. By estimating a model in which ozone is allowed to affect individuals who are already ill differently from individuals who are not, the authors find that ozone is negatively correlated with additional illness and thus, is consistent with avoidance behavior. The estimated improvement in health associated with a 10 percent reduction in ozone corresponds to the results of several other epidemiological studies.

Keywords: application

Krupnick, A.J., K. Harrison, E. Nickell and M. Toman. "The Value of Health Benefits from Ambient Air Quality Improvements in Central and Eastern Europe: An Exercise in Benefits Transfer." *Environmental and Resource Economics* 7: 307-332. 1996.

As stated by the authors, "This study is an initial effort to estimate one important category of benefits of environmental improvements in Central and Eastern Europe (CEE), those related to the effects of air pollution on human health." The estimates are derived from measures of ambient air quality in selected CEE locations. The study focuses on three pollutants: particulate matter (PM), sulfer dioxide (SO_2), and lead (Pb) in Bulgaria, Hungary, Poland, and the Ukraine. A model is used to link ambient air quality standards to physical impacts on health and designates monetary values for these impacts. The values are created from a mixture of willingness to pay estimates and direct damage cost estimates and are then adapted to account for circumstances in the CEE countries. The

significant uncertainties which surround these values and the physical effects of improved air quality are addressed through the use of a Monte Carlo simulation model. The report reaches three significant conclusions which are as follows: health benefits from air quality improvement appear to be significant in many CEE countries, reduced total suspended particle (TSP) exposure provides significant benefits and thus abatement planning efforts should be undertaken, and the effects of meeting EC standards will vary greatly across the CEE countries due to different baseline pollution levels.

Keywords: application

Krupnick, A.J. and R.J. Kopp. *The Health and Agricultural Benefits of Reductions in Ambient Ozone in the United States*. Resources for the Future, Washington, DC. August 1988.

This study estimates the benefits associated with reductions in ambient ozone concentrations. The authors discuss benefits to the health of the population living in Metropolitan Statistical Areas (MSA's) and to US agriculture. The health benefits are assessed according to reductions in acute effects, such as respiratory symptoms and asthma attacks, and the willingness to pay for these reductions. These estimates are differentiated by geographic area, baseline year, type of health effect, design value, and whether the information was developed from an epidemiological study. The benefits of ozone control for agriculture are measured as the net change in produce and consumer surplus for crops such as wheat, corn and cotton. Seven ozone control scenarios for health are examined and three scenarios are developed for agriculture. The authors conclude by discussing the benefits and limitations of the study. For example, the benefits of attaining an ozone standard of 0.12 parts per million range from $51 million to $4.7 billion annually. These benefits include reductions in cough and chest discomfort incidences.

Keywords: application

Lang, C., G. Yarwood, R. Laconde, and R. Bloxam. *Environmental and Health Benefits of Cleaner Vehicles and Fuels*. Prepared for Canadian Council of Ministers of the Environmental Task Force on Cleaner Vehicles and Fuels. October 1995.

The Task Force on Cleaner Vehicles and Fuels in Canada are in the process of evaluating several strategies to reduce vehicle air emissions in Canada by reformulating gasoline and diesel fuels. This study estimates benefits for two representative control scenarios in Canada as part of the benefit-cost analyses of these strategies. Quantitative estimates in dollars and qualitative results for various scenarios are also provided. The benefits include reduced negative health effects associated with air pollution, such as mortality, asthma, and emergency room visits, as well as decreased visibility

degradation and materials soiling. The report includes three supplemental reports: "Selected Concentration-Response Functions for Human Health Effects" by Chestnut et al.; "Selected Economic Evidence of Monetary Valuation of Human Health Effects" by Chestnut et al.; and "Benefits Study Results and Uncertainty Analysis" by Lang et al.

Keywords: application

Loehman, E.T. et al. "Distributional Analysis of Regional Benefits and Cost of Air Quality Control." *Journal of Environmental Economics and Management* 6: 222-243. 1979.

"The methodology and results of an analysis of benefits and costs of air quality control for an urban region in Florida are given. The machinery used considers the spatial distribution of (a) emission sources, (b) the ambient levels resulting from local meteorological conditions and geographic features, and (c) the socioeconomic characteristics of the impacted population groups. This facilitates an examination of the distributional aspects of costs and benefits associated with various control scenarios. With appropriate adaption and inputs the steps in our analysis should apply to a distributional benefit/cost analyses for any region." (Abstract, Loehman et al. 1979)

Keywords: application

Lopez, A., R.N. Dexter, J.C. Reinert. "Valuation of Developmental Toxicity Outcomes." *The Environmental Professional* 17: 186-192. 1995.

This study presents cost-benefit analysis for toxic regulations that prevent adverse environmental and human health outcomes. This report focuses on valuing a specific developmental toxicity outcome - severe birth defects- by examining jury awards in tort cases. Between 1981 and 1990, 132 cases were considered. These cases involved the most severe symptoms, including: cerebral palsy with severe mental retardation, quadriplegia, deafness, blindness, and symptoms that require lifetime custodial care. The value of jury awards spanned a wide range, with a standard deviation of $4.2 million, and a mean value of $4.4 million (in 1991 dollars). The article also compares the valuation approach used in this study to the more traditional willingness-to-pay and human-capital methods of valuing life.

Keywords: application

McDonnell, W.F., K.E. Muller, P.A. Bromberg, and C.M. Shy. "Predictors of Individual Differences in Acute Responses to Ozone Exposure." *American Review of Respiratory Disorders* 147(4): 818-825. April 1993.

"The purpose of this study was to identify personal characteristics that predict individual differences in acute FEV1 response to ozone exposure. Response and predictor data were collected on 290 white male volunteers 18 to 32 years of age who were each exposed to one of six concentrations of ozone between 0.0 and 0.40 parts per million (ppm). The sample was divided into an exploratory sample of 96 and a confirmatory sample of 194 subjects. Exploratory analysis indicated that ozone, age, and several other variables explained a significant proportion of the variance in response. In the confirmatory sample, only age and ozone concentration predicted FEV1 decrement. For the combined sample ozone explained 31 percent of the variance, with age accounting for an additional four percent. The model predicted a decreasing response with increasing age for all nonzero ozone concentrations. For exposure to 0.40 ppm the model predicts decrements in FEV1 of 1.07 and 0.47 L for 18- and 30-year-old subjects, respectively. We concluded that for white male subjects age was a significant predictor of response, with older subjects being less responsive to ozone. Furthermore, we demonstrated that exploratory analysis without control of type I statistical error rates may result in apparent finding that cannot be replicated." (NTIS)

Keywords: application

Ostro, B.D. and L.G. Chestnut. "Assessing the Health Benefits of Reducing Particulate Matter Air Pollution in the United States." *Environmental Research* 76(2): 94-106. February 1998.

This paper develops and applies a methodology for quantifying the health benefits of potential reductions in ambient PM. Although uncertainties exist about several components of the methodology, the results indicate that the annual nationwide health benefits of achieving the new standards for $PM_{2.5}$ relative to 1994-1996 ambient concentrations are likely to be between \$14 billion and \$55 billion annually, with a mean estimate of \$32 billion.

Keywords: application

Ransom, M.R. and C.A. Pope. "Elementary-School Absences and PM(10) Pollution in Utah Valley." *Environmental Research* 58(2): 204-219. August 1992.

"This study assessed the association between school absenteeism and respirable particulate pollution (PM10) in Utah Valley for the six school years of 1985 to 1990. Weekly absenteeism data from the Provo School District and daily data from a single elementary school in the Alpine School District were analyzed for kindergarten through sixth grade. PM10 concentrations during the study period averaged approximately 50 micrograms/meter-cubed with the 24-hour maximum equal to 365 micrograms/meter-cubed. Absenteeism was regressed on PM10 pollution levels, temperature, snowfall, and variables indicating day of week, month of school year, and days preceding and following holidays and extended weekends. Estimated associations between absenteeism and PM10 pollution in both data sets were positive, statistically significant (P less than 0.01), and robust to different model specifications. PM10 effects persisted for up to 3 or 4 weeks. Regression results from both data sets indicated that an increase in 28-day moving average PM10 equal to 100 micrograms/meter-cubed was associated with an increase in the absence rate equal to approximately two percentage points, or an increase in overall absences equal to approximately 40 percent. Similar relationships were observed for all grade levels, although the response of absences to air pollution was generally greater for grades 1-3 compared with grades 4-6. Associations between absenteeism and PM10 pollution were observed even for levels below 150 micrograms/meter-cubed." (NTIS)

Keywords: application

Rowe, R.D. et al. *Benefits of Air Pollution Control in California*. Volume 2. Report to the California State Air Resources Board. Energy and Resource Consultants, Inc., Boulder, CO. December 1986.

This study quantitatively assesses the economic measures of benefits (or damage) from controlling air pollution under five alternative policy relevant scenarios. These scenarios include two no-control comparisons, two prevailing practice comparisons, and one curtailed controls comparison. The authors estimate and compare pollutant emissions, ambient air quality, air pollutant impacts, and the economic measure of the impacts for each of the five scenarios. The study focuses on four air basins in California: the San Diego, the South Coast, the San Joaquin Valley, and the San Francisco Bay Area Air Basins. The best estimates of total annual quantified air pollution control benefits for the five scenarios range from $1.9 billion to $13.3 billion (in 1983 dollars). The study also reports the breakdown of best benefit estimates by effects category (e.g. human health and materials damage), air basin, and by pollutants.

Keywords: application

Rowe, R.D., et al. *The New York Electricity Externality Study.* Oceana Publications, Inc. Dobbs Ferry, NY. 1995.

This report documents the methods and results of an effort sponsored by the Empire State Electric Energy Research Corporation to quantify the externalities of options for generating electric energy in the state of New York. The documentation includes a summary of the strategy used to quantify effects on human health, which result from the dispersion of ambient air pollutants emitted from fossil-fuel fired electric generating plants.

Keywords: application

Seskin, E.P. "An Analysis of Some Short-Term Health Effects of Air Pollution in the Washington, DC Metropolitan Area." *Journal of Urban Economics* 6: 275-291. 1979.

"This study assesses some of the short-term health effects of air pollution in Washington, DC Specifically, regression models are formulated to explain health-care visits to a group practice medical care plan. Primary interest is focused on the effects of mobile-source air pollutants, particularly photo-chemical oxidants. Meteorological conditions, as well as other variables thought to influence the consumption of medical services, are included in the models as explanatory variables. The study found only a small effect of air pollution levels on the health-care visits to the group practice." (Abstract, Seskin 1979)

Keywords: application

Commonly Applied Methods: Averting-Behavior (AB), Contingent Valuation (CV) and Cost-of-Illness (COI)

Abdalla, C.W., B.A. Roach, and D.J. Epp. "Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination." *Land Economics* 68(2): 163-169. May 1992.

This article examines averting expenditures for valuing environmental improvements and uses it to estimate the economic costs of groundwater degradation to households in a southeastern Pennsylvania community. The authors indicate that factors, such as household's knowledge of contamination, perception of risk, and presence of children, determine whether or not averting actions are taken. Expenditure levels are higher if young children are present. The paper concludes that these estimates obtained through averting expenditures are theoretically sound and that they merit consideration in groundwater policy decisions.

Keywords: application, AB

Agee, M.D. and T. D. Crocker. "Parental Altruism and Child Lead Exposure: Inferences from the Demand for Chelation Therapy." *The Journal of Human Resources* 31(3): 677-691. Summer 1996.

This study assesses parents' willingness to pay (WTP) for decreased body burdens of lead in their children. The 256 observations used in this data set were initially gathered to determine the impact of children's body lead burdens upon their intellectual and behavioral development. The paper concludes that the *ex ante* WTP of parents for a one percent decrease in child body lead burden exceeds the estimated *ex post* savings in medical treatment and compensatory education costs caused by the same reduction.

Keywords: application, CV

Akerman, J., F.R. Johnson and L. Bergman. "Paying for Safety: Voluntary Reduction of Residential Radon Risks," *Land Economics* 67: 435-46. November 1991.

This study assesses homeowner's willingness to pay to reduce radon health risks associated with radon intrusion into buildings via soil, gases, water supply and building material. Data collected in Sweden indicates that the implicit value of a statistical life is less than one million dollars, as compared to the two to seven million dollar values in other behavioral studies. The low value of estimated willingness to pay could indicate that regulatory standards are inconsistent with the preferences of the majority of homeowners.

Keywords: application, CV

Bartik, T.J. "Evaluating the Benefits of Non-Marginal Reductions in Pollution Using Information on Defensive Expenditures." *Journal of Environmental Economics and Management* 15(1): 111-27. 1988.

This article uses information on households' defensive expenditures on pollution alleviation to assess the benefits of non-marginal pollution reductions. Data on defensive expenditure technology plays a major role in determining the upper and lower bounds to benefits. This article examines several real-world pollution problems with respect to the accuracy of these bounds and the appropriateness of the defensive expenditure model. The author concludes that these procedures allow policy researches to make quick decisions about the most cost-effective method for estimating the benefits of environmental policies.

Keywords: application, AB

Bresnahan, B.W., M. Dickie and S. Gerking. "Averting Behavior and Urban Air Pollution." *Land Economics* 73(3): 340-357. August 1997.

"Unique panel data are used to explain defensive responses to air pollution using determinants predicted by an averting behavior model. Empirical results indicate that persons who experience smog-related symptoms spend significantly less time outdoors as ozone concentrations exceed the national standard. Many people also report making other behavioral changes to avoid smoggy conditions and the propensity to do so appears to increase with schooling or if health symptoms are experienced. Results provide evidence that people adjust daily activities to defend against acute health effects of air pollution, though mitigation appears less closely linked to chronic health impairments." (Abstract, Bresnahan et al. 1997)

Keywords: application, AB

Chestnut, L.G., L.R. Keller, W.E. Lanbert, and R.D. Rowe. "Measuring Heart Patients' Willingness to Pay for Changes in Angina Symptoms." *Medical Decision Making* 16: 65-77. 1996.

This study compares the willingness to pay (WTP) to avoid health changes with the cost of illness (COI). An indirect and direct approach are used to measure the WTP by heart patients for changes in their angina symptoms. The averting-behavior measurements of WTP are inferred using actual expenditures and perceived angina episodes. Using a contingent valuation (CV) survey, patients are also asked direct WTP questions for a hypothetical medical treatment that could be purchased to

avoid additional angina episodes The results indicate that the subjects have significant WTP to avoid increases in angina, even though the COI is negligible. The study also validates the CV approach because the average WTP of the averting-behavior questions is similar to the directly elicited WTP.

Keywords: application, COI, CV, AB

Chestnut, L.G. et al. *Heart Disease Patients' Averting Behavior, Costs of Illness, and Willingness to Pay to Avoid Angina Episodes*. Final Report to the Office of Policy Analysis, US Environmental Protection Agency. October 1988.

This report uses an economic model of behavior to determine an individuals' health and response to environmental pollution. This study focuses on the effects of air pollution and carbon monoxide on anginal pain, which results from low-oxygen stress when insufficient blood flows to the heart muscle. Two alternative approaches are used to collect data from 50 men suffering from heart disease. The first method, cost of illness, is determined by computing lost work time and expenditures to avoid angina. The second approach, willingness to pay to avoid additional angina, is assessed using averted behavior and contingent valuation methods. This report compares these results and provides recommendations for a more representative study.

Keywords: application, COI, CV, AB

Chestnut, L.G. and D.M. Violette. *Estimates of Willingness to Pay for Pollution-Induced Changes in Morbidity: A Critique for Benefit-Cost Analysis of Pollution Regulation*. Report to the Office of Policy Analysis, US Environmental Protection Agency. September 1984.

This report examines the willingness to pay (WTP) for the reduction or prevention of pollution-induced morbidity. The authors critique four types of review studies that estimate WTP and willingness to accept compensation (WTA): 1) health-production-function (HPF) studies, 2) cost-of-illness (COI) studies, 3) contingent valuation (CV) approaches, and 4) health-status-index (HSI) research. The results of these studies are discussed. The authors conclude that these studies provide few satisfactory estimates of WTP for pollution-induced changes in morbidity. Policy applications and recommendations for future research are also provided.

Keyword: application, COI, CV

Ciracy-Wantrup, S.V. "Capital Returns from Soil-Conservation Practices." *Journal of Farm Economics* 29: 1181-1196. 1947.

This paper suggests the use of the "direct interview method" to measure the values individuals assign to natural resources. The direct interview method is considered a precursor to the contingent valuation method.

Keywords: application, CV

Colditz, G.A. "Economic Costs of Obesity." *American Journal of Clinical Nutrition* 55: 503S-507S. 1992.

This article examines the 1986 economic costs that were attributable to obesity-related medical conditions. The study uses a prevalence-based approach to cost of illness and a discount rate of 4 percent. The abstract notes that "overall, the costs attributable to obesity were $11.3 million for non-insulin dependent diabetes mellitus (NIDDM), $22.2 billion for cardiovascular disease, $2.4 billion for gall bladder disease, $1.5 billion for hypertension, and $1.9 billion for breast and colon cancer. Thus, a conservative estimate of the economic costs of obesity was $39.3 billion, or 5.5 percent of the costs of illness in 1986. Addition of costs due to musculoskeletal disorders could raise this estimate to 7.8 percent." The authors argue that improved health status and quality of life must be weighed against the treatment costs for severe obesity.

Keywords: application, COI

Cooper, B.S. and D.P. Rice, "The Economic Cost of Illness Revisited." *Social Security Bulletin:* 21-36. February 1976.

The distribution of health care resources and the assessment of health-related research and programs is largely determined by the cost of illness (COI). This article updates the study by Rice (1966) titled "Estimating the Cost of Illness." The authors evaluate 16 major diagnostic categories of illnesses using three categories: 1) direct costs for prevention, detection, and treatment; 2) morbidity losses associated with disability; and 3) mortality losses due to premature death. The article indicates that in 1972, the total cost of illness was estimated to be $188 billion: $75 billion for direct costs, $42 billion for morbidity, and $71 billion for mortality. One-fifth of all costs were due to diseases of the circulatory system.

Keywords: application, COI

Cropper, M.L., S. Ayded, P. Portney. *Public Preference for Life Saving*. Resources for the Future, Washington, DC. May 1992.

This paper explores two major problems associated with analyses that compute the cost-per-life saved for health and safety programs: 1) programs may save lives at different times, and 2) programs may prevent death at different ages, and thus save different numbers of life-years. This study was conducted through a survey in which 3,000 members of the general public were asked to choose between pairs of hypothetical life-saving programs. The major finding from this study is that the discount rate for lives saved is almost as high as the discount rate typically used in cost analyses. The median respondents in the surveys also placed more weight on saving young persons than they would if the value of avoiding risk was weighted strictly by life expectancy. For example, respondents judged saving eight 60 year-olds to be equivalent to saving one 20-year old. This article also makes policy recommendations. For example, it suggests that Regulatory Impact Analyses include the age at which premature deaths are averted.

Keywords: application, CV

Cropper, M.L. and A.J. Krupnick. *The Social Costs of Chronic Heart and Lung Disease*. Resources for the Future, Washington, DC. June 1990.

Using the 1977 National Medical Care Expenditure Survey, this article estimates the medical costs associated with chronic heart and lung diseases. The authors use the 1978 Survey of Disabled and Non-Disabled Adults to assess the effects of these diseases on the participation of the labor force and on wages. The duration of disease and the age of onset are the characteristics used to determine labor market effects. The article concludes that diseases with an average age of onset after 40 have a probability of participation that increases with age of onset. The annual medical costs per person distribution, examined by age and gender, is highly skewed. The median expenditures of the distribution fall between 10 and 25 percent of mean expenditures.

Keywords: application, COI

Davis, R.K. *The Value of Outdoor Recreation: An Economic Study of the Maine Woods*. Ph.D. Dissertation. Harvard University, Cambridge, MA. 1963.

This dissertation is considered one of the founding studies using the contingent valuation (CV) approach. The paper focuses on measurement of benefits of a recreational area in Maine. One-hundred and twenty-one hunters and recreationists were interviewed in order to determine their

willingness to pay for the recreational services. The majority of the responses were considered reasonable, which helped to validate the CV method.

Keywords: application, CV

Dickie, M., S. Gerking, D. Brookshire, D. Coursey, W. Schulze, A. Coulson, and D. Tashkin. *Improving Accuracy and Reducing Costs of Environmental Benefit Assessments: Reconciling Averting Behavior and Contingent Valuation Benefit Estimates of Reducing Symptoms of Ozone Exposure*. Draft Report to the Office of Policy, Planning and Evaluation, US Environmental Protection Agency. February 1987.

This report focuses on reconciling differences between contingent valuation (CV) and averting behavior estimates of willingness to pay (WTP) to avoid health symptoms associated with ozone exposure, including chest tightness, throat irritation, headache, and pain when taking deep breaths. CV bids are generally five to ten times larger than averting-behavior bids. In this study, respondents generally reduce their initial WTP bids after they are made aware of the total expenditure implications of their initial bids. For example, original bids to avoid one day of headache average $178.39, while the revised bids average $1.19. The revised bids are found to be lower than the original CV method and averting-behavior bids. The authors conclude that averting-behavior estimates overestimate WTP, and that in addition to reducing symptoms, averting goods used in the averting-behavior method calculations may represent sources of direct utility. The revised bids provide a lower bound to WTP to avoid one day of frequently occurring ozone-related health symptoms.

Keywords: application, AB, CV

Dickie, M., S. Gerking, W. Schulze, A. Coulson, and D. Tashkin. *Improving Accuracy and Reducing Costs of Environmental Benefit Assessments: Value of Symptoms of Ozone Exposure: An Application of the Averting-Behavior Method*. Draft Report to the Office of Policy, Planning and Evaluation, US Environmental Protection Agency. September 1986.

This report estimates the dollar benefits of reducing symptoms to ozone exposure. This study uses the averting-behavior method to estimate the daily willingness to pay (WTP) to avoid ozone-related symptoms. Alternate cost-of-illness (COI) and contingent valuation (CV) methods are found to be inadequate determinants of WTP. The authors' results demonstrate that averting-behavior methods yield significantly lower estimates than those obtained from CV estimates.

Keywords: application, AB, COI, CV

Dor, A, P.J. Held, and M.V. Pauly. "The Medicare Costs of Renal Dialysis - Evidence from a Statistical Cost Function." *Medical Care* 30(10): 879-891. 1992.

Medicare's End Stage Renal Dialysis Program, which includes renal dialysis and kidney transplants for 190,000 patients of all ages suffering from chronic renal failure, costs over $6 billion dollars. This study argues that accounting methods used for Medicare reimbursements of dialysis units may obscure the true economic costs of providing various types of dialysis treatments. The authors use a statistical cost function approach to obtain cost estimates. Results indicate that the average cost and marginal cost of hemodialysis treatments are generally in line with current reimbursement rates, while average and marginal cost of continuous ambulatory peritoneal dialysis treatments may be below this rate. The mainstay of all dialysis units, in-center hemodialysis, was found to have decreasing economies of scale at the mean facility size. The article concludes that the Medicare reimbursement formula may be outdated and that more "rational" payment rules should be researched.

Keywords: application, COI

Doyle, J.K., G.H. McClelland, W.D. Schulze, S.R. Elliott and G.W. Russell. "Protective Responses to Household Risk: A Case Study of Radon Mitigation." *Risk Analysis* 11(1): 121-134. March 1991.

"This study analyzes the effectiveness of a mass-media radon information and testing campaign conducted in the Washington, DC area in the winter of 1988. Although an impressive number of test kits (approximately 100,000) were sold, the ultimate mitigation rates resulting from the campaign were extremely low. Analyses show that low mitigation rates cannot be explained by postulating that people's responses to radon are insensitive to the level of objective risk. They may instead be due to characteristics of the protective response required to reduce radon risk. Radon may be thought of as one of a family of household risks which have risk response profiles that make them particularly difficult for people to manage and remediate. Traditional information campaigns for such risks are likely to be ineffective; instead, they may require regulatory strategies or programs which provide active guidance and assistance." (Abstract, Doyle et al. 1991)

Keywords: application, AB

Garner, T.I. *Economic Analysis of End-Stage Renal Disease Treatments.* Dissertation, University of Maryland. Volume 46/01-A of Dissertation Abstracts International: 210. 1984.

"The purpose of this study was to apply economic analysis to an evaluation of alternative treatments of end-stage renal disease (ESRD) and to obtain additional information concerning the impact of chronic kidney failure and dialysis on patients. The cost-effectiveness model used in their study differs from models used in most earlier studies in that net social costs were used to estimate the implicit value of a life year of individuals undergoing different treatment modes. The use of net as opposed to gross social cost meant that attention was focused on the outcomes of the health care program, i.e., the number of healthy and productive life years provided to individuals due to health

care. Four modes of treatment were considered: home dialysis, in-center dialysis, living related donor (LRD) transplant, and cadaveric donor (CAD) transplant. Life year values were obtained based on high and low estimates of survival probabilities and earnings. In the case of low estimates the most cost-effective treatment mode was a LRD transplant followed by home dialysis, a CAD transplants, and in-center dialysis. When high estimates were used a CAD transplant was more cost-effective than home dialysis...The results of the study have important policy implications for the future direction of the ESRD program." (NTIS)

Keywords: application, COI

Garner, T.I. and R. Dardis. "Cost-Effectiveness Analysis of End-Stage Renal Disease Treatments." *Medical Care* 1: 25-34. January 1987.

"The cost-effectiveness of various end-stage renal disease (ESRD) treatments was compared using two different cost measures. The first measure, gross social costs, excluded output gains due to treatment, whereas the second measure, net social costs, included output gains from both market and non-market activities. The cost-effectiveness criterion was the cost-per-life year gained or the implicit value of a year of life. The lower the cost-per-life year gained, the more cost-effective the treatment was. Four ESRD treatments were evaluated over 20 years. Home dialysis and transplantation were more cost-effective than in-center dialysis, regardless of whether gross or net social costs were used. However, lower values were obtained in the case of net social costs reflecting a provision for output gains due to treatment. The use of net social costs also resulted in greater variations in costs-per-life year gained by age. Changes in survival probabilities affected the results for transplant patients and dialysis patients differently." (Abstract, Garner and Dardis 1987)

Keywords: application, COI

Harrington, W., A.J. Krupnick and W.O. Spofford, Jr. "The Economic Losses of a Waterborne Disease Outbreak." *Journal of Urban Economics* 25(1): 116-137. January 1989.

This study estimates the morbidity costs of a water-contamination problem in Luzerne County, Pennsylvania. The authors first derive an expression for losses due to an environmental pollution episode by developing a model of individual utility maximization. Two approaches are then used to assess the economic losses from a *Giardiasis* outbreak in Luzerne County. The first method involves a questionnaire to 370 individuals in Luzerne County which supports the development of an estimate of the costs incurred by those who were ill. The authors estimate losses in nine categories, including doctor visits, hospital visits, medication, travel time associated with medical treatment, work loss, and leisure time loss. Three different estimates of lost time of homemakers, retirees, and unemployed persons are used. The best cost-of-illness estimates for these three scenarios are $7.00, $5.59, and $4.59 million (1984) dollars. The second method focuses on losses due to averting action, which are determined through 50 random telephone interviews. The study involves three alternate scenarios

relating to the degree to which avoidance activities are performed jointly with other activities. The best estimate of losses due to averting behavior are $38.51, $12.94, and $12.12.

Keywords: application, COI, AB

Hartunian, N.S., C.N. Smart, M.S. Thompson. *The Incidence and Economic Costs of Major Health Impairments*. Lexington, MA: Lexington Books. 1981.

This book describes the results of a three-year study which measured the economic costs of four major illnesses: 1) cancer; 2) coronary heart disease; 3) stroke; and 4) motor vehicle injuries. Each of the four categories is broken down by sub-condition, age and sex groups, and by cost components. The authors evaluate each condition according to: incidence and mortality; direct, indirect, and total costs; and sensitivity analyses, designed to test the significance of specific data imperfections. The results of this study on the economic costs of illness are intended to be used by policy makers when allocating resources to various medical programs.

Keywords: application, COI

Held, P.J., et al. *Cost Effectiveness of ESRD Treatment Modalities*. The Urban Institute, Washington, DC. Final Report to Health Care Financing Administration. April 30, 1992.

This report examines the cost effectiveness of kidney transplantation and five dialysis modalities (center hemodialysis (CH), home hemodialysis (HH), CCPD, and methods 1 and 2 CAPD). The study relies on data from a virtual census of 1984-89 incident US Medicare-eligible ESRD patients in selected age groups. The authors use actuarial techniques, which account for age to evaluate changes in mortality, to estimate survival and lifetime Medicare charges for 24 age/race/disease/modality groups. The lifetime Medicare charges are discounted and adjusted for inflation and geographic wage differences. The paper concludes that for two-way cost effective comparisons among non-elderly patients, transplantation is more cost effective than the dialysis modalities for most age/race/disease groups; and, that CAPD and CH are similarly cost effective for the largest race/disease group (white non-diabetics), but not for the other groups. The authors also note that adjustment for co-morbidity was limited to age, race, and diabetes, which may affect the results since differences among patients selected for different treatment modalities may exist.

Keywords: application, COI

Hoffman, C., D. Rice, and H-S Sung. "Persons with Chronic Conditions: Their Prevalence and Costs" *JAMA* 276(18): 1473-1479. November 13, 1996.

The objectives of this study are to assess the number and proportion of Americans living with chronic conditions, and to determine the magnitude of their costs, including direct costs (annual personal health expenditures) and indirect costs to society (lost productivity due to chronic conditions and premature death. The authors analyze the 1987 National Medical Expenditure Survey for prevalence and direct health care costs, and examine the 1990 National Health Interview Survey and Vital Statistics of the United States for indirect costs. The study reports that in 1987, 90 million Americans were living with chronic conditions, 39 million of whom were living with more than one chronic condition. Total costs incurred for people with chronic conditions (projected to 1990) amount to $659 billion: $425 billion for direct health care costs and $234 billion in indirect costs. The study concludes that persons with chronic conditions have higher health needs and incur disproportionately higher costs.

Keywords: application, COI

Jones-Lee, M.W., M. Hammerton, and P.R. Phillips. "The Value of Safety: Results of a National Sample Survey," *The Economic Journal* 95: 49-72. March 1985.

This study assess the willingness-to-pay approach to estimate the value of safety. The authors compare two methods of estimating willingness to pay: the revealed preference approach, and the questionnaire approach. The paper describes a survey commissioned by the U.K. Department of Transportation. The initial survey involved questions to determine valuation estimates, the consistency of responses, and factual information about the respondents. A follow-up survey was conducted on a subsample of this group. This article discusses the responses, statistical accuracy and problems with the survey design, and offers conclusions for policy. The authors conclude that the estimates the value of statistical life for transport risks determined through this survey are credible. These estimates are similar to the estimates of the value of statistical life for 'self only' occupational risks, which have been determined by studies using the revealed preference method.

Keywords: application, CV

Joyce, T.J., M. Grossman, and F. Goldman. "An Assessment of the Benefits of Pollution Control: The Case of Infant Health." *Journal of Urban Economics* 25(1): 32-51. January 1989.

"Research on the impact of air pollution on race specific neonatal mortality rates is presented. The research used: a behavioral model of the demand for health; econometric techniques to obtain the willingness to pay figures; and the well-documented health indicator, neonatal mortality. A 10 percent reduction in the levels of sulfur dioxide would give an upper bound benefit of $1.09 billion in 1977 dollars and a lower bound benefit of $54 million." (Gabe Group Trade and Industry Database. Foster City, CA: The Gabe Group. 1999)

Keywords: application, AB

Krupnick, A.J. and M.L. Cropper. "The Effect of Information on Health Risk Valuations." *Journal of Risk and Uncertainty* 5: 29-48. 1992.

"This article examines the effect of familiarity with chronic lung disease on people's willingness to pay to reduce their risk of contracting chronic bronchitis, and on their willingness to increase their risk of auto death to reduce chronic bronchitis risk. We find that persons who have a relative with chronic lung disease are willing to give up more income to reduce their risk of chronic bronchitis than persons with no first-hand knowledge of the disease; however, their willingness to increase their risk of auto death [relative] to their risk of chronic bronchitis is no different, on average, than persons with no first-hand knowledge of lung disease. This suggests that responses to risk-risk tradeoffs may be more stable than responses to risk-income choices." (Abstract, Krupnick and Cropper 1992)

Keywords: application, CV

Krupnick, A.J. and M.L. Cropper. *Valuing Chronic Morbidity Damages: Medical Costs, Labor Market Effects, and Individual Valuations*. Report to the Office of Policy, Planning, and Evaluation, US Environmental Protection Agency. Resources for the Future, Washington, DC. February 1989.

This report presents the results of a project for the Office of Policy, Planning, and Evaluation of the US EPA to value chronic morbidity damages. This report provides estimates of per person medical cost of specific chronic conditions, including chronic obstructive lung disease and coronary heart disease, and estimates of the effects of the same chronic conditions on labor force participation and earnings. It also describes plans to estimate the willingness to pay to avoid the risk of all other consequences of chronic disease for chronic respiratory conditions, including the costs of altering leisure activities, costs of averting behavior, the value of pain and anxiety that the disease entails and the cost of premature death.

Keywords: application, COI, AB

Loehman, E.T. and V.H. De. "Application of Stochastic Choice Modeling to Policy Analysis of Public Goods: A Case Study of Air Quality Improvements." *The Review of Economics and Statistics* 64(3): 474-480. 1982.

This study uses a stochastic model to determine the willingness to pay for improved air quality in Tampa Bay, Florida. The survey method used in this study is easier than method described by Brookshire, Randall, and Stoll (1980) in the article "Valuing Increments and Decrements in Natural Resource Service Plans" because it does not require a respondent to identify an exact maximum willing to pay. The survey asked respondents to identify from a standard list of values the highest amount s/he would be willing to pay to avoid disease characteristics such as coughing, sneezing, and shortness of breath. For each given dollar amount, the response to a question is similar to a "paired comparison" between less income and worse health. The authors conclude that a survey can provide a public forum in which preferences about public goods, such as air quality, are revealed.

Keywords: application, CV

Loehman, E.T. et al. *An Interdisciplinary Study of the Health, Social and Environmental Economics of Sulfur Oxide Pollution in Florida.* Report to the Florida Sulfur Oxides Study, Inc. Interdisciplinary Center for Aeronomy and (other) Atmospheric Sciences, University of Florida, Gainesville, FL. 1978.

This study addresses the value of avoiding three health symptoms: shortness of breath/chest pains, coughing/sneezing, and head congestion/eye/ear/throat irritation. The study uses a contingent valuation survey and considers both minor and severe effects, where the survey defined minor as "could continue with daily activities with little or no change," and defined severe as "would need to restrict activities or possibly be confined to bed. Through a mail survey, the respondents were asked to estimate a willingness-to-pay value for avoiding these symptoms.

Keywords: application, CV

Magat, W.A., W.K. Viscusi, and J. Huber. "Paired Comparison and Contingent Valuation Approaches to Morbidity Risk Valuation." *Journal of Environmental Economics and Management* 15: 395-411. 1988.

This study introduces the paired-comparison-questions approach to non-market valuation for morbidity risk reductions associated with safer chemical products. The paired comparison approach produces higher morbidity valuations than contingent valuation in four applications. Compared to estimates determined from wage hedonic studies, both comparison and contingent valuations produce large values. This article concludes by suggesting some explanations for the differences in these estimates and discusses the public policy implications.

Keywords: application, CV

Mauskopf, J.A., and M.T. French. "Estimating the Value of Avoiding Morbidity and Mortality from Foodborne Illnesses." *Risk Analysis* 11(4): 619-631. 1991.

"This study develops a method based on published data to estimate the value of avoiding morbidity and mortality from foodborne illnesses using two metrics: quality-adjusted life-years and dollars. The authors demonstrate their method and derive estimates for the value of avoiding a future case of botulism, salmonellosis, chronic hepatitis, and bladder cancer. These dollar value estimates, which are based on willingness-to-pay values, are compared to the cost-of-illness (COI) method. The authors conclude that unlike COI, this method accounts for the value of avoided pain and suffering and allows for a comparison of avoiding different illnesses on the basis of quality-adjusted life -years gained. They also conclude that it generates morbidity and mortality valuation estimates for any illness in a relatively cost-effective and efficient manner." (Abstract, Mauskopf and French 1991).

Keywords: application, CV, COI

Murdoch, J.C. and M.A. Thayer. "The Benefits of Reducing the Incidence of Nonmelanoma Skin Cancers: A Defensive Expenditures Approach." *Journal of Environmental Economics and Management* 18(2) Part 1: 107-119. March 1990.

The benefits of decreasing the expected increases in the rates of nonmelanoma skin cancers over the next 60 years are estimated using the defensive expenditures approach. These defensive expenditures are then compared to estimates derived from the cost-of-illness methodology. The paper concludes that cost-of-illness estimates are more that double the estimates from the defensive expenditure method.

Keywords: application, AB, COI

Rice, D.P. "Estimating the Cost of Illness." *Health Economics Series* Public Health Service, Washington, DC. May 1966.

"This study presents a framework for calculating economic costs of illness, disability, and deaths, and performs the calculations. It discusses problems involved in measuring annual direct costs of illness, describes the procedures adopted, and presents data for selected types of health expenditures in 1963 by diagnosis. Another section deals with the annual indirect loses associated with illness, disability, and death. Included are the economic concepts, estimating procedures, and estimates of the total person-years and productivity lost in 1963 from morbidity and mortality for each diagnostic category. It presents the methodology and resulting estimates of the value of future earnings for those who died in 1963." (NTIS)

Keywords: application, COI

Rice, D.P., T.A. Hodgson and A.N. Kopstein. "The Economic Cost of Illness: A Replication and Update." *Health Care Financing Review* 39: 61-81. 1985.

The distribution of health care resource and the assessment of health research and programs largely depends on the economic consequences of illness, disability and premature death. This article updates the 1963 and 1972 studies of illness-related expenses, which are co-authored by Rice. The estimated total economic costs of illness in 1980 were $455 billion: $211 billion for direct costs, $68 billion for morbidity, and $176 billion for mortality. The diagnostic distributions of these three costs were affected by age and sex, and the most costly expenditures were diseases of the circulatory system, and injuries and poisonings.

Keywords: application, COI

Rowe, R.D. and L.G. Chestnut. *Valuing Changes in Morbidity: WTP Versus COI Measures*. Boulder, CO: Resources for the Future. Paper presented at the American Economic Association annual meeting, Dallas, Texas. Energy and Resource Consultants, Inc., Boulder, CO. December 1986.

This paper estimates and compares two measures of damage for changes in asthma severity: 1) willingness to pay (WTP), determined through a contingent valuation method; and 2) cost of illness (COI), determined by medical cost plus work loss. The purpose of the study is to evaluate the effectiveness of COI measures in determining the benefits of air pollution control. The authors conclude that WTP measures for reduction in asthma are approximately twice the COI estimates. Discomfort and activity effects of asthma are generally equal to or more important than medical costs and work loss. Consistency checks determine that about 80 percent of the WTP responses can be

considered "probably reasonable". The results of the study imply that for this sample, an increasing marginal utility for additional days of good health exists.

Keywords: application, CV, COI

Rowe, R.D. and L.G. Chestnut. *Oxidants and Asthmatics in Los Angeles: A Benefits Analysis*. Report to the Office of Policy Analysis, US Environmental Protection Agency. Energy and Resource Consultants, Inc., Boulder, CO. March 1985.

This article examines changes in behavior, expenditures, and willingness to pay (WTP) as related to asthma severity. The authors collect data from 82 asthmatics, who represent a population assumed to be sensitive to ambient oxidant levels. The study assesses mitigating behavior and its effect upon epidemiology and economic studies. It also stresses the importance of using a WTP benefit measure rather than a cost-of-illness (COI) measure for morbidity valuation. The data was collected via a diary completed for one month, which determined the accuracy of perceptions about air pollution, and a general questionnaire, which addressed how well COI measures estimated appropriate WTP measures for changes in illness.

Keywords: application, CV, COI

Showstack, J. *Service Use and Cost Associated with Kidney Transplant*. Report to the Agency for Health Care Policy and Research, Rockville, MD. Center for Research Dissemination and Liaison. May 1989.

"The primary goal of the research was to examine changes in overall resources use and costs associated with kidney transplant, particularly as affected by the introduction of cyclosporine (CsA). Specific factors studied included donor status, medication regimen, and clinical characteristics of patients who received a renal transplant at UCSF between 1982 and 1986. The study cohort consisted of 703 patients, of which 464 received kidneys from cadaver donors and 239 received kidneys from living-related donors. Graft survival during the transplant hospitalization was significantly better in CsA treated patients, although the effect was limited almost entirely to cadaver donor patients. In the cadaver donor group, over four times as many no-CsA treated patients lost their graft compared to CsA patients (25.2 percent versus 6.1 percent). During the transplant hospitalization, the use of CsA for cadaver donor patients was associated with a significantly shorter adjusted mean length of stay (27.0 days vs. 35.9 days) and lower adjusted means hospital charges ($28,313 vs. $37, 210), although CsA was associated with little change in service use for living-related donor patients Analyses of one-year follow-up data were conducted using only 202 cadaver-patients. During the post-transplant period there were no significant differences in number of

hospitalization days or in total costs between the CsA and no-CsA groups. The results suggest that cyclosporine had a substantial cost-lowering effect during the transplant hospitalization, but that there was little additional benefit during post-discharge period" (NTIS).

Keywords: application, COI

Smith, D.H., D.C. Malone, K.A. Lawson, L.J. Okamoto, C. Battista, and W.B. Saunders. "A National Estimate of the Economic Costs of Asthma." *American Journal of Respiratory and Critical Care Medicine* 156: 787-793. September 1997.

This cost of illness analysis examines national cost and resource utilization by persons with asthma using a single, comprehensive data source, the 1987 National Medical Expenditure Survey. Direct medical expenditures included payments for ambulatory care visits, hospital outpatient services, hospital inpatient stays, emergency department visits, physician and facility payments, and prescribed medicines. Indirect medical costs included costs resulting from missed work or school and days with restricted activity at work. Point estimates and 95 percent confidence intervals (CI) were calculated and inflated to 1994 dollars. The total estimated cost was $5.8 billion (95 percent CI, $3.6 to $8 billion). The estimated direct expenditures were $5.1 billion (95 percent CI, $3.3 to $7.0 billion), and indirect expenditures were valued at $673 million (95 percent CI, $271 to $1,076 million). Hospitalization accounted for more than half of all expenditures. More than 80 percent of resources were used by 20 percent of the population (defined as "high-cost patients"). The estimated annual per patient cost for those high-cost patients was $2,584, in contrast with $140 for the rest of the sample. Findings from this study indicate that future asthma research and intervention efforts directed at hospitalizations and high-cost patients could help to decrease health care resource use and provide cost savings.

Keywords: application, COI

Smith, V.K., and W.H. Desvousges. "An Empirical Analysis of the Economic Value of Risk Changes." *Journal of Political Economy* 95(1): 89-114. February 1987.

"Detailed empirical tests are presented of how an individual's valuation of a risk change varies with the level of the baseline risk. The findings reject the conventional hypothesis and suggest that the estimated marginal valuation of a risk change decreased with increases in the level of risk. They also suggest that the direction of the risk changes and perceived entitlements to safety affect the reported marginal valuations. The specific application involves a contingent valuation analysis based on the responses of a representative group of households in suburban Boston to proposed reductions in the risks of exposure to hazardous wastes. Further analysis of the role of the setting of risk for risk

perception and the behavioral responses to risk deserve serious attention in efforts to generalize the expected utility framework and in future empirical analysis." (ABI/INFORM. Ann Arbor, MI: Bell and Howell Information and Learning. 1999)

Keywords: application, CV

Smith, V.K., W.H. Desvousges, J.W., Payne. "Do Risk Information Programs Promote Mitigating Behavior?" *Journal of Risk and Uncertainty* 10(3): 203-221. May 1995.

"This article reports the results of a panel study investigating the effects of different radon risk information booklets on households' decisions to undertake mitigation. Multinominal logit models are used to describe how differences in the design of the information booklets along with the radon readings affected the choice to undertake some type of mitigation. To our knowledge this study offers the first example where a large sample was presented with different risk information concerning real risks that they were experiencing, and the research design permitted their risk perceptions and mitigation decisions to be tracked over time. Prescriptive messages along with emphasis on a radon threshold for action as part of the risk information seem to increase the likelihood of mitigating actions." (First Search)

Keywords: application, AB

Smith V.K. and W. Desvousges. "Asymmetries in the Valuation of Risk and the Siting of Hazardous Waste Disposal Facilities." *American Economic Association Papers and Proceedings* 76(2): 291-294. 1986.

This paper examines the differences between willingness to pay and willingness to accept as measures of change in individuals well-being resulting from a change in the conditions or access to (or quality of) a commodity. The authors report the first sizable evidence of perceived entitlement effects on property valuables using only a willingness-to-pay measure, which is important because individuals may have difficulty dealing with the idea of compensation used in willingness-to-accept measures. Respondents in suburban Boston bid significantly more to reduce risk than they indicated they were willing to pay to avoid an equivalent risk increase. While this study concludes that changes in the implied entitlements (to safety) can lead to large differences in welfare measures for risk changes, earlier studies have suggested that individuals are more willing to pay to avoid a risk increase.

Keywords: application, CV

Strauss, M.J. et al. "Cost and Outcome of Care for Patients with Chronic Obstructive Lung Disease." *Medical Care* 24(10): 915-924. October 1986.

This study analyzes the effect of physician specialization and board certification on costs and outcome of health care for a group of 213 patients suffering from chronic lung disease. The author controls differences in pulmonary function, functional ability and socio-demographic characteristic by using linear, semi-logarithmic and logistic regressions. Total charges incurred are used to estimate the costs of health services. The article concludes that patients' pulmonary function, functional ability, number of medical conditions and insurance status represent significant predictors of total costs, and that they can be combined to determine institutional days, outcome health status, and survival. Physician specialization and board certification do not significantly affect total cost of outcome of care for patients with moderate to severe chronic lung disease.

Keywords: application, COI

Thompson, M.S. "Willingness to Pay and Accept Risks to Cure Chronic Disease." *American Journal of Public Health* 76(4): 392-396. April 1986.

This study assesses the economic burden of disease by estimating what people would pay or risk to avoid illness. Specially trained interviewers asked 247 subjects with rheumatoid arthritis how much of their income they would pay and how large a mortal risk they would accept to achieve a hypothetical cure. The report concludes that 98 percent estimated their maximum acceptable risk (MAR) at an average 27 percent chance of immediate death; 84 percent gave responses to willingness to pay (WTP), with a mean WTP of 22 percent of household income. Impairment of daily living activities correlated most strongly with WTP, while measured pain corresponded to MAR. The authors conclude that this study validates the overall feasibility of these methods.

Keywords: application, CV

US Environmental Protection Agency. *Cost of Illness Handbook*. Office of Pollution, Prevention and Toxics. 1997b.

The *Cost of Illness Handbook* examines the direct medical costs associated with illnesses caused by environmental factors. These estimates are intended for use in calculating human health benefits and provide a lower-bound estimate for this purpose. The estimates reported do not reflect society's total willingness-to-pay to reduce risk and therefore do not reflect the total social costs associated with the diseases. The Handbook reports cost information for 17 illnesses related to pollutant exposure. The Handbook includes a discussion of the estimation methodology, data sources, available

treatments, data describing the linkage of the disease to environmental agents, and related studies. Most of the cost estimates are based on recent evaluations of medical practices and their costs.

Keywords: application, COI

US Environmental Protection Agency. *The Medical Costs of Five Illnesses Related to Exposure to Pollutants*. Report to Nicolaas Bouwes, Regulatory Impacts Branch, Economics and Technology Division, Office of Pollution Prevention and Toxics, US Environmental Protection Agency. Prepared by Abt Associates Incorporated. June 1992.

This report examines the direct medical costs of five illnesses: 1) asthma, 2) chronic obstructive pulmonary disease (COPD), 3) lung cancer, 4) coronary artery disease, and 5) asymptomatic high blood lead levels in children. The authors use two methodologies to estimate the medical cost of illness. The first method is the actual cost approach, which estimates the life-cycle disease cost by employing data bases of actual costs incurred by patients. The second method, the engineering approach, develops an average treatment profile for an illness, and assesses costs by multiplying the probability of a patient receiving a treatment by the cost of that treatment. The present value costs are estimated using discount rates of zero percent, two percent, five percent, and ten percent. The study uses both primary and secondary sources to develop the estimates. The authors conclude that the actual cost approach should be used for illnesses for which treatment has not changed significantly since the years covered in the database and rapid technological change is not expected. They also note that major restrictions on the use of the engineering approach are that survival data must be available, and that estimations based on this method are subject to errors of physician recall and unrepresentative experiences.

Keywords: application, COI

US Renal Data System (USRDS). *US Renal Data System: 1995 Annual Data Report*.   Report to the National Institute of Diabetes and Digestive and Kidney Diseases, National Institutes of Health, Bethesda, MD. April 1995.

This report address six goals of the USRDS: (1) to characterize the total renal patient population and analyze the distribution of patients by socio-demographic variables across treatment modalities; 2) to discuss the incidence, prevalence, mortality rates, and trends over time of renal disease by primary diagnosis, treatment modality, and other socio-demographic variables; and 3) to develop and examine data on the effect of various modalities of treatment by disease and patient group

categories; (4) to identify problems and opportunities for more specialized renal research; (5) to conduct economic cost effectiveness studies of end-stage renal disease (ESRD); and (6) to support investigator-initiated projects focusing on biomedical and economic analyses of ESRD patients.

Keywords: application, COI

Viscusi, W.K., W.A. Magat and A. Forrest. "Altruistic and Private Valuations of Risk Reduction." *Journal of Policy Analysis and Management* 7(2): 227-245. Winter 1988.

"To remedy the neglect of altruism in benefit assessments for risk regulation programs, this article reports the findings of a new survey of 785 consumers regarding their valuation of two pairs of risks from insecticide. The risk-dollar tradeoffs revealed by consumers averaged $2,080 and $3,680 per injury pair prevented within the household; they were willing to pay $5.01 and $9.06 per 1,000 injury pairs prevented in the rest of the state and $1.72 and $2.39 for each 1,000 injury pairs avoided elsewhere in the United States. The summed altruistic values for other individuals exceeded the private valuations, which suggests that altruism may be an important benefit component." (Abstract, Viscusi et al. 1988)

Keywords: application, CV

Viscusi, W.K., W. Magat and J. Huber. "Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk-Dollar Trade-offs for Chronic Bronchitis." *Journal of Environmental Economics and Management* 21(1): 32-51. 1991.

This study describes a methodology used to measure the values individuals place on morbidity risk reductions. The authors used an iterative computer program to measure respondents' marginal rates of substitution for chronic bronchitis risk reduction. As stated in the abstract, "the approach is innovative in that it measures the rates of trade-offs for chronic bronchitis risk reduction in terms of the risk of an automobile accident fatality (risk-risk trade-off) , as well as in dollars (risk-dollar trade-off)." The program's ability to generate estimates for individuals allows it to reveal distributions of benefit measures. The median trade-off rate of chronic bronchitis compared to an auto fatality is 32 percent. The median rate of trade-off between chronic bronchitis and an increase in cost of living is $457,000. The median rate of trade-off between an auto fatality and an increase in cost of living is $2.29 million. The results were internally consistent across different risk-risk and risk-dollar trade-offs.

Keywords: application, CV

Viscusi, W.K., W.A. Magat and J. Huber. "An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks." *RAND Journal of Economics* 18(4): 465-479. Winter 1987.

"After developing a conceptual analysis of consumer valuation of multiple risks, we explore both economic and cognitive hypotheses regarding individual risk-taking. Using a sample of over 1,500 consumers, our study ascertains risk-dollar tradeoffs for the risks associated with using an insecticide and a toilet bowl cleaner. We observe the expected positive valuation of risk reductions and find empirical support for a diminishing in the valuation of risk reduction as the extent of the risk reduction increases. We also find evidence of certainty premiums for the total elimination of one risk, but no strong evidence of additional certainty premiums for the elimination of multiple risks." Strong reference risk effects are evident, as avoiding increases in risk was valued much more greatly than was gaining decreases. (Abstract, Viscusi et al. 1987)

Keywords: application, CV

Waitzman, N.J. and R.M. Scheffler and P.S. Romano. *The Costs of Birth Defects.* Lanham, Maryland: University Press of America, Inc. 1996.

This book examines the cost of birth defects, which are the leading cause of infant mortality in the US. Most children with birth defects do not die in infancy, and they usually require special medical treatment, special education, and other nonmedical services throughout their lives. This study uses a cost-of-illness methodology to estimate the cost of eighteen clinically significant birth defects in the US, including *Spina bifida, Truncus arteriosus*, single ventricle, cleft lip, and Down syndrome. The authors estimate the indirect mortality and morbidity costs and direct costs of medical, developmental, and special education services over the entire life span of those born with each defect in California in 1988. The study concludes that the aggregate costs for these conditions ranged between $3.2 billion and $19.5 billion, depending on the discount rate applied to the costs after the first year of life. Using 5% discount rate as a best estimate, the cost in 1992 was $8 billion.

Keywords: application, COI

Weiss, K.B., P.J. Gergen, and T.A. Hodgson. "An Economic Evaluation of Asthma in the United States." Special Article. *The New England Journal of Medicine* 326(13): 862-866. 1992.

This study assesses the distribution of health care resources used for asthma in order to guide policy decisions aimed at reducing the economic burden of this disorder. The cost of illness related to asthma in 1990 was approximately $6.2 billion, with inpatient hospital services representing the single largest direct medical expense at $1.6 billion. The largest single indirect cost was loss of school days, which approached $1 billion in 1990. Forty-three percent of the economic impact of asthma was due to emergency room use, hospitalization and death. The report concludes that costs related to asthma in the US could be reduced by examining the effectiveness of care associated with each category of

costs. Effective primary care interventions for asthma in the ambulatory setting may reduce the costs of this common illness.

Keywords: application, COI

Weitzel, D.L. *Economic Valuation of Environmental Health Benefits: A Review of the Literature*. Report to the Washington State Department of Ecology. National Economic Research Associates, Inc., Seattle, WA. December 31, 1990.

This report reviews current estimates of the economic value of improvements in health states due to improvements in the quality of the environment. It focuses only on morbidity effects and synthesizes the literature of three main subjects: environmental economics, health services planning, and risk assessment. Some of the topics covered in this report include: contingent valuation, cost-of-illness studies, averting-behavior studies, dose-response relationships, hedonic wage and income studies, as well as the valuation of morbidity effects due to lead exposure.

Keywords: application, CV, COI, AB

Wittels, E., J.W. Hay and A.M. Gotto, Jr. "Medical Costs of Coronary Artery Disease in the United States." *The American Journal of Cardiology* 65: 432-440. February 1990.

This study focuses on the development of a model that determines the cost of coronary artery disease (CAD) for five primary events. The authors link medical decision algorithms outlining the diagnosis and treatment of patients with CAD to the costs for diagnostic and therapeutic service for these patients. The estimated five year costs (in 1986 US dollars) of the five CAD events are: $51,211 for acute myocardial infarction, $24,980 for angina pectoris, $40,581 for unstable angina pectoris, $9,078 for sudden death, and $19,697 for nonsudden death. The costs for major CAD surgical procedures are calculated. These figures include $32,465 for coronary bypass surgery per case over five years; and $26, 916 for angioplasty per case over five years. The article concludes that the high costs of CAD reflect the improved technology and more effective (and expensive) therapies.

Keywords: application, COI

Benefits Transfer

Alberini, A., M. Cropper, T-T Fu, A.J. Krupnick, J-T Liu, D. Shaw, and W. Harrington. "Valuing Health Effects of Air Pollution in Developing Countries: The Case of Taiwan." *Journal of Environmental Economics and Management* 34(2):108-125.1997.

This study examines the legitimacy of transferring existing US social benefit values of an improved environment to developing countries. Specifically, the authors evaluate the case of Taiwan through the use of a contingent valuation survey and a willingness to pay (WTP) model in order to investigate the value of avoiding the recurrence of acute respiratory illness. The model relies on characteristics of the illness such as duration, number of symptoms, and nature of the illness as well as characteristics of the individual including income and health history.

Keywords: benefits transfer

Desvousges, William H. et al. *Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method*. Edward Elgar: UK. 1998.

William Desvousges, F. Reed Johnson, and Spencer Banzhaf's book provides an introduction to the basic principles of the benefits transfer method and a case study application to the valuation of air pollutant externalities in Minnesota and Wisconsin. The basic steps proposed for a transfer are similar to those outlined in Chapter 4 of this document. The main premise of the book is that benefits transfers require the same rigor in constructing the theoretical underpinnings and conducting the analysis as does primary research, but that benefits transfers can nonetheless be less costly than primary research by simplifying the often time-intensive data collection phase of research. The case studies also illustrate the use of meta-analysis and Monte Carlo aggregation techniques to address some of the uncertainties in applying existing literature to policy applications different from those assessed in the original study.

Keywords: benefits transfer

Loomis, J.B. "The Evolution of A More Rigorous Approach to Benefit Transfer: Benefit Function Transfer." *Water Resources Research* 28(3): 701-705. March 1992.

"The desire for economic values of recreation for unstudied recreation resources dates back to the water resource development benefit-cost analyses of the early 1960s. Rather than simply applying existing estimates of benefits per trip to the study site, a fairly rigorous approach was developed by a number of economists. This approach involves application of travel cost demand equations and contingent valuation benefit functions from existing sites to the new site. In this way the spatial market of the new site (i.e., its differing own price, substitute prices and population distribution) is accounted for in the new estimate of total recreation benefits. The assumptions of benefit transfer from recreation sites in one state to another state for the same recreation activity is empirically tested.

The equality of demand coefficients for ocean sport salmon fishing in Oregon versus Washington and for freshwater steelhead fishing in Oregon versus Idaho is rejected. Thus transfer of either demand equations or average benefits per trip are likely to be in error. Using the Oregon steelhead equation, benefit transfers to rivers within the state are shown to be accurate to within five to fifteen percent." (Abstract, Loomis 1992)

Keywords: benefits transfer

Smith, V.K. "On Separating Defensible Benefit Transfers from 'Smoke and Mirrors.'" *Water Resources Research* 28(3): 685-694. March 1992.

"Benefits transfer methods increasingly are being applied to value nonmarketed resources for both policy evaluation and natural resource damage litigation. This paper illustrates the need for guidelines for deciding when benefits transfer methods can be used to value changes in environmental resources. It begins by discussing applied economic modeling perspectives and relating them to benefits transfers as tools for evaluating policy. It reviews the history of benefits transfers and summarizes how they are typically undertaken, including the influence of the analysts's judgements on their outcome, by comparing the development of two different analyses that use benefits transfers to consider the same issue-estimating the benefits form limiting industrial effluents discharged into specific rivers. It proposes an agenda for future benefits transfer research: devising strategies for extending available benefits transfer theory, learning from existing research, and formulating transferable versus "portable" modeling strategies." (Abstract, Smith 1992)

Keywords: benefits transfer

Valuation of Mortality Risk

Fisher, A., L.G. Chestnut, and D.M. Violette. "The Value of Reducing Risks of Death: A Note on New Evidence." *Journal of Policy Analysis and Management* 8(1): 88-100. Winter 1989.

Proposed policies often would reduce small risks of fatality for each of many people. The most credible evidence for estimating society's value for reducing such risks is individuals' willingness to pay (or willingness to accept compensation) for changes in risks. Studies of risky consumption choices are limited, but more evidence is now available relating wages to job risks. New contingent valuation studies reinforce the implications from wage-risk studies. A critique of twenty-one empirical studies suggests a value-per-statistical-life range of $1.6 million to $8.5 million (1986 dollars) for comparison with the cost per life saved of proposals to reduce fatal risks.

Keywords: valuation of mortality risk

Miller, T.R. "The Plausible Range for the Value of Life: Red Herrings Among the Mackerel." *Journal of Forensic Economics* 3(3): 17-39. 1990.

This study assesses the credibility of willingness to pay in benefit-cost analysis or courtroom debate over the liability of damages. Values of a statistical life generated from 67 analyses fall into four classes: (1) wage-risk studies; (2) market studies; (3) behavioral studies; and (4) contingent valuation surveys. These analyses yielded values ranging from $0 (Dorsey 1983, for non-union workers) to $15 million (Viscusi and Moore 1989). This paper narrows this range by adjusting some of the sources of inconsistency and weeding out those studies with serious flaws. Selected systematic biases were corrected, and uniform values for travel time and the discount rate were used to convert risk aversion estimates into values. The author concludes that 70 percent of the values of a statistical life are reasonably sound. The mean and median adjusted values from these studies are both $2.2 million and the standard deviation is $0.65 million. All the values, except one survey, lie within two standard deviations of the mean.

Keywords: valuation of mortality risk

Viscusi, W.K. *Fatal Tradeoffs: Public and Private Responsibilities for Risk*. New York: Oxford University Press. 1992.

This book focuses on the social regulation of risk and covers topics relating to the value and empirical estimates of the value-of-statistical life, the rationality of individual responses to risk, and the role of government policy. Viscusi provides a survey of the value-of-life and workplace safety literature and several discussions of the policy case studies that illustrate applications of value-of-life and morbidity valuation literature. In addition, he examines issues in the estimation of value-of-life

estimates, including isolation of value-of -life estimates in scenarios that reflect both fatal and non-fatal risks, and subjective worker perceptions of job risks. The book also includes a review of the 1980s era regulatory reforms and guidelines for risk policy.

Keywords: valuation of mortality risk

<u>Regulatory Support Documents</u>

US Environmental Protection Agency. *National Primary Drinking Water Regulations, Contaminant Specific Fact Sheets*, Office of Water. October 1995.

EPA's Office of Water published a series of fact sheets for specific drinking water contaminants cover by the National Primary Drinking Water Regulations. These fact sheets are grouped by chemical type: volatile organic chemicals, synthetic organic chemicals, and inorganic chemicals. Fact sheets are available in two versions, a technical version and a consumer version. The technical version includes chemical/physical properties, drinking water standards, a health effects summary, usage patterns, release patterns, environmental fate, and other regulatory information for each chemical. The consumer version of each booklet, adapted for the public, examines the chemical's use, regulation, health effects, release into the environment, and existence in drinking water.

Keywords: regulatory support document

US Environmental Protection Agency. *Regulatory Impact Analysis For The Particulate Matter and Ozone National Ambient Air Quality Standards and Proposed Regional Haze Rule*. Office of Air Quality Planning and Standards. July 1997.

The Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) Regulatory Impact Analysis evaluates the costs and benefits of further regulations to restrict two pollutants, ground level ozone and particulate matter (PM), which have been associated with significant health and welfare effects below current regulated levels. The report is designed to inform the public of the potential impact of revisions to the Ozone and PM NAAQS but is not relevant to creating the standards themselves (by statutory requirement, the standards are set based solely on health effects). Benefit estimates are presented as estimates of post-control air quality, human health and welfare effects, and the monetized value of health and welfare effects. The report concludes that estimated partial attainment benefits of the ozone and PM NAAQS greatly exceed estimated costs while full attainment estimates provide mixed conclusions.

Keywords: regulatory support document

US Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act, 1970 to 1990*. Report to the United States Congress, Washington, DC. October 1997.

This Report to Congress describes the results and conclusions of EPA's Section 812 assessment, which presents a retrospective analysis of the benefits and costs of the Clean Air Act from 1970 to 1990. This study compares and contrasts two regulatory scenarios in order to determine the effects of pollutant emissions reductions. The "control scenario" represents the actual conditions resulting

from the 1970 and 1977 Clean Air Acts, while the "no-control" scenario reflects the expected conditions assuming the Clean Air Act was never implemented. This no-control scenario represents a "baseline" against which the public health, economic and environmental effects of the Clean Air Act can be measured. The report concludes that the Clean Air Act has yielded significant reductions in the emissions of pollutants, including sulfur dioxide, carbon monoxide, nitrogen oxides, volatile organic compounds, particulate matter, ozone, and lead.

Keywords: regulatory support document

US Environmental Protection Agency. *Regulatory Impact Analysis: Benefits and Costs of Final Surface Water Treatment Rule*. Office of Drinking Water, Washington, DC. February 1989.

"The report presents an analysis of the costs and benefits of controlling microbiological contaminants in public water systems using surface water sources through the criteria specified in the final Surface Water Treatment Rule (SWTR). The analysis was prepared in compliance with Executive Order 12291 and the Regulatory Flexibility Act. A draft Regulatory Impact Analysis was prepared on September 1, 1987, in support of the proposed SWTR which was published in the Federal Register on November 7, 1987. The present document does not duplicate material presented previously. Instead, the document focuses on items which have changed in the analysis since the publication of the proposed rule, largely in response to public comments" (NTIS)

Keywords: regulatory support document

US Environmental Protection Agency. *Regulatory Impact Analysis: Benefits and Costs of Proposed National Primary Drinking Water Regulations for Inorganic Chemicals*. Office of Drinking Water, Washington, DC. March 1989a.

This report examines the costs and benefits of regulations for maximum contaminant level goals (MCLGs) and maximum contaminant levels (MCLs) pertaining to inorganic chemical contaminants (IOCs). This Regulatory Impact Analysis (RIA) addresses these major issues: problem definition; market imperfections, the need for Federal regulation; and consideration of regulatory alternatives; assessment of total costs and benefits; regulatory flexibility and paperwork reduction analyses; and a summary of costs and benefits.

Keywords: regulatory support document

US Environmental Protection Agency. *Estimating and Valuing Morbidity in a Policy Context: Proceedings of June 1989 Association of Environmental and Resource Economists Workshop*. Research Triangle Park, N.C. June 1989b.

Eleven articles from the proceedings of the 1989 Association of Environmental and Resource Economists Workshop comprise this report. Topics relating to the Estimation of the Amount of Illness and Injury Associated with Specific Causes include: The Role of Epidemiology in Developing Useful Data for Public Health Policy; Acute Health and Variable Air Pollutants; and, Estimating Skin Cancer (Melanoma) Deaths from Sunlight Exposure. Topics covered during the Valuation of Changes in Illness and Injury Session Include: Pricing Environmental Health Risks: Survey Assessment of Risk-Risk and Risk-Dollar Trade-offs; The Social Costs of Chronic Heart and Lung Disease; Estimating the Value of Avoiding Morbidity and Mortality from Foodborne Illnesses; Utility-Adjusted Impairment Years: A Low-Cost Approach to Morbidity Valuation; Valuing Nonmarket Goods: A Household Production Approach; Valuation of Morbidity Reduction Due to Air Pollution Abatement Direct and Indirect Measurements; Risk, Self-Protection and *Ex Ante* Economic Value; and the Economics of Quarantines: An Application to Pesticide Regulation.

Keywords: regulatory support document

US Environmental Protection Agency. *Review of the National Ambient Air Quality Standards for Ozone: Assessment of Scientific and Technical Information*. Air Quality Management Division, Office of Air Quality Planning and Standards, Washington, DC. June 1989c.

This paper assesses the scientific and technical information relevant to the review of primary (health) and secondary (welfare) national ambient air quality standards (NAAQS) for ozone. With regard to primary standards, the information studied includes respiratory tract absorption and deposition of ozone; studies of mechanisms of ozone toxicity; controlled human exposure; field, epidemiological and animal toxicology; and air quality information. With regard to the secondary standards, the report covers the following subjects: impacts on vegetation; natural ecosystems; materials; and symptomatic effects on humans. The provides recommendations for revising both the primary and secondary NAAQS standards. For example the authors recommend that ozone should remain the surrogate for controlling ambient concentrations of photochemical oxidants.

Keywords: regulatory support document

US Environmental Protection Agency. *Regulatory Impact Analysis: Protection of Stratospheric Ozone*. Volumes 1-2. Stratospheric Protection Program, Office of Program Development, Office of Air and Radiation, Washington, DC. December 1987.

This Regulatory Impact Analysis (RIA) examines the probable effects of regulatory measures designed to protect stratospheric ozone. These measures are a result of the "Montreal Protocol" which called for a freeze on the use of CFCs in 1989, a 20 percent reduction in their use by 1998 and another 30 percent decrease in their use in 1998. The international protocol also called for a freeze on Halon usage at 1986 beginning in 1992. The report concludes that the benefits of reducing CFC/Halon use outweigh the economic costs of the regulations, under almost all of the scenarios examined. The report consists of two volumes. Volume I describes the RIA and Volume II (parts 1 and 2) provides the appendices to the RIA.

Keywords: regulatory support document

US Environmental Protection Agency. *Costs and Benefits of Reducing Lead in Gasoline: Final Regulatory Impact Analysis*. Office of Policy Analysis, Washington, DC. February 1985.

This report examines the basis for reducing lead in gasoline, and the costs and benefits of lead reduction. The report was written at the time EPA proposed to reduce the amount of lead in gasoline from 1.10 grams per leaded gallon (gplg) to 0.50 gplg by July 1985 and 0.10 gplg by January 1, 1986. EPA also proposed to allow refineries that reduced lead earlier than 1985 to "bank" those extra lead rights for use in 1986 or 1987. The costs for the second half of 1985 were less than $100 million under the 0.50 gplg limit, and $608 million in 1986 to $441 million in 1992 under the 0.10 gplg limit. Banking was estimated to reduce the present value of the cost by about $200 million over the 1985 to 1987 period. The authors estimated four major categories of benefits: (1) children's health and cognitive effects associated with lead; (2) blood-pressure-related effects in adult males due to lead exposure; (3) damages caused by excess emissions of HC, NOx, and CO from misfueled vehicles; and (4) impacts on maintenance and fuel economy. The report concludes that although many benefits were difficult to monetize, they were estimated to far exceed the costs of reducing lead in gasoline.

Keywords: regulatory support document

APPENDIX B

**LITERATURE REVIEW FOR
ECONOMIC VALUATION OF
PAIN AND SUFFERING**

APPENDIX B

LITERATURE REVIEW FOR ECONOMIC
VALUATION OF PAIN AND SUFFERING

This appendix supplements the discussion in Chapter 5 of the economic valuation of pain and suffering associated with non-cancer health effects. The appendix includes additional details on the literature reviewed in support of the Chapter 5 discussion, as well as a more detailed explanation of methods used in that chapter to estimate the pain and suffering component of available willingness-to-pay and other health effects valuation estimates.

Further Details on WTP/COI Comparisons

A few researchers have compared estimates of WTP and COI for environmental health effects. Two types of WTP to COI comparisons can be distinguished. First, some researchers have estimated both WTP and COI for the same individuals, using a single source of survey data. These studies usually compare individual WTP to an individual's COI (exclusive of costs borne by others, such as third-party compensation for medical expenses or lost wages). Second, researchers occasionally have compared WTP estimates from one study to COI estimates from another. These comparisons usually involve individual WTP, but social COI (inclusive of costs borne by others), and thus are not directly comparable to comparisons based on an individual's WTP and COI.

The first type of comparison is more informative about the relative magnitudes of WTP and COI, because all the data pertain to the same people, and the same or similar data collection and analysis procedures underlie the estimates of both WTP and COI. Studies comparing WTP and COI estimates from separate sources face the problem of accounting for differences between the studies in characteristics of individuals (such as age), in severity of health effects, and in research methodology.

Results of four studies which have estimated WTP and COI for the same individuals are summarized in Exhibit B-1. All monetary values have been converted to 1996 dollars using the Consumer Price Index (though this does not affect the ratios of values).

Berger et al. (1987)

Berger et al. (1987) conducted a survey to measure WTP to avoid seven relatively minor, acute symptoms and the individual COI associated with experiencing the symptoms. Door-to-door and mall-intercept methods were used to interview 131 people between September 1984 and January 1985. WTP was estimated using contingent valuation (CV).

WTP AND COI ESTIMATES FROM SAME DATA SOURCE

Health Effect	Study	1996 Dollars for:	WTP Method	WTP $1996	Medical Expenses $1996 (MED)	Foregone Earnings $1996	Individual COI $1996	Ratio WTP/MED	Ratio WTP/COI
Symptoms	Berger et al. 1987	One symptom day	CV						
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
Angina Episodes	Chestnut et al. 1988, 1996	One episode	CV, AB						
			AB	$ 54.40	Negligible	Negligible	$ 18.54		2.9
			CV	$ 57.26	Negligible	Negligible	$ 18.54		3.1
			CV	$ 60.13	Negligible	Negligible	$ 18.54		3.2
			CV	$ 147.45	Negligible	Negligible	$ 18.54		8.0
Health Effects of Ozone (Unspecified)	Dickie-Gerking 1991	Reduce to zero days/year of ozone:	AB						
		over 12 pphm		$ 138.53	$ 36.45			3.8	
				$ 167.69	$ 84.57			2.0	
				$ 249.35	$ 67.08			3.7	
				$ 304.76	$ 160.40			1.9	
		over 9 pphm		$ 249.35	$ 59.79			4.2	
				$ 298.93	$ 131.24			2.3	
				$ 380.58	$ 94.78			4.0	
				$ 457.87	$ 215.81			2.1	
Asthma Severity	Rowe-Chestnut 1985	Reduce number of bad asthma days/year	CV						
				$ 631.70	$ 196.91	$ 116.57		3.2	2.0
				$ 919.98	$ 196.91	$ 116.57		4.7	2.9
				$ 697.86	$ 70.89	$ 116.57		9.8	3.7

Mean WTP and COI estimates are shown in Exhibit B-1 along with the computed ratio of mean WTP to mean COI for each symptom. Ratios range from 3.1 (throat congestion) to 78.9 (heavy drowsiness), with a ratio of 20.5 for all symptoms combined. Excluding the results for "drowsiness" (based on only 5 observations), the median of the WTP/COI ratios shown is 6.2, and the mean is 12.6.

Chestnut et al. (1988, 1996)

Chestnut et al. (1996) presented estimates of WTP, based on averting behavior (AB) and CV, for reduced frequency of angina symptoms, along with COI information. Fifty men with a physician diagnosis of angina pectoris and a history of chest pain served as subjects for the 1986 study. The AB estimate presented in Exhibit B-1 represents the average averting expenditure for each perceived angina episode avoided. CV estimates of WTP presented are based on an open-ended WTP question, converted to reflect WTP per episode avoided (Chestnut et al. 1996, Table 3). Three values are obtained depending on the treatment of high outlying WTP responses.

Chestnut et al. (1996) reported a sample mean of annual individual COI for ischemic heart disease of $20,556 ($1996). The overall COI was not sensitive, however, to the frequency of angina episodes. Over 95% of respondents reported no out-of-pocket medical expenses for a typical angina episode (almost all had full insurance coverage), and in a regression of COI on angina frequency and other variables, the coefficient of angina frequency was not statistically significant.

Chestnut et al. (1996) concluded that individual COI for an angina episode is negligible, though WTP to avoid an episode is substantial. If "negligible" is interpreted to mean "zero" cost of illness, then the WTP/COI ratio is undefined (or alternatively could be viewed as infinite). Nonetheless, a positive, if statistically insignificant, estimate of COI per angina episode can be constructed from the regression of annual, individual COI on angina frequency and other variables. Chestnut et al. (1988) report this regression in Table 4.1-3; the angina coefficient is 155.40. Converting the coefficient to measure the effect of annual rather than monthly frequency (dividing by 12) implies that an additional angina episode costs an individual $12.95 (1986 dollars). Finally, converting this figure to 1996 dollars yields the COI per episode estimate presented in Exhibit B-1.

Using the constructed COI figure, the WTP/COI ratio based on the AB estimate is 2.9. Ratios based on the three CV estimates of WTP range from 3.1 to 8.0.

Dickie and Gerking (1991)

Dickie and Gerking (1991) applied a variant of the AB model in which medical care, air pollution, and other variables were viewed as inputs used to produce an individual's overall acute health status. They estimated savings in medical expenses associated with various reductions in

ambient ozone concentrations and the corresponding WTP. Data were obtained from repeated surveys of 226 Los Angeles-area residents during 1985-86.

Dickie and Gerking estimate medical expense changes and WTP separately for residents of two communities (Burbank and Glendora) and for two different target concentrations of ozone, using two alternate specifications of their model. Thus, 8 pairs of medical expense, WTP estimates are presented (Dickie and Gerking 1991, Table II). As shown in Exhibit B-1, WTP to medical cost ratios range from 1.9 to 4.2, with a mean and median of 3.0.

Rowe and Chestnut (1985)

Rowe and Chestnut (1985) estimated WTP and COI for asthma-related illness using a sample of 82 asthmatics in Glendora, California, during Fall of 1983. WTP was estimated using CV, where respondents marked a payment card indicating the value closest to the maximum tax increase they would be willing to pay for a 50% reduction in "bad asthma days." Rowe and Chestnut also estimated the savings in medical expenditures associated with the 50% reduction in asthma severity. Data on lost earnings were not collected, however, implying the Rowe and Chestnut study is best suited to comparing WTP and medical expenses. Ratios of WTP to medical expenses range from 3.2 to 9.8, depending on how the sample is defined.

Rowe and Chestnut also used two approaches to construct rough estimates of foregone earnings. In the first approach (not shown in Exhibit B-1), they simply assumed that foregone earnings and medical expenses were equal, implying that WTP/COI ratios would be one-half of WTP to medical expense ratios. Second, they imputed a foregone earnings figure based on responses to a separate WTP question concerning work loss effects of asthma. Adding the imputed foregone earnings to medical expenses to compute individual COI results in WTP/COI ratios ranging from 2.0 to 3.7.

WTP/COI Estimates from Common Data: Overall Results

These four studies offer consistent support for the idea that WTP exceeds individual COI by a margin that may vary widely with the health effects or pollution reductions considered (and that also may vary depending on methods and data used). Taking all the studies together, the ratio of WTP to medical expenses ranges from 1.9 to 9.8, with a median of 3.7 and a mean of 3.8. WTP/COI ratios range from 2.0 to 31.5 (still excluding the outlying "drowsiness" ratio of Berger et al.), with a median of 3.9 and a mean of 8.1.

Rowe and Chestnut (1985) suggested that, as a rule of thumb, WTP could be approximated by scaling COI by a factor of two. Chestnut (1995) adapted this procedure to estimate WTP for several health endpoints affected by acid rain controls, estimating WTP as twice the COI, plus or

minus 50 percent. Cropper and Freeman (1989), however, argue that WTP is unlikely to be a constant mark-up of COI, but rather that the WTP/COI ratio is illness specific and may differ from one population group to another depending on the fraction of medical expenses and foregone earnings borne by individuals in each group.

The ratios in Exhibit B-1 cast doubt on the proposition that the WTP/COI ratio is constant (as well as on the idea that any such constant would equal approximately 2). More formally, a statistical test of the hypothesis of a constant WTP/COI ratio can be performed by regression the logarithm of WTP on a constant term and the logarithm of COI. If the WTP to COI ratio is constant, the coefficient of the log of COI must be unity. (This test also can be performed if other explanatory variables are included in the regression; the test then concerns whether the WTP/COI ratio is constant after accounting for effects of the additional variables.)

The test was performed by regressing log WTP on log COI (or on the logarithm of medical expenses), a constant, and dummy variables to distinguish study-specific effects. Using results from Dickie-Gerking and Rowe-Chestnut, the estimated coefficient of the log of medical expenses is 0.45 (standard error = 0.155), which is significantly different from unity at the one percent level. Using results from Berger et al. and Chestnut et al., the estimated coefficient of log COI is -0.19 (s.e. = 0.268), which is significantly different from unity at the one percent level. Thus, the hypothesis that the WTP/COI ratio is constant, as well as the hypothesis that the ratio of WTP to medical expenses is constant, is rejected at the one percent significance level.

Application of this procedure using the figures reported in Exhibit B-1 not surprisingly leads to rejection of the hypothesis of a constant WTP/COI ratio, and the hypothesis of a constant WTP to medical expense ratio. Both hypotheses are rejected at the one percent significance level.

WTP and COI Estimates from Different Sources

As mentioned previously, other studies have compared WTP and COI estimates based on different data sources, though the potential lack of comparability in the separate studies complicates interpretation of these results. Outcomes of two such comparisons are summarized in Exhibit B-2. Agee and Crocker (1996) adapted the Dickie and Gerking (1991) procedure to estimate the demand for chelation therapy and parents' WTP to reduce the lead body burden of their children. Aggregating to all US households with children aged 7 years and younger in metropolitan areas, they obtain an overall WTP estimate as well as separate estimates for households who choose or do not choose chelation therapy.

Agee and Crocker compare the aggregate WTP estimates to a single, aggregate COI-type estimates of US EPA (1985), based on costs of medical treatment and compensatory schooling (Agee and Crocker 1996, Table 3). Ratios of WTP to COI range from 2.1 for households not choosing chelation therapy to 20.0 for households choosing chelation therapy.

WTP to COI ratios for chronic bronchitis were prepared by US EPA (1996). WTP estimates were derived from the Viscusi et al. (1991) risk-risk tradeoff study, with an adjustment for severity level based on the related study of Krupnick and Cropper (1992). Cost-of-illness estimates, which vary according to age at onset, were taken from Cropper and Krupnick (1990). Ratios of the single WTP estimate to the age-dependent COI estimates range from 3.4 to 6.3.

Results presented in Exhibit B-2 support the idea that WTP estimates based on the amounts individuals are willing to pay to avoid a health effect exceed *social* costs of illness. The mark-up of WTP over social COI appears to vary according the characteristics of individuals (age or choice of chelation therapy) and, like the markup of WTP over individual COI, appears to vary according to health effect.

Information from Damage Award Studies

In this section, we explore the extent to which analysis of damage awards provides insights into the magnitude of the pain and suffering component of willingness to pay to avoid health effects. Chapter 3 contains a brief overview of the key features of damage award data, so that material is not repeated here.

Overview of Sources of Damage Award Data and Amounts of Compensation

Hensler et al. (1991) provide extensive documentation of costs of injuries and compensation received. Their prevalence-based estimates of annual direct and indirect costs of injury in the US sum to $175.9 billion (1988 dollars, $97.9 billion direct cost and $78 billion lost earnings), or approximately 4% of GDP.[1] Of this total, injured persons receive $109.4 billion (62 percent) in compensation. Most (68 percent) receive compensation from their own health or automobile insurance; only 10 percent to 11 percent of injured persons are compensated through the liability system. Although this represents a small fraction of the overall population of injured persons, it amounts to 1.4 million persons annually. Estimated liability payments total $15.2 billion, or $12.9 billion net of legal fees. Hensler et al. estimate that $7.7 billion compensates for direct and indirect costs, while $5.2 billion compensates for pain and suffering.

---

[1] The National Center for Health Statistics estimates the annual incidence of injuries requiring medical attention or activity restrictions in the US as 26 per 100 persons (NCHS 1988). Results from the national survey by Hensler et al. (1991) indicate that the most frequent cause of injury is a slip or fall, accounting for 38 percent of all injuries. Accidents associated with use of products or machinery (30 percent) or motor vehicles (18 percent) account for most of the remainder.

Exhibit B-2							
WTP AND COI ESTIMATES FROM DIFFERENT DATA SOURCES							
Health Effect	**Study**	**1996 Dollars for:**	**WTP Method & Source**	**COI Method & Source**	**WTP $1996**	**COI $1996**	**Ratio WTP/ COI**
Child Lead	Agee-Crocker 1996	Reduce Body Lead 1% US Children Age 7/Under	AB, Agee-Crocker	Medical Treatment, Schooling, % discount. US EPA 1985			
		All			$ 670,252,427	$218,974,515	3.1
		Not choose chelation			$ 460,798,544		2.1
		Choose chelation			$4,379,490,291		20.0
Chronic Bronchitis	US EPA 1997	Case of Pollution-Related CB	Risk-Risk, Viscusi et al. 1991, Krupnick-Cropper 1992	Medical Costs, Lost Earnings, 5% discount. Cropper-Krupnick 1990			
		All			$ 260,000		
		Age 30				$ 77,000	3.4
		Age 40				$ 58,000	4.5
		Age 50				$ 60,000	4.3
		Age 60				$ 41,000	6.3

In sum, a large number of people are injured each year; associated direct and indirect costs are not trivial amounts in relation to national income, and aggregate compensation falls short of fully replacing injured persons' pecuniary losses. Relatively few persons, accounting for a small share of total compensation for injury, receive liability payments.

Even fewer persons are compensated in consequence of jury verdicts. Viscusi (1988) examined all product liability claims closed by a national sample of 23 insurance companies over approximately a one-year period during 1976-77. He found that 19 percent of claims were dropped, 77 percent were settled out of court, 4 percent went to a jury, and 1.5 percent resulted in a verdict for the plaintiff. Danzon and Lillard (1983) likewise reports that only 10 percent of medical malpractice claims reach a jury verdict. Although only 18 percent of injuries are caused by motor vehicle accidents, automobile cases account over half of person injury litigation (Bovbjerg et al. 1991).

Overview of Damage Awards

Although settlements between insurers and injured persons (or their attorneys) determine the vast majority of damage awards, the negotiations are heavily influenced by the parties' assessments of likely outcomes at trial (Priest and Klein 1984; Prahl and Ultrata 1985). In consequence, jury awards have a greater influence in determining damage payments than would be suggested by the small fraction of cases evaluated by juries.

Juries generally award compensatory damages only; punitive damages are rare (Bovbjerg et al. 1991). Compensatory damages in tort cases are meant "to represent the closest possible financial equivalent of the harm suffered by the plaintiff, and to restore him to the position he occupied before the tort" (Pfennigstorf and Gifford, 1991). Compensation consists of special and general damages. *Special damages* denote pecuniary losses such as medical expenses and lost earnings, and must be established by evidence of loss. *General damages*, which do not require a specific showing of monetary amounts lost, include intangibles such as pain, suffering, mental anguish, disfigurement, inconvenience, humiliation, and loss of the enjoyment of life.

Juries determine damages with little guidance or control from the trial judge, particularly with respect to general damages (Pfennigstorf and Gifford 1991). Usually, juries return general verdicts, without itemizing the amounts awarded for each of the multiple injuries often suffered by a single plaintiff, or the amounts awarded for general and special damages. Judges can, but rarely do, decrease (remittitur) or increase (additur) damage awards. Bovbjerg et al. (1991) estimate that post-trial adjustments are made to 20 percent of personal injury verdicts; almost all are reductions and most occur by settlement.

Jury awards for pain and suffering are quite controversial among legal scholars. Key points of controversy include whether compensation for pain and suffering is desirable in principle, and whether the amounts awarded by juries are appropriate (Croley and Hanson 1995, Geistfeld 1995, Levin 1989, Taylor 1994). Many states have responded to criticisms of awards for pain and suffering by enacting caps on general damages. Other proposals for reform include giving jurors more quantitative information on amounts that might be appropriate for general damages. Some scholars recommend providing jurors with data on prior jury awards (Bovbjerg et al. 1989), while others recommend using results of WTP studies (Miller 1989; Taylor 1994).

In current practice, there are few guidelines for determining general damages, and the task appears quite difficult for liability claims adjustors and potential jurors alike (Prahl and Utrata 1985, Vidmar 1993). Although the determination of special damages is not necessarily straightforward, particularly when future wage losses and medical expenses must be forecast, determining general damages is far more difficult.

Liability claims adjusters may use a mark-up rule-of-thumb to generate a starting offer for negotiations. Mark-ups of three to five times special damages may be used (Prahl and Utrata 1985), while others suggest insurers will pay three to ten times special damages to settle claims (Levin 1989).

A second method of computing general damages is represented by the "unit of time" and related approaches (Prahl and Utrata 1985). A dollar amount is assigned to pain and suffering for a small length of time, such as a day, and then multiplied by the number of days of pain and suffering. The basic issue of choosing the original dollar amount remains, however. In view of the lack of a reliable method to compute general damages, claims adjusters usually estimate general damages based on their assessments of likely jury verdicts (Prahl and Utrata 1985).

Jurors have wide latitude in determining general damages. Judges usually forbid any use of mathematical formulas to compute general damages, and often forbid introduction of any quantitative evidence on appropriate dollar amounts. Jury instructions offer little guidance on how general damages should be determined, beyond appeals to jurors' "collective good conscience" (Chase 1995; Pfennigstorf and Gifford 1991).

In view of the discretion allowed juries, and the lack of quantitative evidence presented to them, it is not surprising that awards for general damages are widely dispersed, even within injury categories (Bovbjerg et al. 1989). Nonetheless, awards for pain and suffering appear systematically related to key determinants, including the severity of injury (Bovbjerg et al. 1989, 1991; Rodgers 1993, Viscusi 1988). Bovbjerg et al. report regressions in which over 50 percent of the variation in general damage awards is accounted for by key determinants, an impressive figure when compared to corresponding statistics from environmental valuation studies. In short, it does not appear that jury awards for pain and suffering and other general damages are arbitrary. But whether the amounts awarded represent appropriate compensation, and whether they would approximate WTP, remain open questions.

Overview of Empirical Studies

Relatively few empirical studies of damage awards have been published, and some of these such as Leebron (1989) focus exclusively on fatal injuries. Results of five studies presenting estimates of special and general damages are presented in Exhibit B-3. Estimates of general damages represent monetary valuations (though not necessarily WTP) of pain and suffering and other nonfinancial losses. Ratios of total damages to special damages are analogous to WTP/COI ratios (i.e., a comprehensive valuation compared to a purely financial one), and are useful in summarizing results from the individual studies. More detailed results of three studies containing separate estimates of general and special damages are summarized in Exhibits B-4, B-5, and B-6. All monetary values have been converted to 1996 dollars using the Consumer Price Index.

Study and Method	Injury	Mean Total Damages	Mean Special Damages	Mean General Damages	Ratio Total / Special
Exhibit B-3					
DAMAGE AWARDS FOR PERSONAL INJURY					
Viscusi 1988, Nonfatal Injury data from closed claims for product liability					
	Amputation	$87,993	$43,996	$43,996	2.0
	Asphyxiation	$4,799	$2,303	$2,495	2.1
	Brain Damage	$286,939	$169,294	$117,645	1.7
	Bruise	$7,438	$3,794	$3,645	2.0
	Burn	$56,055	$24,104	$31,951	2.3
	Cancer	$71,989	$33,835	$38,154	2.1
	Concussion	$17,542	$8,420	$9,122	2.1
	Dermatitis	$1,473	$869	$604	1.7
	Dislocation	$38,608	$22,393	$16,215	1.7
	Disease-other	$15,427	$8,330	$7,096	1.9
	Electrical shock	$11,979	$5,990	$5,990	2.0
	Fracture	$27,166	$19,016	$8,150	1.4
	Laceration	$9,420	$4,616	$4,804	2.0
	Para/quadriplegia	$426,172	$323,891	$102,281	1.3
	Poison	$1,294	$660	$634	2.0
	Respiratory	$64,922	$38,953	$25,969	1.7
	Sprain/strain	$29,994	$14,997	$14,997	2.0
	Other	$15,175	$9,864	$5,311	1.5
	Mean	$65,244	$40,851	$24,392	1.9
Rodgers 1993, Nonfatal injury (scaled by severity) data from jury awards for product liability					
	Severity 1	$42,726	$7,048	$35,678	6.1
	Severity 2	$67,597	$17,709	$49,888	3.8
	Severity 3	$97,686	$20,747	$76,939	4.7
	Severity 4	$354,847	$39,437	$315,410	9.0
	All	$83,439	$17,282	$66,157	4.8
	Weighted Mean Ratio				5.9
Hammitt 1985, Damages by state, rather than injury, data from claims for automotive insurance					
	California	$6,745	$2,612	$4,132	2.6
	Washington	$8,311	$2,667	$5,644	3.1
	North Carolina	$3,842	$1,476	$2,366	2.6
	Maryland	$6,095	$2,294	$3,801	2.7
	New Jersey	$11,625	$2,017	$9,608	5.8
	Massachusetts	$12,316	$4,267	$8,050	2.9
	Mean	$6,885	$2,421	$4,465	2.9

Exhibit B-3					
DAMAGE AWARDS FOR PERSONAL INJURY					
Study and Method	**Injury**	**Mean Total Damages**	**Mean Special Damages**	**Mean General Damages**	**Ratio Total / Special**
Bovbjerg et al. 1989, Fatal and nonfatal injury scaled by severity, data from jury awards for personal injury cases					
	Emotional	$51,103	$16,574	$34,529	3.1
	Temporary Insignificant	$30,386	$16,574	$13,812	1.8
	Temporary Minor	$95,300	$22,099	$73,202	4.3
	Temporary Major	$281,757	$196,125	$85,632	1.4
	Permanent Minor	$338,385	$117,399	$220,986	2.9
	Permanent Significant	$882,563	$349,434	$533,129	2.5
	Permanent Major	$2,882,485	$-	$3,189,103	-
	Permanent Grave	$6,999,729	$1,127,028	$5,872,701	6.2
	Death	$1,690,542	$-	$1,715,403	-
	Mean	$676,769	$261,040	$415,730	2.6
Cohen 1988, Injuries suffered by crime victims, data from jury awards in personal injury cases					
	Severely Disabling Psychological	$178,344	$36,090	$142,254	4.9
	Traumatic Neurosis	$117,589	$6,018	$111,571	19.5
	Gunshot wound	$92,139	$5,605	$86,534	16.4
	Burn	$61,668	$2,552	$59,116	24.2
	Internal Injury or Concussion	$37,795	$3,723	$34,072	10.2
	Broken Bones or Teeth	$24,750	$2,479	$22,271	10.0
	Multiple Minor	$6,541	$1,703	$4,838	3.8
	Mean	$74,118	$8,310	$65,808	12.7

All estimates are in 1996 dollars. See text for more information on individual studies.

Note: Damage awards, while a potentially useful source of data, have not been fully evaluated by economists as to their usefulness for valuation of health effects. The conditions under which juries determine damage awards may include factors that make the values less useful for health effect valuation applications. Economists continue to evaluate the theoretical and practical underpinnings of damage award data -- see text for discussion.

	Exhibit B-4							
	DAMAGE PAYMENTS FOR NONFATAL INJURY							
	Positive Bodily Injury Payment				**Positive P&S Payment**			
(Nonfatal) Injury	**Mean General Damages $1996**	**Mean Special Damages $1996**	**Mean Total Damages $1996**	**Ratio of Total to Special**	**Mean General Damages $1996**	**Mean Special Damages $1996**	**Mean Total Damages $1996**	**Ratio of Total to Special**
Amputation	$ 43,996	$ 43,996	$ 87,993	2.0	$ 59,507	$ 28,004	$ 87,511	3.1
Asphyxiation	$ 2,495	$ 2,303	$ 4,799	2.1	$ 3,565	$ 1,252	$ 4,817	3.8
Brain Damage	$117,645	$169,294	$286,939	1.7	$202,349	$ 82,650	$284,999	3.4
Bruise	$ 3,645	$ 3,794	$ 7,438	2.0	$ 5,013	$ 2,359	$ 7,373	3.1
Burn	$ 31,951	$ 24,104	$ 56,055	2.3	$ 38,156	$ 17,142	$ 55,298	3.2
Cancer	$ 38,154	$ 33,835	$ 71,989	2.1	$ 44,513	$ 27,282	$ 71,796	2.6
Concussion	$ 9,122	$ 8,420	$ 17,542	2.1	$ 11,591	$ 5,971	$ 17,563	2.9
Dermatitis	$ 604	$ 869	$ 1,473	1.7	$ 915	$ 537	$ 1,452	2.7
Dislocation	$ 16,215	$ 22,393	$ 38,608	1.7	$ 25,946	$ 12,779	$ 38,725	3.0
Disease-other	$ 7,096	$ 8,330	$ 15,427	1.9	$ 9,105	$ 6,070	$ 15,175	2.5
Electrical shock	$ 5,990	$ 5,990	$ 11,979	2.0	$ 8,104	$ 3,814	$ 11,918	3.1
Fracture	$ 8,150	$ 19,016	$ 27,166	1.4	$ 15,849	$ 11,477	$ 27,326	2.4
Laceration	$ 4,804	$ 4,616	$ 9,420	2.0	$ 6,378	$ 3,001	$ 9,379	3.1
Para/quadriplegia	$102,281	$323,891	$426,172	1.3	$178,794	$193,694	$372,488	1.9
Poison	$ 634	$ 660	$ 1,294	2.0	$ 879	$ 494	$ 1,373	2.8
Respiratory	$ 25,969	$ 38,953	$ 64,922	1.7	$ 50,700	$ 15,144	$ 65,845	4.3
Sprain/strain	$ 14,997	$ 14,997	$ 29,994	2.0	$ 19,643	$ 10,577	$ 30,219	2.9
Other	$ 5,311	$ 9,864	$ 15,175	1.5	$ 9,912	$ 5,576	$ 15,488	2.8
Median	$ 8,636	$ 12,430	$ 22,354	2.0	$ 13,720	$ 8,323	$ 22,444	3.0
Ratio of Medians				1.8				2.7
Mean	$ 24,392	$ 40,851	$ 65,244	1.9	$ 38,384	$ 23,768	$ 62,152	3.0
Ratio of Means				1.6				2.6

Source: Viscusi 1988 and IEc Calculations

Note: Damage awards, while a potentially useful source of data, have not been fully evaluated by economists as to their usefulness for valuation of health effects. The conditions under which juries determine damage awards may include factors that make the values less useful for health effect valuation applications. Economists continue to evaluate the theoretical and practical underpinnings of damage award data -- see text for discussion.

Exhibit B-5				
JURY AWARDS FOR NONFATAL INJURY				
	Special Damages	**General Damages**	**Total Damages**	
Injury Category	Mean	Mean	Mean	Total / Special
1	$ 7,048	$ 35,678	$ 42,726	6.1
2	$ 17,709	$ 49,888	$ 67,597	3.8
3	$ 20,747	$ 76,939	$ 97,686	4.7
4	$ 39,437	$315,410	$354,847	9.0
All	$ 17,282	$ 66,157	$ 83,439	4.8
Median Ratio				5.4
Mean Ratio				5.9
Ratio of Means				4.8

Source: Rodgers 1993 and IEc Calculations

Note: Damage awards, while a potentially useful source of data, have not been fully evaluated by economists as to their usefulness for valuation of health effects. The conditions under which juries determine damage awards may include factors that make the values less useful for health effect valuation applications. Economists continue to evaluate the theoretical and practical underpinnings of damage award data -- see text for discussion.

Exhibit B-6				
DAMAGE PAYMENTS FOR AUTOMOBILE INJURY				
State	**Mean Special Damages**	**Mean General Damages**	**Mean Total Damages**	**Mean Total / Mean Special**
California	$ 2,612	$ 4,132	$ 6,745	2.6
Washington	$ 2,667	$ 5,644	$ 8,311	3.1
North Carolina	$ 1,476	$ 2,366	$ 3,842	2.6
Maryland	$ 2,294	$ 3,801	$ 6,095	2.7
New Jersey	$ 2,017	$ 9,608	$ 11,625	5.8
Massachusetts	$ 4,267	$ 8,050	$ 12,316	2.9
Mean	$ 2,421	$ 4,465	$ 6,885	2.9
Median Ratio				2.8
Ratio of Weighted Means				2.8

Source: Hammitt 1985 and IEc Calculations

Note: Damage awards, while a potentially useful source of data, have not been fully evaluated by economists as to their usefulness for valuation of health effects. The conditions under which juries determine damage awards may include factors that make the values less useful for health effect valuation applications. Economists continue to evaluate the theoretical and practical underpinnings of damage award data -- see text for discussion.

Viscusi (1988)

Viscusi (1988) examined all product liability claims closed by a national sample of 23 insurance companies over about a one-year period in 1976-77. The data included 10,784 claims, of which 321 were dropped because of incomplete information. Viscusi estimated damages for pain and suffering by subtracting special damages (computed as lost earnings plus medical expenses and any other monetary losses) from total damages. If the resulting amount was negative, he assumed damages for pain and suffering were zero. Thus, the "pain and suffering" measure used incorporates any general damages paid.

Results based on Viscusi's estimates for nonfatal personal injuries (see Viscusi 1988, Table 2) are presented in Exhibit B-4. Estimated average payments for pain and suffering, financial losses and total damages by injury type, along with computed ratios of mean total to mean financial (special) damages, are shown separately for all 7855 claims with positive bodily injury payments and for the subset of claims with positive payments for pain and suffering. Both settlements and jury verdicts are included.

Among all claims with positive payments, the ratio of total to special damages ranges from 1.3 (para- or quadriplegia) to 2.3 (burn). The median of the ratios shown is 2.0, and the mean is 1.9. The proportion of claims with positive pain and suffering payments (not shown) ranges from 0.5 to 0.9 by injury type. Among these claims, the average total to special damage ratio ranges from 1.9 (para- or quadriplegia) to 4.3 (respiratory), with a median and mean of 3.0.

Rodgers (1993)

The Rodgers (1993) study is a useful complement to Viscusi's (1988) work. Both studies examined damage awards in product liability cases, but Rodgers used jury award data while only 1.5% of Viscusi's observations represent jury awards. Rodgers obtained data from Jury Verdict Research, Inc. He used 843 cases from a sample of 859 cases of nonfatal injury over the years 1974-86. Rodgers classified injuries according to a 4-point severity scale used for product liability cases (1 represents the least, and 4 the most, severe nonfatal injury). He imputed general damages from total and special damages.

Results from the Rodgers study are summarized in Exhibit B-5. Means of total and general damages exceed corresponding figures from Viscusi's work. Ratios of mean total to mean special damages also exceed ratios computed from Viscusi's research, ranging from 3.8 (severity 2) to 9.0 (severity 4), with a value of 4.9 for the full sample. As shown in the Exhibit, the ratio does not uniformly increase or decrease with severity.

Hammitt (1985)

Hammitt (1985) examined payments for personal injury by automobile insurance companies. His data, like Viscusi's, are from claims closed by insurance companies and consequently include mainly settlements along with a relatively small number of jury verdicts. Hammitt's data were obtained from a nationwide survey, conducted by the All-Industry Research Advisory Council during the fall of 1977, of 29 insurance companies that wrote over 60% of private automobile policies in the US The original data included over 40,000 claims, representing all claims closed by the insurers during a seven week period. Hammitt used data from eight states chosen to represent different legal arrangements for automobile insurance and liability. Relevant results for the six of these states which allowed payment for pain and suffering (including 5920 claims) are shown in Exhibit B-6. The ratio of mean total to mean special damages by state ranges from 2.6 (California) to 5.8 (New Jersey), with an overall sample mean of 2.9.

Bovbjerg et al. (1989, 1991)

Bovbjerg et al. (1989, 1991) examined total and general (nonfinancial) damages awarded by juries in personal injury cases in jurisdictions in Florida and Kansas City, during 1973-87. The 898 verdicts from both state and federal courts include fatal and nonfatal injuries from automobiles, medical malpractice and products liability, as well as all injury cases involving government defendants. Bovbjerg et al. imputed general damages by subtracting financial losses from total damages; however numerous cases had incomplete information on financial loss and general damages could be estimated only for 301 cases.

Bovbjerg et al. (1989) coded all injuries according to the 9-point injury severity scale developed for medical malpractice cases. On this scale, 1 denotes an "emotional" injury, 2 through 4 represent progressively more severe temporary injuries, 5 through 8 represent progressively more severe permanent injuries, and 9 denotes death. Bovbjerg et al. found that both total and general damages increase with the severity of nonfatal injury, but the dispersion of awards within injury categories is wide.

Exhibit B-7 summarizes relevant results from the Bovbjerg et al. (1989) study. Estimated general, special and total damages are presented by injury severity, along with ratios of total to special damages, based on mean and median awards. The original study presents information on total awards (Bovbjerg et al. 1989, Table 2) and on general damages (Table 3). Special damages shown in Exhibit B-5 were computed here as the difference between total and general damages. Unfortunately, the number of cases included in the Bovbjerg et al. general damage analysis represents fewer than half the cases in the total damage analysis. This disparity apparently causes the imputed special damages to be negative for injury category 7, "permanent major" injury.

		Based on Means				Based on Medians			
Injury Type	**Severity Scale**	**General Damages, $1996**	**Special Damages, $1996**	**Total Damages, $1996**	**Ratio of Total to Special**	**General Damages, $1996**	**Special Damages, $1996**	**Total Damages, $1996**	**Ratio of Total to Special**
Emotional	1	$ 34,529	$ 16,574	$ 51,103	3.1	$34,529	$ 16,574	$51,103	3.1
Temporary Insignificant	2	$ 13,812	$ 16,574	$ 30,386	1.8	$2,762	$6,906	$9,668	1.4
Temporary Minor	3	$ 73,202	$ 22,099	$ 95,300	4.3	$12,430	$ 23,480	$35,910	1.5
Temporary Major	4	$ 85,632	$196,125	$281,757	1.4	$49,722	$ 63,533	$113,255	1.8
Permanent Minor	5	$220,986	$117,399	$338,385	2.9	$63,533	$ 82,870	$146,403	1.8
Permanent Significant	6	$533,129	$349,434	$882,563	2.5	$ 403,299	$201,650	$604,949	3.0
Permanent Major	7	$3,189,103	$-	$2,882,485		$2,267,868	$-	$1,964,012	
Permanent Grave	8	$5,872,701	$1,127,028	$6,999,729	6.2	$2,530,289	$3,289,928	$5,820,217	1.8
Death	9	$1,715,403	$-	$1,690,542		$ 752,733	$106,349	$859,083	8.1
Total		$415,730	$261,040	$676,769	2.6	$29,004	$ 84,251	$113,255	1.3
Mean		$976,284	$263,605	$1,239,889	3.2				
Ratio of Means					4.7				
Median						$56,628	$ 73,202	$129,829	1.8
Ratio of Medians									1.8

Exhibit B-7

DAMAGE AWARDS FOR NONFATAL INJURY

Source: Bovbjerg 1989 and IEc Calculations

Note: Damage awards, while a potentially useful source of data, have not been fully evaluated by economists as to their usefulness for valuation of health effects. The conditions under which juries determine damage awards may include factors that make the values less useful for health effect valuation applications. Economists continue to evaluate the theoretical and practical underpinnings of damage award data -- see text for discussion.

Setting aside "permanent major" injury in view of the negative imputed special damage, as well as "emotional" injury (only one case in the data) and "death" (as discussed earlier, subject to different rules for assigning general damages) leaves six categories of nonfatal injury. Based on these six categories, the ratio of mean total to imputed mean special damages ranges from 1.4 to 6.2, with a mean of 3.2. The corresponding ratios for median awards range from 1.4 to 3.0, with a median of 1.8.

Cohen (1988)

Cohen (1988) attempted to monetize the pain and suffering endured by victims of crime. He used data compiled by Jury Verdict Research, Inc., to estimate linear regressions to predict general damages from special damages for types of injuries often suffered by crime victims. Arguing that injuries represented in jury award data are unrepresentative of the severity of injuries suffered by crime victims, he constructed separate estimates of medical costs and wage losses associated with crime-related injuries. He then used these estimates together with the estimated regression equations to predict the monetized value of pain and suffering of crime victims.

Relevant results from Cohen's study are presented in Exhibit B-8 (see Cohen 1988, Table 2). As shown, ratios of total to special damages range from 3.8 to 24.2, with a median of 10.2 and a mean of 12.7. Cohen's results thus imply a much larger share of pain and suffering in total damages than do results from the other two studies. Presumably, Cohen's focus on crime-related injuries and separate estimation procedure for medical costs and wage losses results in the relatively high pain and suffering estimates.

Concluding Remarks on Damage Award Studies.

Overall, 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 substantial margin. The ratios of total to special damages appear much less variable than the ratios of WTP to COI considered earlier, ranging from 1.3 to 24.2, or 1.3 to only 6.2 if the Cohen study is excluded. Moreover, the hypothesis that the ratio of total to special damages is constant, based on damage estimates presented in Exhibits B-3 through B-6, is not rejected in a formal statistical test.

The result of the hypothesis test, which contrasts with the outcome of the corresponding test for constancy of WTP/COI ratios, is as at odds with regression results presented in four of the original studies (Hammitt 1985, Viscusi 1988, Bovbjerg et al. 1991, Rodgers 1993). The inability to reject the hypothesis appears to be attributable to the fifth study, by Cohen (1988). Cohen's results differ markedly from the others, presumably because of the additional adjustments Cohen used to account for differences between injuries to crime victims and injuries typically seen by juries. If his results are set aside the hypothesis of a constant total-to-special-damage ratio is rejected at the one

percent significance level. In a regression of the logarithm of total damages on the logarithm of special damages, a constant, and dummy variables to account for study-specific effects, the estimated coefficient of special damages is 0.85 (s.e. = 0.0489), which differs significantly from unity at the one percent level. The hypothesis of a constant ratio of total to special damages is rejected.

		Exhibit B-8		
		DAMAGE PAYMENTS		
Injury	Mean General Damages $1996	Mean Special Damages $1996	Mean Total Damages $1996	Ratio Total to Special
Severely Disabling Psychological	$142,254	$ 36,090	$178,344	4.9
Traumatic Neurosis	$111,571	$ 6,018	$117,589	19.5
Gunshot wound	$ 86,534	$ 5,605	$ 92,139	16.4
Burn	$ 59,116	$ 2,552	$ 61,668	24.2
Internal Inury or Concussion	$ 34,072	$ 3,723	$ 37,795	10.2
Broken Bones or Teeth	$ 22,271	$ 2,479	$ 24,750	10.0
Multiple Minor	$ 4,838	$ 1,703	$ 6,541	3.8
Median	$ 59,116	$ 3,723	$ 61,668	10.2
Ratio of Medians				16.6
Mean	$ 65,808	$ 8,310	$ 74,118	12.7
Ratio of Means				8.9
Source: Cohen 1988 and IEc Calculations				
Note: Damage awards, while a potentially useful source of data, have not been fully evaluated by economists as to their usefulness for valuation of health effects. The conditions under which juries determine damage awards may include factors that make the values less useful for health effect valuation applications. Economists continue to evaluate the theoretical and practical underpinnings of damage award data -- see text for discussion.				

Further Details on QALY/COI Comparisons

General issues bearing on morbidity valuation using health state indexes and quality-adjusted life years (QALYs) were discussed in Chapter 3. Additional issues specifically related to valuation of pain and suffering are discussed below.

The valuation procedure involves two main steps. The first is to estimate the number of QALYs lost for each type of injury considered. Miller (1997) describes using physician-based estimates of losses in ability to function because of injury. This information is combined with survey data linking functional status to QALYs, to estimate the number of QALYs lost from reduced ability to function. The functioning years lost then are added to the loss in life expectancy (if any) to compute the overall loss in QALYs.

The second step is to monetize the lost QALYs using a dollar value per life year, obtained from the literature on the value of a statistical life, usually from labor market studies. The product of the value of the life-year and the lost QALYs then is interpreted as the WTP to avoid the injury. In some cases, additional adjustments are made to estimate social, rather than individual, WTP.

This valuation method is a benefits transfer procedure in which the WTP to reduce risk of death on the job is transformed into an estimate of the value of avoiding a nonfatal injury, by expressing the injury in terms of QALYs. The validity of the procedure hinges on three key assumptions: (1) all relevant consequences of injury can be measured as lost QALYs; (2) the number of QALYs lost is estimated accurately, and (3) the appropriate value of a life-year is applied. In practice, it is difficult to ensure that these assumptions are valid in any particular application. See EPA (2000a) for guidance on the use of QALYs, and Chapter 3 for more discussion of the limitations of the approach for environmental benefits analysis.

Miller, Luchter and Brinkman (1989)

Key computations based on results reported in two QALY-based injury valuation studies are presented in Exhibit B-9. Miller, Luchter and Brinkman (1989) estimate values for injuries in automobile accidents. Injury data from the National Accident Sampling System are used; severity is measured using the five-point Abbreviated Injury Scale (AIS) of the Association for the Advancement of Automotive Medicine. Miller et al. acknowledge that the Association has warned against using the AIS scale to monetize injuries.

They estimate COI for each severity of injury using data and methods of Hartunian et al. (1981). Lost QALYs were estimated using National Highway Traffic Safety Administration information on impairments from injuries. Miller et al. use a value of $120,000 per life year to monetize the QALYs. This figure is derived from a $1.95 million dollar value of a statistical life obtained by Miller in a review of value of life studies, taken over a 39-year lifespan at a 6% discount rate.

As shown in the Exhibit, the ratio of QALY valuations to the COI ranges from 3.2 for the least severe injury, to 14.9 for severity level 3. The mean ratio is 8.8 and the median is 7.5. This study yields higher ratios of comprehensive valuation to financial valuation than damage award studies.

Exhibit B-9			
QALY VALUES AND COI FOR INJURY			
1996 Dollars (Miller et al. 1989)			
Injury Severity	**COI = Medical Costs + Productivity Losses**	**Value of Lost Qalys**	**Value of QALYs / COI**
MAIS 1	$ 709	$ 2,233	3.2
MAIS 2	$ 4,710	$ 34,358	7.3
MAIS 3	$ 17,299	$ 257,682	14.9
MAIS 4	$ 163,216	$1,219,697	7.5
MAIS 5	$ 464,324	$5,170,828	11.1
Median	$ 17,299	$ 257,682	7.5
Ratio of Medians			14.9
Mean	$ 130,051	$1,336,960	8.8
Ratio of Means			10.3
Millions of 1996 Dollars (Miller 1997)			
Age (Years)	**COI = Medical Costs + Lost Earnings**	**Value of Lost Qalys**	**Value of Lost QALYs / COI**
0 to 4	16496	162170	9.8
5 to 14	29197	364182	12.5
15 to 24	105680	612769	5.8
25 & older	293993	1754037	6.0
All	467828	2897233	6.2
Injury			
Motor Vehicle	150547	577532	3.836
Fall	108407	822662	7.589
Poisoning	17908	69623	3.888
Near Drowning	6386	25443	3.984
Gun Unintended	3410	18728	5.492
Gun Suicide	20670	77980	3.773
Gun Assault	33009	112021	3.394
Other Suicide	12134	55186	4.548
Other Assault	23306	168930	7.248
Sources: Miller et al. 1989, Miller 1997 and IEc Calculations			

Miller (1997)

Miller (1997) presents QALY- and COI-based valuations drawn from his research. Valuations reported in Exhibit B-9 are aggregated for the US in millions of 1996 dollars. Miller (1997) used a $72,300 value per QALY in his paper, rather than the $120,000 value applied by Miller et al. (1989). Although he does not indicate how the lower value was derived, Miller states that $72,300 is the value of a QALY net of productivity or earnings losses. Earnings losses are subtracted from the QALY valuation in order to estimate social, rather than individual, WTP. In the Exhibit, however, QALYs are evaluated at $120,000 per unit for comparability with the results of Miller et al. above and with the WTP/COI comparisons presented earlier (in which individual, not social, WTP is estimated).

As shown, results highlight the potential for ratios of comprehensive valuations to COI to vary with the characteristics of affected individuals (age). The highest ratios of QALY losses to COI are obtained for injuries to younger persons, whose earnings are low. By age, ratios range from 5.8 to 12.5, with an overall ratio of 6.2. By injury, ratios fall in the 3.4 to 7.6 range.

Overall, results based on QALY valuation relative to COI reinforce the conclusion that comprehensive valuations of illness or injury exceed purely financial valuations by a wide margin. The ratios of QALY values to COI appear to vary by injury and by age of persons affected, although the hypothesis of constant ratios over injury categories cannot be rejected in a formal statistical test.

ECONOMIC VALUATION OF PAIN AND SUFFERING REFERENCES

Bovbjerg, R.R., F.A. Sloan and J.F. Blumstein. "Public Policy: Valuing Life and Limb in Tort: Scheduling 'Pain and Suffering.'" Northwestern University Law Review 83: 908-976. Summer 1989.

Bovbjerg, R.R., F.A. Sloan, A. Dor and C.R. Hsieh. "Juries and Justice: Are Malpractice and Other Personal Injuries Created Equal?" Law and Contemporary Problems 54(1): 5-42. Winter 1991.

Chase, O.G. "Helping Jurors Determine Pain and Suffering Awards." Hofstra Law Review 23: 763-790. Summer 1995.

Chestnut, L.G. and D.M. Violette. "The Relevance of Willingness-to-Pay Estimates of the Value of a Statistical Life in Determining Wrongful Death Awards." US EPA 230-07-90-079. June 1990.

Croley, S.P. and J.D. Hanson. "The Nonpecuniary Costs of Accidents: Pain and Suffering Damages in Tort Law." Harvard Law Review 108: 1785-1917. June 1995.

Danzon, P.M. and Lillard. "Settlement Out of Court: The Disposition of Medical Malpractice Claims." Journal of Legal Studies 12: 345-357. 1983.

Geistfeld, M. "Placing a price on pain and suffering: A Method for Helping Juries Determine Tort Damages for Nonmonetary Injuries." California Law Review 83: 773-851. May 1985.

Hammitt, J.K. Automobile Accident Compensation, Volume II: Payments by Auto Insurers. Santa Monica, California: The Rand Corporation. 1985.

Hensler, D.R., M.S. Marquis, A.F. Abrahamse, S.H. Berry, P.A Ebener, E.G. Lewis, E.A. Lind, R.J. MacCoun, W.G. Manning, J.A. Rogowski, M.E. Viana. Compensation for Accidental Injuries in the United States. Santa Monica, California: RAND. 1991.

Leebron, D.W. "Final Moments: Damages for Pain and Suffering Prior to Death," New York University Law Review 64: 256-360. May 1989.

Levin, F.S. "Pain and Suffering Guidelines: A Cure for Damages Measurement 'Anomie'," University of Michigan Law Review 22: 303-332. Winter 1989.

Miller, T.R. "Injury Cost Estimation: A Pain in the Neck." mimeo. 1997.

Miller, T.R. "Willingness-to-Pay Comes of Age: Will the System Survive?" Northwestern University Law Review 83: 876-907. Summer 1989

Miller, T.R, S. Luchter and C.P. Brinkman. "Crash Costs and Safety Investment." Accident Analysis and Prevention 21(4): 303-315. 1989.

National Center for Health Statistics. Current Estimates from the National Health Interview Survey, 1987. Series 10 (149). Washington, DC: US GPO. 1988.

Pfennigstorf, W. and D.G. Gifford.   A Comparative Study of Liability Law and Compensation Schemes in Ten Countries and the United States. Oak Brook, Illinois: Insurance Research Council. 1991.

Prahl, R.J. and S.M. Ultrata. Liability Claim Concepts and Practices. Malvern, Pennsylvania: Insurance Institute of America. 1985.

Pratt, J.W. and R.J. Zeckhauser. "Willingness to Pay and the Distribution of Risk and Wealth." Journal of Political Economy 104(4): 747-763. 1996.

Priest, G.L. and B.Klein. "The Selection of Disputes for Litigation." Journal of Legal Studies 13: 1-56. 1984.

Rodgers, G.B. "Estimating Jury Compensation for Pain and Suffering in Product Liability Cases Involving Nonfatal Personal Injury." Journal of Forensic Economics 6(3): 251-262. 1993.

Schwab C., N.G. and N.C. Soguel. "The Pain of Rode Accident Victims and the Bereavement of their Relatives: A Contingent Valuation Experiment." Journal of Risk and Uncertainty 13: 277-291. 1996.

Taylor, D.C. "Your Money or Your Life? Thinking About the Use of Willingness-to-Pay Studies to Calculate Hedonic Damages." Washington and Lee Law Review 51: 1519-1556. Fall 1994.

Vidmar, N.   "Empirical Evidence on the Deep Pockets Hypothesis: Jury Awards for Pain and Suffering in Medical Malpractice Cases." Duke Law Journal 43: 217-265. November 1993.

Viscusi, W.K.   "Pain and Suffering in Product Liability Cases: Systematic Compensation or Capricious Awards?" International Review of Law and Economics 8: 203-220. 1988.

APPENDIX C

CASE STUDIES OF NON-CANCER HEALTH VALUATION

Table of Contents

ECONOMIC VALUATION OF LUNG FUNCTION

Description of the Effect

Decrements in lung function are a non-cancer health effect commonly associated with air pollution exposure. Lung function refers to the lung mechanics which allow the lungs to exhale air; a related term, lung capacity, refers to the volume of air one can hold in his or her lungs. Lung capacity can be assessed by measuring forced vital capacity (FVC, the maximum volume of air one can inhale), while forced expiratory volume (FEV_s, the maximum volume of air one can exhale in *s* seconds) is a measure of lung function. Health scientists measure respiratory parameters in a variety of other ways as well, including peak expiratory flow (PEF) and airway resistance (R_{aw}).

Normal levels of lung function vary with height, sex and age. Men and taller persons often have higher mean FEV_1 and FVC than do women and shorter persons, and lung function usually increases in infancy and early childhood, before it begins to decline continuously in adolescence and early adulthood. In addition to these natural patterns in healthy persons, many patients with chronic lung disease suffer permanently reduced lung function.

Types of Exposures that Cause the Effect

Environmental factors including air pollution affect lung function. A well-documented correlation exists between short-term exposures to several criteria air pollutants and temporary, reversible decrements in lung function. Chronic exposure to air pollutants, for example ozone, may lead to permanently reduced lung function, but existing studies "provide only suggestive evidence that such a linkage exists."[1] Air pollutants associated with lung function changes include particulate matter, ozone, and oxides of nitrogen and sulfur.

Figure 1 illustrates the dose-response relationship between ozone levels and the fraction of the heavily exercising population experiencing a ten percent decrement in lung function. For example, this figure indicates that between two and ten percent of the heavily exercising population would experience a ten percent decrement in lung function from a short-term exposure to 0.12 ppm of ozone. At higher ozone concentrations, a larger proportion of the population is affected.

---

[1] US EPA, *Air Quality Criteria for Ozone and Related Photochemical Oxidants,* Vol. III, July 1996.

Figure 1

**PROPORTION OF HEAVILY EXERCISING INDIVIDUALS
PREDICTED TO EXPERIENCE A 10% DECREMENT IN
FORCED EXPIRATORY VOLUME (FEV) FOLLOWING A
ONE- OR TWO-HOUR EXPOSURE TO OZONE**
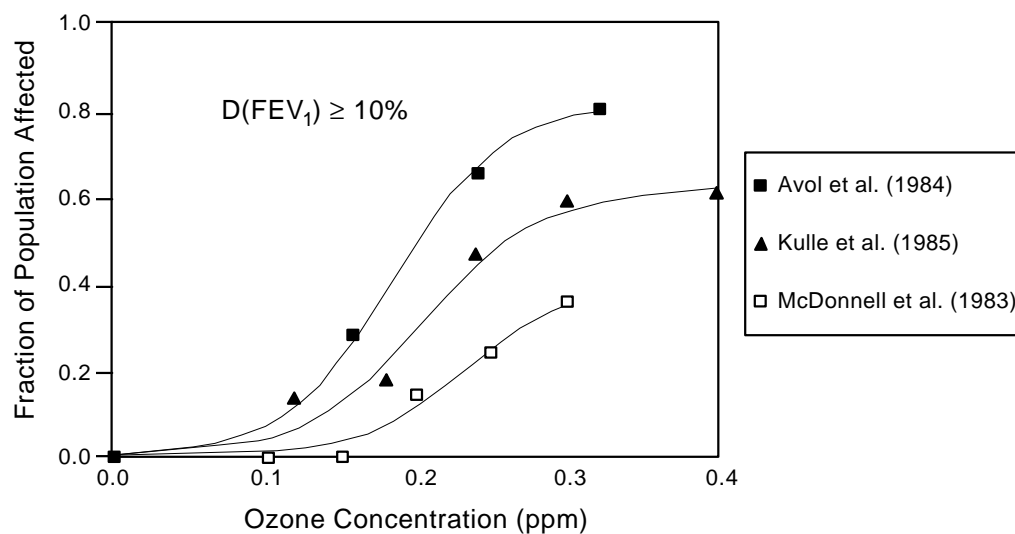
Source: U.S. EPA, *Review of the National Ambient Air Quality Standards for Ozone: Assessment of Scientific and Technical Information*, Staff Paper, Office of Air Quality Planning and Standards, 1989.

Figure 2

**PREDICTED MEAN DECREMENTS IN
FORCED EXPIRATORY VOLUME (FEV) FOLLOWING
TWO-HOUR EXPOSURES TO OZONE WHILE UNDERGOING
HEAVY INTERMITTENT EXERCISE FOR THREE AGE GROUPS**
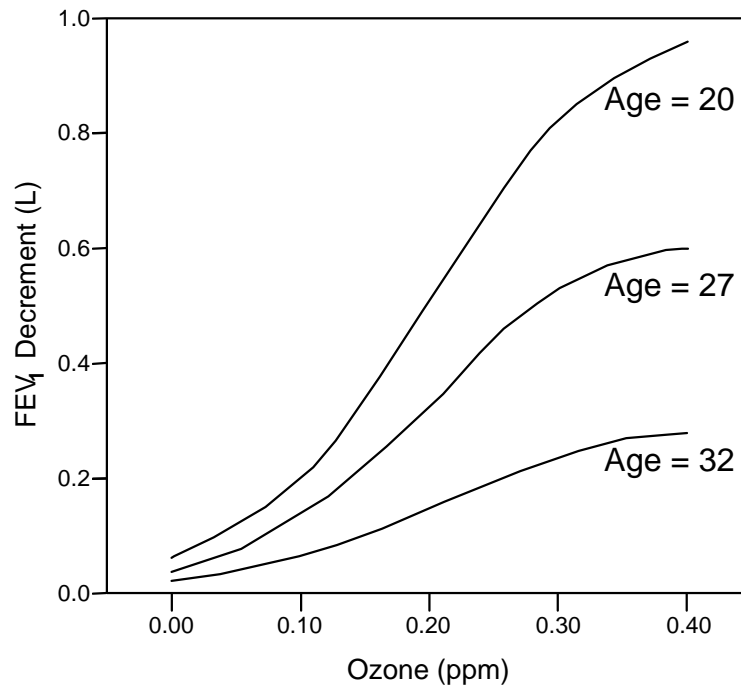
Source: McDonnell, W.F., et al., "Predictors of Individual Differences in Acute Response to Ozone Exposure," *American Review of Respiratory Disorders*, vol. 147, pp. 818-825.

The dose-response relationship between ambient air pollution and decrements in lung function is sensitive to age. As illustrated in Figure 2, young adults exhibit a greater decrement in lung function than do older adults under the same exposure conditions. Given the larger initial lung function of most younger adults, however, the larger decrements they experience may not leave most of them any worse off than older adults, unless they have an existing respiratory problem, such as asthma, that has impaired normal function of the lungs.

Existing Studies Characterizing Values

There appear to have been no studies estimating an economic value for avoiding reduced lung function. The lack of research is partly attributable to the absence of a clear connection between decrements in lung function and decrements in well-being. Reduced pulmonary function is associated with several health effects that clearly have an adverse impact on well-being, including aggravation of asthma, cough and pain on deep inspiration; for at least some of these effects, a person might seek medical advice or hospitalization. But it is not clear whether temporary changes in lung function themselves have any real effect on many persons independently of related symptoms. In the absence of the symptoms, a change in lung function might come and go altogether unnoticed, having no impact on a person's life and thus no economic value (Freeman 1993). However, it is also possible that sufficient reduction in lung function could impair an individual's ability to continue normal activity or cause increased use of medication.

Economists prefer to measure values for respiratory symptoms or aggravation of asthma, because these are unpleasant occurrences which people notice and wish to avoid. Health scientists measure lung function in part because it is more quantitative and objective (e.g., has greater test-retest reliability) than symptom scores. The subjective nature of symptoms is less troubling to economists, because economic well-being and value are themselves subjective.

A sample of acute health effects valued by economists is provided along with daily WTP values in Exhibit 1. Among the effects listed, aggravation of asthma, cough, pain on deep inspiration, and shortness of breath are correlated with decrements in lung function.

Potential Valuation Strategy

The first question in valuing lung function is whether it has an economic value independent of associated morbidity. For small changes lung function, in those cases where lung function decrement does not lead to symptoms or noticeable effects, it is not clear whether such a value exists or how large it might be. The next questions, then, are whether it is plausible that a separate value for lung function exists, how such a value might be measured, and what valuation procedure could be followed in the meantime. These questions are addressed in turn.

		Exhibit 1	

BENEFIT ESTIMATES FOR REDUCTIONS IN MORBIDITY
VALUE OF ONE-DAY REDUCTION IN SYMPTOMS

Respiratory Symptom (severity)	Source Study	Benefit Per Day ($1995)	
		Median Value	Mean Value
Asthma Attack (moderate)	Rowe (1985)	--	$58.12
Cannot Breathe Deeply	Dickie (1987)	$1.42	$1,616.13
Chest Tightness	Dickie (1987)	$7.09	$1,153.57
Coughing/Sneezing (minor)	Loehman (1979)	$11.34	$110.58
Pain on Deep Inspiration	Dickie (1987)	$4.96	$1,352.63
Shortness of Breath (severe)	Loehman (1979)	$25.52	$180.04
Throat Irritation	Dickie (1987)	$4.25	$21.26
Wheezing	Dickie (1987)	$2.84	$82.22

Source: Weitzel, D., *Economic Valuation of Environmental Health Benefits: A Review of the Literature*, prepared for the Washington State Department of Ecology, December 31, 1990.

People may be willing to pay to avoid a permanent decrement in lung function, even if they were not consciously aware of the condition. There are at least two reasons why this value would exist. First, "excess" lung capacity is a reserve that may be called on at time of disease or other stress. Decrements in lung function which pass unnoticed during normal activities may compromise a person's ability to meet future challenges. Second, conscious awareness may be delayed for years as a person makes subtle adaptations in lifestyle to reduce exertion, a common occurrence in cases of chronic lung disease. A person could be willing to pay to maintain the ability to meet future challenges or to return to a more active lifestyle.

Although it is plausible that people would value avoidance of permanently reduced lung function, it is not as clear how temporarily reduced lung function would affect well-being, independently of associated respiratory symptoms. It is clear that even temporary lung function decrements on individuals with pre-existing respiratory conditions can effect their well-being. In addition, if temporarily decreased lung function in the general population caused reduced athletic performance, lower productivity, activity restrictions, or some other noticeable effect, then avoiding

it would have economic value. But at present, information on the connection between temporary decrements in lung function in the general population and well-being is scarce, making it difficult to conclude with confidence that people would be willing to pay to avoid the effect apart from associated symptoms.

The next question is how to test for and measure a potential value for lung function decrements. Two general strategies could be applied. One approach would attempt to value lung function directly.   The other would value morbidity effects associated with lung function changes, and then "back out" a value for lung function using a quantitative relationship between lung function and morbidity. The main difficulty of the first strategy is the subtlety of the effect to be valued, while the main drawback of the second is the great potential for double-counting of benefits.

Review of Techniques

The potential application of four valuation techniques to estimate benefits of avoiding lung function decrements is illustrated in Exhibit 2.

Exhibit 2 POTENTIAL LUNG FUNCTION VALUATION METHODS	
Valuation Technique	**Relevant Issues**
COI (cost of illness)	Decreased lung function is not itself an illness, but is related to conditions for which costs of illness can be estimated, such as asthma morbidity.
CV (contingent valuation)	A well-designed CV study could provide evidence on whether people value temporary decrements in lung function independently of associated morbidity, and on the magnitude of the potential value. Note: children and young adults, who may be less reliable than older adults as respondents to CV studies, are the most susceptible to lung function decrements.
Averting Behavior	People may avoid decrements in lung function by curtailing exercise, remaining indoors, purchasing air conditioners, and increasing medication use, but valuing the aspect of their behavior specifically linked to lung function would be difficult.
Benefits Transfer	Applying dollar values listed in Exhibit 1 for effects correlated with lung function may provide plausible benefit estimates, but one should exercise caution to avoid double-counting.

Any of the four valuation techniques could be used to implement the second strategy of valuing health effects associated with lung function, but contingent valuation may be the only method capable of valuing directly an effect as subtle as lung function changes. A well-designed CV survey might allow researchers to test for a distinct value for decreased lung function, whether permanent or temporary. A survey also could test for subtle responses that might occur, like activity restrictions or reduced athletic or exercise performance.

In the absence of an existing CV study of the value of lung function, it appears that the only feasible way to monetize the effect is to "back out" a value based on links between lung function and the other health effects. For example, decrements in pulmonary function in response to short-term ozone exposure have been linked to several symptoms.[2] Exposure to ozone may cause a reduction in lung function, but this reduction may manifest itself in symptoms such as shortness of breath. Specifically, the ozone exposure-response relationships, temporal patterns of responses to repeated exposure, and the effects of medication are similar for symptoms and lung function (US EPA 1996).

The symptoms most closely associated with lung function are cough, pain on deep inspiration, shortness of breath, and total respiratory symptoms. It would seem that the value would lie in avoiding the symptoms rather than in avoiding the reduced lung function, but a monetary value could be assigned to the reduced lung function based on the value of the symptoms. There are two reasons why lung function valuation might be desirable: (1) a wider group of people may experience lung function decrements compared to those who are symptomatic; and (2) studies may indicate a higher degree of confidence in the lung function dose-response relationship than in the dose-response relationship for individual symptoms.

Avoidance of symptoms can be monetized by contingent valuation, benefits transfer, or possibly by averting behavior. A value for avoiding reduced lung function then could be assigned by applying the symptom values to the quantitative relationship between group mean lung function changes and group mean symptoms. A major issue would be avoiding double-counting: one could not add symptom values to the lung function value to compute total benefits. Analysts might best use symptom values as an explicitly defined alternative method for valuing the direct benefits of avoiding lung function decrements.

---

[2] Although it appears impossible to predict accurately the symptoms any individual experiences based on changes in his or her lung function, the group means of incidence and severity of symptoms and lung function decrements are more closely linked.

Important Caveats and Uncertainties

The analysis presented here suggests that benefits analyst use caution in attempting to value lung function changes for use in policy analysis, absent additional forthcoming evidence from primary research on the nature and size of the value. If lung function is to be monetized in the absence of new CV research, then benefits transfer would appear to be the best approach. Analysts might consider using the criteria documents (and if necessary the original sources) to determine the health effects associated with decrements in lung function, and if possible the quantitative relationships involved.

In addition to the previously discussed importance of avoiding double-counting when imputing values for lung function, all of the caveats of benefits transfer discussed in Chapter 4 apply here. Specifically, the quality of the valuation studies listed in Exhibit 1, the uncertainty of the link between symptom values and lung function values, the similarity of the populations affected, and the extent of the market all are sources of potential concern.

All of the values in Exhibit 1 were obtained by contingent valuation, but each of the studies falls far short of current views of the state of the art in CV research. In the Loehman (1979) study, for example, researchers used a mail survey of Florida residents to value three symptoms (shortness of breath, coughing/sneezing, and head congestion). Among the limitations associated with this study, the survey response rate was low (22 percent) and a review of the study by Krupnick (1987) found that respondents may have had difficulty understanding what was being valued. As another example, the Dickie (1987) study used telephone interviews of California residents to value 26 health symptoms. While the study had a high response rate (97 percent), the sample size for each symptom was relatively small for this type of survey (<50 observations). As noted in Weitzel (1990), reviewers of the Dickie (1987) study recommended using the median estimates instead of the mean estimates given the wide range of values yielded by the small sample size.

Analysts may also want to be alert to potential mismatches between the populations underlying the valuation studies and the population affected by lung function changes. The sensitivity and responsiveness of lung function to ozone exposure is highly variable from one individual to the next, and depends on health status, age, exposure to other pollutants or allergens, and other factors. Because of this variability, caution is warranted in applying values to avoid decrements in lung function among asthmatics, persons exercising heavily, or children playing outdoors, for example, to the general population. Similarly, if noticeable effects of lung function decrements tend to be restricted to subgroups such as these, then the "extent of the market" may be much smaller than the total number of persons exposed to the ambient concentrations.

ECONOMIC VALUATION OF LUNG FUNCTION REFERENCES

Dickie, M., S. Gerking, D. Brookshire, D. Coursey, W. Schulze, A. Coulson, and D. Tashkin. *Improving Accuracy and Reducing Costs of Environmental Benefit Assessments: Reconciling Averting Behavior and Contingent Valuation Benefit Estimates of Reducing Symptoms of Ozone Exposure*. Draft Report to the Office of Policy, Planning and Evaluation, US Environmental Protection Agency. September 1987.

Freeman, A.M. III. *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington, DC: Resources for the Future. 1993.

Krupnick, A.J. *Benefit Estimation and Environmental Policy: Setting the NAAQS for Photochemical Oxidants*. Resources for the Future, Washington, DC. December 1986.

Loehman, E.T. et al. "Distributional Analysis of Regional Benefits and Cost of Air Quality Control." *Journal of Environmental Economics and Management* 6: 222-243. 1979.

McDonnell, W.F., K.E. Muller, P.A. Bromberg, and C.M. Shy. "Predictors of Individual Differences in Acute Responses to Ozone Exposure." *American Review of Respiratory Disorders* 147(4): 818-825. April 1993.

US Environmental Protection Agency. *Air Quality Criteria for Ozone and Related Photochemical Oxidants*. Office of Research and Development, Washington, DC. July 1996.

US Environmental Protection Agency. *Review of the National Ambient Air Quality Standards for Ozone: Assessment of Scientific and Technical Information*. Air Quality Management Division, Office of Air Quality Planning and Standards, Washington, DC. June 1989.

Weitzel, D.L. *Economic Valuation of Environmental Health Benefits: A Review of the Literature*. Report to the Washington State Department of Ecology. National Economic Research Associates, Inc., Seattle, WA. December 31, 1990.

ECONOMIC VALUATION OF ENDOCRINE DISRUPTION: INTRODUCTION

Description of the Effect

Endocrine disruption occurs when a chemical interferes with the function of natural hormones in the body, for example by mimicking a hormone, blocking its effects, or stimulating or inhibiting the endocrine system (US EPA 1997a). The endocrine system consists of various organs known as endocrine glands, including the ovaries, the testes, and the adrenal, thyroid and pituitary glands. These glands release hormones, such as estrogen, testosterone or adrenaline, into the bloodstream. Hormones travel through the bloodstream in small concentrations, bringing chemical messages to distant cells, to regulate diverse functions including reproduction, development, and metabolism. The endocrine system is one of at least three main integrating and regulating systems in the body, along with the nervous and immune systems.

Colborn et al. (1996) compare endocrine disruption to more familiar toxic and carcinogenic effects:

> Up to now, our concept of injury from toxic chemicals has focused primarily on two things: whether a chemical damages and kills cells as poisons do or whether it attacks the DNA, our genetic blueprint, and permanently alters it by causing a mutation as carcinogens do. With poisoning, the consequences can be illness or death for the affected human or animal. Mutations can eventually give rise to cancer. At levels typically found in the environment, however, hormone-disrupting chemicals do not kill cells nor do they attack DNA. Some hormonally active chemicals appear to pose little if any risk of cancer. Instead, these chemicals target hormones, the chemical messengers that move about constantly within the body's communications network. The key concept in thinking about this kind of toxic assault is chemical messages. Not poisons, not carcinogens, but chemical messages.

Scientists refer to hormone-disrupting chemicals as endocrine disruptors; often branded "gender benders" by the popular press.

Figure 1 illustrates one mode of endocrine disruption: a hormone mimic blocks a natural hormone from delivering its chemical message, possibly substituting an improper chemical signal of its own. Endocrine disruptors also may interfere with the synthesis, secretion, transport, or elimination of natural hormones.

FIGURE 1
**CONTAMINANTS DISRUPT THE ENDOCRINE SYSTEM BY DECEIVING CELLS**

NORMAL
RESPONSE

Cell
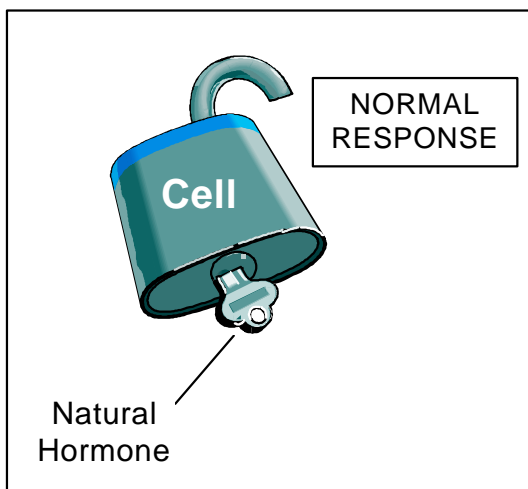
Natural
Hormone

Scenario #1
Cell accepts natural hormone; a proper
hormonal message prompts a positive
biological response.

ABSENCE OF
RESPONSE

Cell

Natural
Hormone

Hormone
Impostor

Scenario #2
Hormone impostor tricks the cell by
mimicking a natural hormone; the
impostor transmits no message of its
own to the cell, but succeeds in
preventing the natural hormone from
delivering its anticipated message.
The resulting absence of a biological
response may have adverse effects.

Cell

NEGATIVE
RESPONSE

Hormone
Impostor
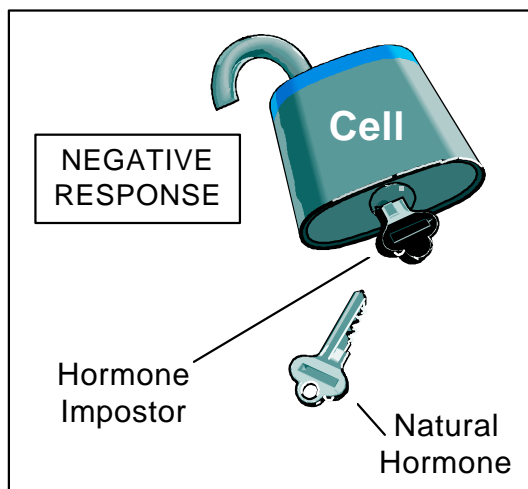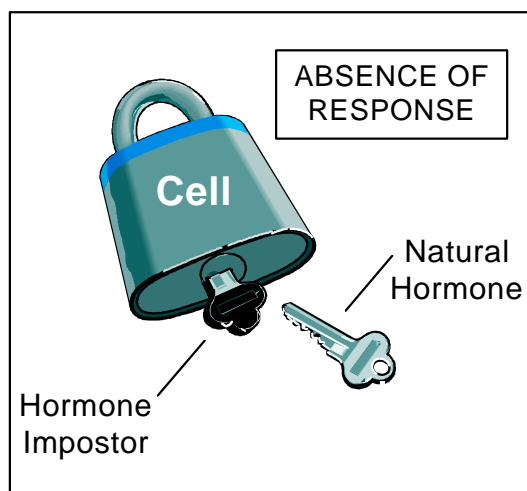
Natural
Hormone

Scenario #3
Hormone impostor tricks the cell by
mimicking a natural hormone; under the
guise of the natural hormone, the
impostor conveys a negative hormonal
message to the cell which triggers an
unexpected, and often time deleterious,
biological response.

C-13

Based on scientific research to date, EPA "does not consider endocrine disruption to be an adverse endpoint *per se*, but rather to be a mode or mechanism of action potentially leading to other outcomes, for example, carcinogenic, reproductive or developmental effects...." (US EPA 1997b, p. viii). Potential reproductive effects include disruption of ovarian function, reduced sperm production, and reduced fertility. Potential developmental effects include low birth weight and both structural and functional defects.

Types of Exposures that Cause the Effect

Recent scientific research supports the notion that endocrine disruptors are prevalent in the environment. For example, scientists have detected trace amounts of endocrine disruptors in common household items such as plastic toys and metal food cans. For the general population, however, three main exposure pathways exist: (1) drinking water; (2) contaminated foods (fish, meat, and produce in particular); and, for children, (3) pesticide ingestion from residential lawns, home interiors, pets, and playgrounds (B.D.S. 1996).[3] According to EPA estimates, drinking water and food contribute 90 to 95 percent of the total human absorption of suspected endocrine disruptors (Dold 1996). The most recent data from the 1995 Toxic Release Inventory (TRI) support these estimates. In 1995, public and private entities released 60 million pounds of suspected endocrine-disrupting chemicals in the US (EIC 1997).

Considerable scientific uncertainty exists concerning which chemicals interfere with normal functioning of hormones, but some chemicals with endocrine-disrupting potential have been identified. We provide two lists of potential endocrine disruptors. The first list, presented in Exhibit 1, reflects work by the Illinois EPA to distinguish between chemicals known and suspected of endocrine disruption. The second list, presented in Exhibit 2, summarizes the results of endocrinology research from scientists around the world (Colborn 1994).

---

[3] While humans and animals may inhale endocrine disruptor particles (e.g., from combustion or waste incineration), this exposure pathway represents a relatively negligible share of total contamination.

Exhibit 1

PRELIMINARY LIST OF CHEMICALS ASSOCIATED WITH ENDOCRINE SYSTEM EFFECTS IN ANIMALS AND HUMANS (*) OR IN VITRO (+)

Known	Probable	Suspect
Atrazine	Alachlor	Aldicarb
Chlordanes	Aldrin	Butyl Benzyl Phthalate
Chlordecone (Kepone) (*)	Amitrole (Aminotriazole)	tert-Butylhydroxyanisole (+)
DDD	Benomyl	p-sec-Butylphenol (+)
DDE	Bisphenol A(+)	p-tert-Butylphenol (+)
DDT	Cadmium (*)	Carbaryl
1,2-Dibromo-3-Chloropropane (*)	2,4-D	Cypermethrin
Dicofol (Kelthane)	Di(2-Ethylhexyl)Phthalate	2,4-Dichlorophenol (+)
Dieldrin	Endrin	Dicyclohexyl Phthalate
Diethylstilbestrol (DES)(*)	Heptachlor	Di(2-Ethylhexyl)Adipate (+)
Dioxins (2,3,7,8-)	Heptachlor Epoxide	Di-n-butyl Phthalate (+)
Endosulfans	Hexachlorobenzene	Di-n-hexyl Phthalate
Furans (2,3,7,8-)	$-Hexachlorocyclohexane	Di-n-pentyl Phthalate
Lindane	Lead (*)	Di-n-propyl Phthalate
Methoxychlor	Mancozeb	Esfenvalerate
p-Nonylphenol	Maneb	Fenvalerate
PCBs	Mercury (*)	Malathion
Toxaphene	Methyl Parathion	Methomyl
Tributyl Tin	Metiram	Metribuzin
	Mirex	Nitrofen
	p-Octylphenol	Octachlorostyrene
	Parathion	PAHs
	Pentachlorophenol	p-iso-Pentylphenol (+)
	Polybrominated Biphenyls (PBBs)	p-tert-Pentylphenol (+)
	Styrene (*,+)	Permethrin

<table>
<tr><td colspan="3" align="center">Exhibit 1 (continued)

PRELIMINARY LIST OF CHEMICALS ASSOCIATED WITH ENDOCRINE SYSTEM EFFECTS IN ANIMALS AND HUMANS (*) OR IN VITRO (+)</td></tr>
</table>

Known	Probable	Suspect
	2,4,5-T	Ziram
	Trifluralin	
	Vinclozolin	
	Zineb	

Note: Chlordanes includes "- and (-Chlordane, Oxychlordane, and cis- and trans-Nonachlor;
  Endosulfans includes "- and $-Endosulfan and technical grade Endosulfan.

Source: Illinois EPA, *Endocrine Disruptors Strategy*, February 1997.

Exhibit 2
CHEMICALS WITH WIDESPREAD DISTRIBUTION IN THE ENVIRONMENT REPORTED TO HAVE REPRODUCTIVE AND ENDOCRINE-DISRUPTING EFFECTS

Chemical	Reference
Pesticides	
Herbicides	
2,4-D	Berwick 1970; Hayes and Laws 1991
2,4,5-T	Amdur et al. 1991
Alachlor	Hayes and Laws 1991; US EPA 1984
Amitrole	Tjalve 1974; Jukes and Shaffer 1960
Atrazine	Simic et al. 1991; Babic-Gojmerac et al. 1989
Metribuzin	Porter et al. 1993
Nitrofen	Gray 1992
Trifluralin	US EPA 1987
Fungicides	
Benomyl	Hess et al. 1991
Hexachlorobenzene	Gocmen et al. 1989; Smith et al. 1987; Haake et al. 1987; Arnold et al. 1985
Mancozeb	US EPA 1987
Maneb	US EPA 1988a; Laisi et al. 1985
Metiram-complex	US EPA 1988b
Tributyl tin	Huggett et al. 1992; Bryan et al. 1987
Zineb	Laisi et al. 1985
Ziram	Hayes and Laws 1991

Exhibit 2 (continued)	
CHEMICALS WITH WIDESPREAD DISTRIBUTION IN THE ENVIRONMENT REPORTED TO HAVE REPRODUCTIVE AND ENDOCRINE-DISRUPTING EFFECTS	
Chemical	**Reference**
Insecticides	
$-HCH	Van Velsen 1986
Carbaryl	Amdur et al. 1991
Chlordane	Cranmer et al. 1984
Dicofol	Fry and Toone 1981
Dieldrin	Haake et al. 1987
DDT and metabolites	Fry and Toone 1981
Endosulfan	ATSDR 1990; A. Soto unpublished
Heptachlor and H-epoxide	Haake et al. 1987
Lindane 1-HCH	Chowdhury et al. 1987
Methomyl	Porter et al. 1993
Methoxychlor	Gray et al. 1989; Cummings and Gray 1987
Mirex	A. Soto unpublished
Oxychlordane	Cranmer et al. 1984
Parathion	Rattner and Ottinger 1992
Synthetic pyrethroids	Eil and Nisula 1990
Toxaphene	A. Soto unpublished
Transnonachlor	Cranmer et al. 1984
Nematocides	
Aldicarb	Porter et al. 1993
DBCP	Gray 1992; Hayes and Laws 1991
Industrial Chemicals	
Cadmium	ATSDR 1991a
Dioxin (2,3,7,8-TCDD	Mably et al. 1992a, 1992b, 1992c
Lead	ATSDR 1991a, 1991b
Mercury	ATSDR 1988
PBBs	Allen-Rolands et al. 1981

<table>
<tr><td colspan="2" align="center">Exhibit 2 (continued)

CHEMICALS WITH WIDESPREAD DISTRIBUTION IN THE ENVIRONMENT REPORTED
TO HAVE REPRODUCTIVE AND ENDOCRINE-DISRUPTING EFFECTS</td></tr>
<tr><td align="center">Chemical</td><td align="center">Reference</td></tr>
<tr><td>PCBs</td><td>Bush et al. 1986; Sager et al. 1987; Dieringer et al. 1979</td></tr>
<tr><td>Pentachlorophenol (PCP)</td><td>Choudhury et al. 1986</td></tr>
<tr><td>Penta- to nonylphenol</td><td>Rories and Spelberg 1992</td></tr>
<tr><td>Phthalates</td><td>Treinen et al. 1990; Wams 1987; Lloyd and Foster 1988; Gray and Gangolli 1986; Thysen et al. 1990; Laskey and Berman 1993</td></tr>
<tr><td>Styrenes</td><td>Gray 1992; Arfini et al. 1987; Mutti et al. 1984</td></tr>
<tr><td colspan="2">Source: Colborn, T., et al., "Developmental Effects of Endocrine-Disrupting Chemicals in Wildlife and Humans," Environmental Impact Assessment Review, vol. 14, pp. 469-489, 1994.</td></tr>
</table>

Most studies linking endocrine disruptors to adverse health effects involve wildlife observations or laboratory animals. "Compelling evidence" exists that endocrine systems of certain fish and wildlife have been disrupted by chemical contaminants (US EPA 1997b).[4] A good example occurred at Lake Apopka, Florida following a pesticide spill: alligators developed defects including reduced body size, demasculinization of males, and reduced hatching success.

Endocrine disruption also has been observed in laboratory animals, including effects on female and male reproductive function. Exhibit 3 summarizes potential adverse health effects of endocrine disruptors. For nearly every one of the chemicals listed, however, no well-established causal link exists between exposure and adverse human health effects.

---

[4] Some chemicals listed in the exhibits bioaccumulate in body fat or breast milk. Endocrine disruptors have been found to bioaccumulate in animal tissues all over the world, from black-footed albatross on Midway Island in the middle of the Pacific Ocean to beluga whales in Canada's St. Lawrence River (Dold 1996).

Exhibit 3

**NON-CANCER HEALTH EFFECTS ASSOCIATED WITH EXPOSURES TO
ENDOCRINE-DISRUPTING CHEMICALS IN ANIMALS AND HUMANS**

Chemical	Menstrual Abnormalities	Male Infertility	Female Infertility	Spontaneous Abortion	Structural Birth Defects	Functional Defects	Low Birth Weight	Other
Solvents								
Toluene	h	h		H/a	H/a	h	A	
Xylene	a		a	h/A	h/a		A	
Styrene	h	h/a		a	a			
TCE		h/a		h	h			Childhood leukemia
PCE		h	h	H/a			a	Infant jaundice
1,1,1-TCA				h	h			
Glycol Ethers		H/A	A	h/A	h/A	a	A	
Epichlorohydrin		h/A						Chromosome damage
Metals								
Cadmium		h/A	a	A	A	A	h/A	SIDS, Placental Toxicity
Organic Mercury		a		h/a	H/A	H/A		

Chemical	Menstrual Abnormalities	Male Infertility	Female Infertility	Spontaneous Abortion	Structural Birth Defects	Functional Defects	Low Birth Weight	Other
Inorganic Mercury	h	A		h/A	h/a			
Manganese		h/A	a	A	a	h/A	A	
Lead		H/A	h	H/A	h/a	H/A	H/A	
Pesticides								
Organophosphates								
Malathion							a	
Parathion		A		A		A		DNA damage
Dimethoate		a						
Diazinon		a		a	A			DNA damage
Tetrachlovinphos								Ovarian toxicity
Chlorpyrifos					a			
Acephate				a		a		
Carbamates								
Carbaryl		a	a		a			

Exhibit 3

NON-CANCER HEALTH EFFECTS ASSOCIATED WITH EXPOSURES TO ENDOCRINE-DISRUPTING CHEMICALS IN ANIMALS AND HUMANS

Exhibit 3

**NON-CANCER HEALTH EFFECTS ASSOCIATED WITH EXPOSURES TO
ENDOCRINE-DISRUPTING CHEMICALS IN ANIMALS AND HUMANS**

Chemical	Menstrual Abnormalities	Male Infertility	Female Infertility	Spontaneous Abortion	Structural Birth Defects	Functional Defects	Low Birth Weight	Other
Organochlorines								
Lindane	a	A		A				
Endosulfan		A						Stimulates breast cancer cells in culture
Dicofol		A				A		
Piperonyl Butoxide				a	a	a		
Dieldrin					a	A		
Methoxychlor	a	A	a	a	a			
Fungicides								
Benomyl		a			A			
Dithiocarbamate	a	a			a			
Fumigants								
DBCP		H/A						
EDB		H/A						
Ethylene Oxide		A		H	a		a	Chromosome damage
Herbicides								
Atrazine				a	a		a	
Cyanazine				a	A		a	
Paraquat					a		a	
Dicamba				a			a	

C-22

Exhibit 3

NON-CANCER HEALTH EFFECTS ASSOCIATED WITH EXPOSURES TO ENDOCRINE-DISRUPTING CHEMICALS IN ANIMALS AND HUMANS

Chemical	Menstrual Abnormalities	Male Infertility	Female Infertility	Spontaneous Abortion	Structural Birth Defects	Functional Defects	Low Birth Weight	Other
2,4-D		a						Chromosome damage
Pyrethrins								
Cypermethrin						a	a	
Fenvalerate						a		
Other								
Phthalates		A		a	a			
Dioxin		A	a	h/A	h/a	a		Endometriosis in animals
PCBs	A	a	A	h/A	a	H/A	H/A	Interferes with thyroid function
Alkylphenols		a						

Notes: a = one animal study or conflicting animal studies
A = Consistently positive animal studies
h = one human study or conflicting human studies
H = Consistently positive human studies
[blank] = Data gap or generally negative studies

Source: Schettler, T., et al., *Generations at Risk: How Environmental Toxins May Affect Reproductive Health in Massachusetts*, A Report by Greater Boston
Physicians for Social Responsibility (GBPSR) and the Massachusetts Public Interest Research Group (MASSPIRG) Education Fund, Cambridge, MA, 1996.

The "DES Legacy"

A widely known case where a causal link has been established between an endocrine disruptor and human health arises from a past American medical mistake: DES. From 1945 to 1971, doctors prescribed the drug diethylstilbestrol (DES) to an estimated five million pregnant women in the US. Now recognized as a potent endocrine disruptor capable of distorting fetal development, doctors originally encouraged pregnant women to take DES to prevent miscarriages (Dold 1996). In the early-1970's, doctors began to notice reproductive abnormalities in the sons and daughters of DES mothers. Specifically, DES daughters exhibited malformed reproductive organs and reduced fertility, and experienced a high incidence of ectopic pregnancies, miscarriages, and premature births. DES sons suffered from small and undescended testicles, hypospadias, and abnormal semen (Schettler 1996). The DES experience suggests that fetal exposure to endocrine disruptors can cause long-term adverse health effects in humans.

The DES case and research conducted by Theo Colborn, a senior scientist for the World Wildlife Fund, suggest that the embryo is the most sensitive life stage of animals and humans to the hazards posed by endocrine disruptors. Hormones released by the endocrine system play a critical role in embryonic development and early fetal exposure to endocrine disruptors can lead to major structural changes in the genital tract, including abnormal cell growth. These changes typically go unnoticed until maturity, when the effects are often irreversible (Lindala 1995).

Scientific Uncertainties

Considerable scientific uncertainty surrounds the issue of endocrine disruptors and human health. Some scientists argue that endocrine disruption is not a significant environmental health risk because: (1) humans ingest more endocrine-disrupting compounds from plants than from anthropogenic chemicals; and (2) the quantities absorbed are too small to cause adverse health effects. For example, many hormone mimics are weaker than natural hormones, and the body has mechanisms to regulate hormone levels.

Human ingestion of endocrine disrupting chemicals in plants, however, does not establish that exposure to synthetic endocrine disruptors is safe, for three reasons. First, exposure during the sensitive fetal period causes more damage than exposures during adulthood; consumption of plants containing endocrine disruptors, such as fruits and soybeans, usually occurs in adulthood. Second, human defense mechanisms may protect against plant-derived hormones, but prove ineffective against synthetic hormones. For example, plant-derived estrogens stimulate the synthesis of binding proteins and "bound" estrogen is physiologically inactive. By contrast, EPA scientists postulate that if human and animal defense mechanisms could protect against synthetic hormones, then "we never would have had any problems with estrogens in wildlife and domestic animals, and we do" (L. Earl Gray, as quoted in Lutz 1996). Finally, while the body metabolizes and excretes plant-derived hormones, many synthetic chemicals resist biodegradation and accumulate in the human body over time.

In addition, unlike toxicological effects where low contaminant doses (below the threshold dose) have no effect, the small quantities of endocrine-disrupting chemicals absorbed by humans may be sufficient to elicit an adverse health response. Specifically, endocrine disruption may occur at extremely minute chemical doses, even at levels 100 times lower than those associated with appreciable cancer risks (Mitchell 1997). Frederick vom Saal, a biologist at the University of Missouri, argues that endocrine disruptors defy the dose-response paradigms applied to toxic and carcinogenic chemicals: the response function is shaped like an upside-down U (Lutz 1996). Illustrative dose-response functions for toxic, carcinogenic, and endocrine effects are sketched schematically in Figure 2.

In considering uncertainties in the scientific underpinnings of an endocrine-disrupting effect, it is important to remember that scientific research on endocrine disruption is relatively sparse. Although endocrine disruption researchers offer convincing reasons why endocrine disruption is a significant environmental health risk, current evidence is insufficient to refute the challenges of dissenting scientists.

EPA Statement on Endocrine Disruptors

In a special report on endocrine disruption, EPA concluded that "with few exceptions (e.g., DES, dioxin, DDT/DDE), a causal relationship between exposure to a specific environmental agent and an adverse effect on human health operating via an endocrine disruption mechanism has not been established" (US EPA 1997b). Based on other toxicological properties, however, EPA has already banned the use in this country of several chemicals suspected of endocrine disruption, including: PCBs, chlordane, DDT, aldrin, dieldrin, endrin, heptachlor, kepone, toxaphene, and 2,4,5-T (US EPA 1997c). In addition, the Endocrine Disruptor Screening and Testing Advisory Committee (EDSTAC), established under the mandates of the Food Quality Protection Act of 1996 and the Safe Drinking Water Act Amendments of 1996, advises the Agency on the screening and testing of potential endocrine disruptors.[5]

---

[5] In July 1997, the National Drinking Water Advisory Council recommended 58 chemical and 13 microbiological contaminants for future drinking water regulation by the EPA. Among the contaminants proposed for regulation, six (e.g., aldrin, metribuzin) appear on the Illinois EPA list of endocrine disruptors (BNA 1997).

FIGURE 2

ILLUSTRATIVE DOSE-RESPONSE RELATIONSHIP FOR A CONTAMINANT SUSPECTED OF ENDOCRINE DISRUPTION

COMPARISON OF CARCINOGENIC, TOXIC, AND ENDOCRINE RESPONSES

Carcinogenic Effects*	*de minimis Effect*	Potential Effect	**Increasing Effect**	**Increasing Effect**

| **Toxic Effects*** | *No Effect* | *No Effect* until threshold dose | **Increasing Effect** beyond threshold dose | **Increasing Effect** |

| **Endocrine Disrupting Effects** | Potential Effect | **Increasing Effect** | ***Decreasing Effect*** masking by toxic effect | *No Observable Effect* masked by toxic effect |

Very Low   Low to Moderate   Moderate to High   Very High

Contaminant Dose

Notes: Carcinogenic effects are often associated with premature mortality. Toxic effects may include premature mortality at higher doses.

ECONOMIC VALUATION OF ENDOCRINE DISRUPTION: INTRODUCTION
REFERENCES

B.D.S. "Hormonal Sabotage: Synthetic Chemicals in the Environment May be Wreaking Havoc with the Endocrine Systems of Humans and Animals." *Natural History*: 42-49. March 1996.

Bureau of National Affairs (BNA). "Advisory Committee Recommends Draft List of Substances for Regulation," *Environment Reporter* 28 (13): 594-595. July 25, 1997.

Colborn, T., D. Dumanoski, and J. Peterson Myers. *Our Stolen Future*. New York: Penguin Books. 1996.

Colborn, T., F. vom Saal, and A. Soto. "Developmental Effects of Endocrine-Disrupting Chemicals in Wildlife and Humans," *Environmental Impact Assessment Review* 14: 469-489. 1994.

Dold, C., "Hell." *Discover:* 52-59. September 1996.

Environmental Information Center. *Environmental Information Center Regional Analysis of Major Toxic Chemical Releases: Great Lakes Report on Hormone Disrupting Chemicals.* Washington, D.C. June 1997.

Fantle, W. "The Incredible Shrinking Man: Hazardous Chemical Pollution and Genetic Deformities." *The Progressive* 58 (10): 12. October 1994.

Illinois Environmental Protection Agency. *Endocrine Disruptors Strategy*. February 1997.

Lindala, E. "Chemical Pollutants Linked to Male Infertility." *Alternatives* 21 (3): 11. July 17, 1995.

Lutz, D. "No Conception: Effect of Chemicals on Human Fertility and Health." *The Sciences* 36 (1): 12. January/February 1996.

Mitchell, J. "Nowhere to Hide: The Global Spread of High-Risk Synthetic Chemicals." *WorldWatch*: 26-36. March/April 1997.

Schettler, T., et al. *Generations at Risk: How Environmental Toxins May Affect Reproductive Health in Massachusetts*. Greater Boston Physicians for Social Responsibility (GBPSR) and the Massachusetts Public Interest Research Group (MASSPIRG) Education Fund. 1996.

US Environmental Protection Agency. *EPA Activities on Endocrine Disruptors: Background Paper,* Office of Prevention, Pesticides, and Toxic Substances, February 1997c. Document obtained from an EPA Internet web page on June 6, 1997 at the following address: http://www.epa.gov/opptintr/opptendo/endo2_2.htm.

US Environmental Protection Agency. *Questions and Answers: Potential of Chemicals to Affect the Endocrine System, Office of Prevention, Pesticides, and Toxic Substances*. Document obtained from an EPA Internet web page on June 6, 1997 at the following address: http://www.epa.gov/opptintr/opptendo/endo2_1.htm. January 1997a.

US Environmental Protection Agency. *Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis*. Prepared for the Risk Assessment Forum, US Environmental Protection Agency, Washington, DC. February 1997b.

ECONOMIC VALUATION OF ENDOCRINE DISRUPTION: DEVELOPMENTAL EFFECTS

Description of the Effect

Developmental effects of toxic exposures include death of the fetus, altered growth, and structural and functional defects (US EPA 1991). *Structural* developmental defects are deformities that are visible, or detectable on physical examination or autopsy. *Functional* developmental defects occur when organs that may appear normal nonetheless work abnormally. Reduced IQ from fetal or childhood exposure to lead is an example of a functional defect. The case study of lead provides further discussion of adverse developmental effects, focusing on functional defects such as reduced IQ.

This case study focuses mainly on two types of developmental effects: *congenital anomalies* and *low birth weight*. When available, we provide scientific evidence of a potential link between endocrine disruptors and adverse developmental health effects. Since health scientists lack a defined dose-response function for endocrine disruptors, however, any causal link implicating endocrine disruptors is tenuous.

Congenital Anomalies

Congenital anomalies are abnormalities present at birth. There are over 200 separate congenital anomalies, ranging from purely cosmetic to generally fatal. Some defects can be corrected with surgery and rehabilitation early in life, while others cause permanent disability.

According to US health statistics, congenital anomalies are the leading reported cause of infant mortality (US DOC 1995, Table No. 122). The National Center for Health Statistics (NCHS) reports that congenital anomalies caused 21 percent of infant deaths (death before reaching one year of age) in the birth cohort of 1991. Infant deaths due to congenital anomalies account for over five percent of all potential life years lost before age 65, according to Waitzman, Scheffler and Romano (1996). These figures are particularly striking given the extremely low incidence of many birth defects (Exhibit 1).

Waitzman et al. report survival patterns for children in California with various congenital anomalies or cerebral palsy (usually not considered a birth defect). Combining these data with national infant mortality rates allows estimation of infant mortality ratios. Estimated mortality ratios in Exhibit 1 give the risks of infant mortality for persons with birth defects as multiples of the risk of infant death in the general population. The mortality ratios vary widely by defect, ranging from a relative risk of 9.9 for infants with atresia of the small intestine to 68.8 for infants with renal agenesis.

Exhibit 1				
BIRTH DEFECTS AND CEREBRAL PALSY: **INFANT MORTALITY RATIOS, INCIDENCE, AND COSTS OF ILLNESS**				
Health Condition	**Percentage of Live Births**	**Infant Mortality Ratio (Relative Risk)**	**Cost per Case ($1000s, 1992)**	**Aggregate Cost ($1000s, 1992)**
Spina bifida	.042%	22.2	$294	$489,289
Truncus arteriosus	.011%	68.5	$505	$209,676
Transposition of great arteries/ Double Outlet Right Ventricle	.049%	44.2	$267	$514,529
Single ventricle	.013%	59.6	$344	$172,631
Tetralogy of Fallot	.035%	27.0	$262	$340,486
Cleft lip or palate	.177%	15.4	$101	$695,501
Tracheoesophageal fistula	.029%	27.6	$145	$165,002
Atresia of the small intestine	.038%	9.9	$75	$110,061
Colorectal atresia	.045%	27.2	$123	$219,262
Renal agenesis	.043%	68.8	$250	$424,159
Urinary tract obstruction	.104%	21.0	$84	$343,223
Upper-limb reduction	.044%	15.9	$99	$176,036
Lower-limb reduction	.021%	21.0	$199	$167,067
Diaphragmatic hernia	.037%	62.0	$250	$364,348
Gastroschisis	.026%	16.1	$108	$108,763
Omphalocele	.019%	41.9	$176	$132,004
Down syndrome	.105%	10.4	$451	$1,847,752
Cerebral palsy	--	1.2	$503	$2,425,781

Notes:

(1) Infant morality ratios computed from infant mortality rates in Waitzman et al. (1996) for specific health conditions and national infant mortality rate for the general population. Infant mortality ratio is equivalent to: [(number of infant deaths related to birth defects/1,000 infants born with birth defects) / (number of infant deaths in the general population/1,000 infants born in the general population)]. The mortality ratios shown should be viewed as less reliable than corresponding figures computed from national infant mortality rates for congenital anomalies because of the relatively small number of some birth defects in the Waitzman et al. study.

(2) Incidence computed by weighting sex-specific incidence in Waitzman et al. (1996) by percentages of male/female births.

(3) Costs per case and aggregate costs from Waitzman et al. (1996), five percent discount rate.

For most birth defects, the relative risk of death for first-year survivors is dramatically lower than the relative risk of infant mortality (Waitzman et al. 1996, Table 3-5). But congenital anomalies remain a leading cause of death throughout childhood, accounting for 13 percent of deaths between ages one and four years, and five percent of deaths at ages five to fourteen (US DOC 1995, Table No. 122).

In addition to premature mortality, congenital anomalies cause the full range of adverse effects of ill health on economic well-being. Many birth defects cause excess morbidity, while some cause permanent disability, resulting in higher medical expenses, foregone market and nonmarket production, and costs of special education and rehabilitation. These financial costs are accompanied by the pain and suffering of the individual and his or her family.

While scientists observe birth defects in mice exposed to PCBs, the paucity of reliable scientific data for humans precludes any concrete conclusions inculpating endocrine disruptors. One study found a weak link between the exposure of Vietnam veterans to the herbicide "Agent Orange" (containing dioxin) and congenital birth defects in their offspring (Erickson et al. 1984). The study examined 7,000 babies for the presence of one or more of 96 birth defects. Study results suggest that while Vietnam veterans in general do not have an increased risk of fathering babies with birth defects, veterans with high Agent Orange exposure histories may have an increased risk of fathering babies with spinal cord abnormalities (e.g., spinal bifida) and cleft palates. Erickson et al. note that this increased risk may result from chance events or an unidentified risk factor.

Low Birth Weight

The median birth weight in the US has been quite constant in recent years, at 7 pounds, 7 ounces or about 3375 grams (US DOC 1995, Table No. 96). Infants weighing less than 2500 g (5 lbs., 8 oz., about 75 percent of the median) at birth have low birth weight. The low birth weight class includes newborns weighing less than 1500 g (very low birth weight), which in turn includes those weighing less than 1000 g (extremely low birth weight).

Low birth weight is more common than congenital anomalies. As shown in Exhibit 2, 7.1 percent of live births in 1991 were infants with low birth weight. The condition occurs more frequently among infants born to mothers who are African-American, or have low income and education. For example, black mothers are 2.3 times as likely as white mothers to give birth to a low birth weight infant (Exhibit 2).

Exhibit 2

LOW BIRTH WEIGHT: INCIDENCE AND INFANT MORTALITY BY RACE AND GESTATIONAL AGE

Group		Percentage of Live Births		Normal Birth Weight	Mortality Ratio	Relative Risk	
		Low Birth Weight			Low/Normal Birth Weight	Low Birth Weight	Infant Mortality
		Incidence	Infant Mortality	Infant Mortality			
All Live Births		7.1%	7.2%	0.38%	19.0	N/A	
Infant Race	White	5.8%	6.7%	0.34%	20.1		
	Black	13.5%	8.4%	0.60%	14.0		
	Black/White Relative Risk	N/A				2.3	2.3
Gestational Age (weeks)	< 37 weeks	41.0%	10.2%	0.97%	10.5	N/A	
	$37 weeks	3.0%	2.1%	0.32%	6.5		
Short Gestation		N/A				13.7	12.8

Source: Calculations based on data from US National Center for Health Statistics, "Infant Deaths and Mortality Rates by Race of
Mother and for 61 Selected Causes of Death and Birth Weight: United States, 1991 Birth Cohort," and "Infant Deaths and Mortality Rates by Race
of Mother, Birth Weight, and Gestational Age: United States, 1991 Birth Cohort."

Notes: (1) To calculate the Low/Normal Birth Weight mortality ratio, divide the low birth weight infant mortality rate by the normal birth weight infant
mortality rate (e.g., 7.2% ÷ 0.38% = 19.0).
(2) To calculate the Black/White relative risk of low birth weight, divide the Black low birth weight incidence by the White low birth weight
incidence (e.g., 13.5% ÷ 5.8% = 2.3).
(3) To calculate the Short Gestation relative risk of low birth weight, divide the short gestational age low birth weight incidence by the normal
gestational age low birth weight incidence (e.g., 41.0% ÷ 3.0% = 13.7).
(4) Calculating the Black/White and Short Gestation relative risks of infant mortality entails a weighted (i.e., incidence * mortality rate) comparison
of risk factors.
(5) Some scientific studies suggest a potential link between maternal exposure to endocrine disruptors and an increased incidence of low birth
weight. This exhibit suggests that low birth weight infants are 19 times more likely to die than normal birth weight infants.

Infant mortality ratios for low birth weight are larger than for some congenital anomalies. As shown in Exhibit 2, low birth weight infants are 19 times more likely to die before their first birthday than are infants weighing 2500 g or more at birth. This excess mortality is highly concentrated among infants with very low birth weight. Newborns weighing between 1500 g and 2499 g are 5.7 times more likely than heavier newborns to die within a year, but very low birth weight infants are 78.5 times more likely to die. Although fewer than 20 percent of low birth weight infants weigh less than 1500 g at birth, this group accounts for over 75 percent of deaths among low birth weight infants.

Low birth weight often is associated with short gestation, which itself is a significant risk factor for infant mortality, with a mortality ratio of 12.8 (Exhibit 2). Disorders related to short gestation and low birth weight are the fourth leading cause of infant mortality, after congenital anomalies, sudden infant death syndrome, and respiratory distress syndrome (US DOC 1995, Table No. 122). As shown in Exhibit 2, however, low birth weight appears to exert a substantial influence on infant mortality independently of effects of short gestation. Among newborns with a gestational age of less than 37 weeks, for example, those weighing less than 2500 g at birth face a risk of infant mortality 10.2 times larger than their heavier counterparts.

Low birth weight is less closely linked to mortality and disability throughout life than are congenital anomalies. But some low birth weight survivors experience continued disadvantages, ranging from greater morbidity (Lewit et al. 1995) to greater chances of preschool developmental delays, enrollment in special education, and grade repetition (Chaikind and Corman 1991, Corman and Chaikind 1993). Persons of low birth weight and their families may experience significant financial and nonfinancial burdens during the first year of life as well as in later years.

Observed adverse effects in aquatic life and wildlife exposed to endocrine disruptors include abnormal thyroid function and low birth weight. Scientists know that the thyroid gland and the hormones it produces contribute to body growth. In fish having a bony skeleton (teleosts), for example, skeletal growth is "particularly sensitive to the state of the thyroid gland" (US EPA 1997). Targeted scientific research indicates possible links between pesticide exposure and reduced birth weight in various fish and bird species, and between PCB exposure and reduced birth weight in monkeys and rats (Schettler et al. 1996).

Two scientific studies suggest a potential link between maternal exposure to endocrine disruptors and an increased incidence of low birth weight in humans. The first study examined mothers living in Michigan who ate two or three meals of Great Lakes fish a month in the six years prior to pregnancy (Jacobson et al. 1984). Great Lakes fish in the 1970s and early-1980s contained significant levels of PCBs and other contaminants currently suspected of endocrine disruption. Since PCBs bioaccumulate in human body fat, the mothers unknowingly passed the harmful contaminants on to their babies through the placenta during pregnancy and through breast milk during infancy. Jacobson et al. observed evidence of a direct correlation between maternal fish consumption and

birth weight: the higher the mother's consumption of Lake Michigan fish, the lower the infants birth weight. Specifically, the study found that exposed infants weighed 190 g to 250 g less than normal infants at birth, and had a gestational age six to 12 days shorter than that of normal infants.

The second study examined women employed by either of two capacitor manufacturing facilities in New York between the years 1946 and 1975 (Taylor et al. 1989). Employees worked with PCBs in the manufacturing process and regularly experienced air and/or dermal contact exposures. Taylor et al. observed small decreases in birth weight in relation to increasing levels of PCB exposure. The authors note, however, that while these results may suggest a causal link between maternal PCB exposure and reduced birth weight, the exposed infants investigated in this study had a healthy mean birth weight of 3,300 g.

Types of Exposures that Cause the Effect

Exhibit 3 in the Introduction to the Endocrine Disruption case studies provides an overview of evidence linking endocrine disruptors to low birth weight, and to structural and functional defects. In most cases, no solid causal connection between exposure to endocrine disruptors and the adverse developmental effect has been established.[6]

Existing Studies Characterizing Values

There have been few studies of the economic value of avoiding developmental defects or low birth weight. In a recent overview of valuation of reproductive and developmental effects, Cannon et al. (1996) recommended using stated and revealed preference methods to value reductions in birth defects and low birth weight. Stated preference methods would rely on parents' responses to hypothetical questions concerning willingness to pay (WTP) for reduced risk of birth defects or low birth weight. The revealed preference approach, on the other hand, would infer WTP from actions taken by parents, especially the mother, to improve chances of delivering a healthy baby. Cannon et al. suggested focusing on reduced consumption of alcohol and tobacco; the decision to seek adequate and early prenatal care would also be important.

---

[6] It is often not clear that a low birth weight outcome occurred through an endocrine disruption mechanism. To the extent that low birth weight is associated with the endocrine disrupting chemicals, however, a comprehensive valuation of policies directed toward these chemicals should account for all adverse health effects, including low birth weight.

Although both revealed and stated preference approaches appear promising for valuing developmental effects, there have been no studies of low birth weight or birth defects employing these methods. Joyce, Grossman and Goldman (1989) conducted a revealed preference study of pollution-related neonatal mortality, but did not provide estimates for low birth weight or birth defects. Apart from one jury award study of developmental defects, the few remaining studies all use cost-of-illness methods.

Congenital Anomalies

Costs of Illness

Waitzman et al. provide the best available information relevant for valuing the prevention of birth defects. Waitzman et al. (1996) estimate lifetime costs of illness for incident cases in 1988 of 17 birth defects and cerebral palsy. As discussed in Chapter 3, the incidence approach computes discounted lifetime costs of incident (new) cases in a given year and is better suited than the prevalence approach for valuing preventive policies. Waitzman et al. examined birth defects representing serious structural abnormalities that span major organs; the defects are not representative of the more than 200 birth defects included in the International Classification of Diseases. Costs were estimated for California, which has an extensive birth defects surveillance system and where one in seven US births occur. Estimates for California were projected to the US as a whole.

Direct cost estimates include expenses for medical, developmental, and special education services. Indirect costs include foregone earnings and fringe benefits from premature mortality and excess morbidity, as well as from the lower wages and labor force participation rates of birth defects survivors. Indirect costs also include foregone nonmarket production, which was valued using costs of hiring out household work. The study estimates "incremental" costs -- costs in excess of those incurred by the average individual.

Estimated aggregate costs of birth defects for the US, and costs per case, were computed using discount rates of two, five and ten percent. An illustrative set of results, using the middle, five percent discount rate, are presented in Exhibit 1, in 1992 dollars. Costs per case vary widely by defect, ranging from $75,000 (atresia of the small intestine) to $505,000 (truncus arteriosus). Aggregate costs are similarly variable by defect. Waitzman et al. report that aggregate costs are sensitive to three main factors: incidence, life years lost, and extent of functional limitations. Aggregate costs for the 17 birth defects total $5.5 billion; including cerebral palsy, the total cost increases to $8.0 billion. Indirect costs account for over 60 percent of the total.

Waitzman et al. compared their estimates to the prevalence-based estimates of Rice, Hodgson and Kopstein (1985). As discussed in Chapter 3, the prevalence approach estimates costs of all cases in a given year and is more relevant for valuing treatment than prevention programs. Rice et al. estimated aggregate costs of illness in the US for major health effects including birth defects. Accounting for over 200 birth defects (all congenital anomalies in the ICD code range 740-759), but excluding nonmedical direct costs (such as special education), Rice et al. obtain annual aggregate costs of $6.2 billion (1980 dollars, four percent discount rate). This figure represents 1.4 percent of the annual costs of illness in the US.

Waitzman et al. also compared their estimates to the costs of spina bifida estimated by Lipscomb (1986). Lipscomb accounted for medical and nonmedical direct costs, and his indirect cost estimate included foregone income of parents. Incidence-based costs of the typical case of spina bifida in North Carolina in 1985 were estimated to be $181,745 (1985 dollars, five percent discount rate). Adjusting for inflation, this estimate is reasonably close to the $294,000 per case estimate of Waitzman et al.

Jury Awards

Additional valuation information is provided by the jury award study of Lopez, Dexter and Reinert (1995). They examined jury awards in negligence cases involving severe developmental defects, including mental retardation, cerebral palsy, spastic quadriplegia, and blindness or deafness, over the years 1981-90. Verdicts in the 132 cases ranged from $0.79 million to $23 million (1991 dollars), with a mean of $4.4 million and a standard deviation of $4.2 million. These values substantially exceed the costs per case estimates presented earlier. For example, the second largest cost per case in Exhibit 1 is $503,000 for cerebral palsy, an effect also included in the jury award study. After converting the mean jury award to its value in 1992 dollars ($4.53 million) using the Consumer Price Index, the award is nine times greater than the cost of cerebral palsy.

Low Birth Weight

Cannon et al. (1996) reviewed two studies of the direct costs of low birth weight. Lewit et al. (1995) estimated incremental costs for the prevalent population of 3.5 to 4 million children aged 0-15 years in 1988 who had been born with low birth weight. Only direct costs were estimated, including expenses for medical care, education and child care in excess of costs of other children aged 0-15 in 1988. Lewit et al. found that health care costs during infancy averaged $15,000 per low birth weight infant. In the aggregate, over one-third of the $11.4 billion spent on infant health care represented incremental costs of low birth weight infants. Aggregate annual direct costs of low birth weight children aged 0-15 years in 1988 were estimated at $5.4 billion. Higher than normal health care costs represented 75 percent of the total.

Schwartz (1989) estimated immediate inpatient hospital costs associated with several categories of birth weights. Data were collected from a nationally representative sample of perinatal centers which had a neonatal intensive care unit and at least one full-time neonatologist, and which retained all neonates requiring treatment. Schwartz found that average costs per low birth weight patient were over 13 times greater than average costs of heavier infants. Costs increased rapidly with reductions in birth weight. Costs per low, but not very low, birth weight infant were 6.7 times those for normal birth weight infants; costs for very low, but not extremely low, birth weight infant were 34.8 times those for normal birth weight infants; and costs per extremely low birth weight infant were 72.4 times those for normal birth weight infants. This pattern of increasing medical costs is similar to the pattern of increasing mortality as birth weight falls.

Schwartz estimated cost savings for the population of hospitals represented by the sample, where 53 percent of low birth weight infants in the US are treated, under a scenario in which 20 percent of infants in each 250 g interval below 2500 g were moved into the next higher weight interval. Estimated cost savings ranged from $73 million to $96 million per year.

Discussion of Valuation Strategies

Three major obstacles complicate valuation of developmental effects potentially linked to endocrine disruptors:

1.   There are no estimates of WTP to reduce the risk of congenital anomalies, low birth weight, or other developmental effects possibly associated with endocrine-disrupting chemicals.

2.   Available COI estimates are incomplete. The Waitzman et al. (1996) study includes fewer than 20 defects, while low birth weight studies account only for direct costs, ignoring indirect costs of premature mortality. More fundamentally, any COI estimates must be viewed as lower bounds, and if the jury award study of Lopez et al. (1995) is any guide, the COI for developmental effects may fall well short of a comprehensive valuation.

3.   There is no clear causal connection between exposure to many endocrine-disrupting chemicals and human developmental effects.

In view of the uncertainty of the dose-response relationships, efforts to quantify precisely the WTP to avoid developmental effects appear unwarranted (unless these effects can be linked more confidently to other exposures). Analysts might choose to use an interim valuation strategy of using cost-of-illness measures as lower bound values for congenital anomalies and low birth weight. For

purposes of screening analyses of comprehensive valuations, the jury award study of Lopez et al. (1995) could be used to estimate the order of magnitude of the pain and suffering values of developmental disabilities.

As more precise dose-response information becomes available, or if it is necessary to value developmental effects because of links to other exposures, analysts might choose to estimate WTP to prevent birth defects and low birth weight using contingent valuation methods. The averting behavior method also appears promising, particularly in the case of low birth weight, and might be implemented in conjunction with contingent valuation. Finally, as discussed more fully in the Reproductive Effects case study, analysts may use the economic theory of fertility as a framework to model both reproductive and developmental effects.

Apart from the choice of valuation method, four general issues are relevant for valuing congenital anomalies or low birth weight.

1. Benefits may vary widely depending on the specific congenital anomalies considered. Exhibit 1 illustrates the variation in COI for different birth defects, a variation attributable in part to differences in premature mortality shown in the exhibit. It is reasonable to expect WTP to show similar variation over birth defects. Consequently, it may be necessary to conduct numerous valuation studies of separate birth defects.

2. The benefits of reduced incidence of low birth weight will depend on the distribution of changes in birth weight. As discussed earlier, incidence of low birth weight is concentrated among newborns weighing more than 1500 grams, but excess infant mortality and excess infant health care costs are concentrated among newborns weighing less than 1500 g.

3. Incidence data are much easier to obtain for low birth weight than for congenital anomalies. The incidence of low birth weight is far higher than the incidence of specific birth defects, and birth weight is recorded for nearly all infants born in the US. It is difficult, in contrast, to obtain reliable quantitative data on rare events like occurrence of specific birth defects.
    Finally, the demographic variation in incidence of low birth weight raises important issues of environmental justice and underlines the need to control for personal characteristics in studies of low birth weight.

Cost of Illness

Environmental policy may affect future incidence of congenital anomalies, but it is less likely to ameliorate existing cases. Thus, incidence-based COI estimates are likely to be preferable to prevalence-based measures. Also, estimates accounting for the full range of illness costs, including nonmedical direct costs like special education, and indirect costs of premature mortality, are preferable to estimates that omit important categories of losses.

Unfortunately, no studies of low birth weight provide incidence-based measures of the full range of illness costs. The Waitzman et al. study, in contrast, provides reliable estimates of costs of the 18 defects considered. It may be possible to transfer these estimates to other congenital anomalies which lack COI estimates, provided the major cost factors (survival patterns and extent of disability) are carefully matched. But caution should be exercised in any benefits transfer across birth defects, in view of the apparently wide variation in illness costs.

Even COI studies computing incidence-based measures of all relevant illness costs must be viewed as lower bound values. Some adjustment of COI numbers to reflect additional benefit categories might be useful in screening analyses of benefits. For example, discounted values for life years, instead of foregone earnings, might be used to value the excess mortality of congenital anomalies or low birth weight, or the Lopez et al. jury award study could be used as an indicator of the magnitude of pain and suffering values.

Contingent Valuation

The contingent valuation (CV) method provides the best option for valuing avoidance of adverse developmental effects. CV would support estimation of parents' WTP for reduced risk of specific birth defects or low birth weight. One major advantage of CV is that it can be focused narrowly on specific adverse developmental effects much more easily than can the AB method.

Key issues in designing a CV study include the following. First, there are few if any prior CV studies of parents' WTP for infant or child health to provide empirical guidance for survey design. Second, the low incidence of specific birth defects requires that careful attention be paid to the presentation of risk information, because survey respondents often find it difficult to understand and value small risks. Third, results of Krupnick and Cropper (1992) suggest that stated WTP may be quite sensitive to the amount of information individuals have concerning the effect being valued, but many respondents may have little knowledge of the consequences of low birth weight or specific birth defects. Researchers would have to control for respondents' degree of knowledge, and give careful consideration to the information presented prior to the valuation questions.

Averting Behavior

The averting behavior (AB) method appears quite promising for valuation of low birth weight, but is not as well-suited for congenital anomalies. The most feasible way to implement the approach would be to examine actions taken by pregnant women to increase chances of delivering a healthy baby, rather than actions specifically directed toward avoiding exposure to endocrine disruptors.

Several behavioral risk factors for adverse birth outcomes are well-known, such as cigarette smoking, alcohol consumption, and delaying prenatal care. Pregnant women differ in their choices of these behaviors, with corresponding differences in birth outcomes. In 1991, for example, fewer than 18 percent of live births were to cigarette-smoking mothers -- but low birth weight infants were 1.8 times more likely to be born to smoking than to nonsmoking mothers (NCHS 1996). Likewise, the results of Joyce et al. (1989) highlight the importance of early prenatal care, but in 1991, 21 percent of live births for whites, and 38 percent for blacks, were to mothers who did not obtain prenatal care during the first trimester (NCHS 1996).

The AB approach is particularly well-suited for valuation of low birth weight, because of the relatively high incidence, the close link to observable personal characteristics like race, schooling and income, and the degree of knowledge concerning behavioral risk factors. In addition, secondary data sources contain much of the information needed to implement the approach (Cannon et al. 1996). Conversely, the AB approach appears somewhat less suitable for valuation of congenital anomalies, because of the low incidence, the lack of a strong connection to measurable personal characteristics, and, with a few exceptions like neural tube defects, the more limited knowledge concerning behavioral risk factors.

Two problems must be overcome in applying the AB method to value low birth weight or congenital anomalies. First, actions taken by pregnant women, such as abstinence from cigarettes or alcohol or obtaining prenatal care, reduce risks of several adverse infant health outcomes. Allocating the costs and perceived benefits of these actions to specific endpoints would be difficult. Second, as discussed by Cannon et al., the costs of actions such as reduced consumption of alcohol and tobacco are mainly subjective rather than monetary. Full implementation of the method would require primary data collection to account for these subjective costs, as well as for mothers' perceptions of effectiveness of their actions. Thus, the AB method might be best employed in conjunction with a contingent valuation survey.

ECONOMIC VALUATION OF ENDOCRINE DISRUPTION: DEVELOPMENTAL EFFECTS REFERENCES

Cannon, M.R. Kopp and A. Krupnick. *Valuation of Developmental and Reproductive Effects: A Scoping Study.* Resources for the Future. October 1996.

Chaikind, S. and H. Corman, "The Impact of Low Birth weight on Special Education Costs." *Journal of Health Economics* 10 (3): 291-311. 1991.

Corman, H. and S. Chaikind. "The Effect of Low Birth weight on the Health, Behavior, and School Performance of School Age Children," Working Paper No. 4409. Cambridge, Massachusetts: National Bureau of Economic Research. 1993.

Erickson, J., J. Mulinare, P. McClain, T. Fitch, L. James, A. McClearn, and M. Adams. "Vietnam Veterans' Risks for Fathering Babies with Birth Defects." *Journal of the American Medical Association* 252 (7): 903-912. August 17, 1984.

Jacobson, J., S. Jacobson, P. Schwartz, G. Fein, and J. Dowler. "Prenatal Exposure to an Environmental Toxin: A Test of the Multiple Effects Model," *Developmental Psychology* 20 (4): 523-532. 1984.

Joyce, T., M. Grossman, and F. Goldman. "An Assessment of the Benefits of Air Pollution Control: The Case of Infant Health." *Journal of Urban Economics* 25: 32-51. 1989.

Lewit, E., L. Baker, H. Corman, and P. Shiono. "The Direct Cost of Low Birth Weight." *The Future of Children* 5 (1): 35-56. 1995.

Lipscomb, J. *Human Capital, Willingness-to-Pay and Cost Effectiveness Analyses of Screening for Birth Defects in North Carolina.* Durham, North Carolina: Duke University. 1986.

Lopez, A., R. Dexter and J. Reinert. "Valuation of Developmental Toxicity Outcomes." *The Environmental Professional* 17: 186-92. 1995.

Rice, D., T. Hodgson, and A. Kopstein. "The Economic Costs of Illness: A Replication and Update." *Health Care Financing Review* 7 (1): 61-80. 1985.

Schettler, T., et al., *Generations at Risk: How Environmental Toxins May Affect Reproductive Health in Massachusetts.* Greater Boston Physicians for Social Responsibility (GBPSR) and the Massachusetts Public Interest Research Group (MASSPIRG) Education Fund. 1996.

Schwartz, R. "What Price Prematurity?" *Family Planning Perspectives* 21 (4): 170-94. 1989.

Taylor, P., J. Stelma, and C. Lawrence, "The Relation of PCBs to Birth Weight and Gestational Age in the Offspring of Occupationally Exposed Mothers." *American Journal of Epidemiology* 129 (2): 395-406. 1989.

US Department of Commerce. *Statistical Abstract of the United States, 1995: The National Data Book*. Washington, D.C. 1995.

US Environmental Protection Agency. "Guidelines for Developmental Toxicity Risk Assessment." *Federal Register* 56 (234): 63798-63826. 1991.

US Environmental Protection Agency. *Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis*. Prepared for the Risk Assessment Forum, US Environmental Protection Agency, Washington, D.C. February 1997.

US National Center for Health Statistics. *Health, United States, 1995*. Hyattsville, Maryland: Public Health Service. 1996.

US National Center for Health Statistics. "Infant Deaths and Mortality Rates by Race of Mother and for 61 Selected Causes of Death and Birth weight: United States, 1991 Birth Cohort." Statistical tables obtained from an internet web site at this address: http://www.cdc.gov/nchswww/datawh/statab/unpubd/mortabs.htm

US National Center for Health Statistics, "Infant Deaths and Mortality Rates by Race of Mother, Birth weight, and Gestational Age: United States, 1991 Birth Cohort." Statistical tables obtained from an internet web site at this address: http://www.cdc.gov/nchswww/datawh/statab/unpubd/mortabs.htm

Waitzman, N., R. Scheffler, and P. Romano. *The Costs of Birth Defects: Estimates of the Value of Prevention*. Lanham, Maryland: University Press of America. 1996.

ECONOMIC VALUATION OF ENDOCRINE DISRUPTION: REPRODUCTIVE EFFECTS

Description of the Effect

Human exposure to endocrine disruptors can cause varying degrees of reproductive impairment. As noted above, fetal exposures, in particular, can lead to severe reproductive deformities. Since endocrine disruptors affect males and females in different ways, we separate the non-cancer health effects by sex.

Male Health Effects

Health effects observed in males during recent years, which may be linked to environmental endocrine disruptors, include: cryptorchidism (undescended testicles), decreased sperm count, reductions in sperm motility (forward motion of the sperm) and morphology (percentage of sperm having a normal shape), hypospadia (abnormal urethral opening), and shortened penis size (US EPA 1997). Great Britain, for example, reported a doubling of both cryptorchidism and hypospadia among males between 1970 and 1987 (Burger 1996).

Reductions in sperm count present the greatest threat to male reproductive health. Canadian doctors consider sperm counts of 30 million/mL to 100 million/mL as normal, with most men producing about three milliliters of seminal fluid per ejaculation (Nichols 1996). To determine the current status of global sperm counts, a team from Denmark analyzed 61 sperm count studies published between 1938 and 1991 (Carlsen et al. 1992). The results of their meta-analysis indicate a significant decrease in mean sperm count, from 113 million/mL in 1940 to 66 million/mL in 1990.[7] In addition to dramatic sperm count reductions, the team observed a decrease in seminal volume, from 3.40 mL to 2.75 mL per ejaculation. We present the results of the Danish meta-analysis and the results of two studies where the data support the Danish findings in Exhibit 1 (Auger et al. 1995; Irvine et al. 1996).

---

[7] Although the estimated 1990 mean value is well within the range of "normal" sperm counts, the reduction in mean values suggests that more *individuals* have sperm counts below the minimum "normal" value.

Other researchers dispute the conclusion that human sperm counts have declined worldwide. Controversy remains as to whether sperm counts have in fact fallen, and whether any decline is restricted to certain geographic locations or to the period before 1970. For example, the results of research efforts in Finland and New York suggest no historic decline in sperm count or seminal volume (US EPA 1997). In any event, a causal link between the possible reduction in sperm counts and environmental endocrine disruptors has not been established.

Exhibit 1						
GLOBAL TRENDS IN HUMAN SPERM COUNTS						
Study Location	**Sample Size (number of men)**	**Starting Year**	**Sperm Count (x10^6/mL)**	**Ending Year**	**Sperm Count (x10^6/mL)**	**Percent Change**
Denmark (meta-analysis)	14,947	1938	113	1990	66	-42%
France	1,351	1973	89	1992	60	-33%
Scotland	577	1940	120	1969	75	-38%
Source: Jensen, T., et al., "Do Environmental Estrogens Contribute to the Decline in Male Reproductive Health?," *Clinical Chemistry*, vol. 41, no. 12, pp. 1896-1901, 1995.						

Female Health Effects

Health effects observed in females during recent years, which may be linked to environmental endocrine disruptors, include: reduced fertility, irregular menstrual cycles, altered ovarian function, endometriosis (reproductive disease leading to pelvic and menstrual discomfort, and infertility), and complicated pregnancies (e.g., miscarriage) (US EPA, 1997). The US, for example, reported a 400 percent increase in ectopic pregnancies (formed in the fallopian tubes) among women between 1970 and 1987 (Burger, 1996). Aside from the work on DES, however, only a limited number of endocrine disruption studies evaluate reproductive function in females.

Existing Studies Characterizing Values

Endocrine disruption is a relatively recent health concern, thus economists have only recently begun to consider measuring society's willingness to reduce the health risks from endocrine disruption. Endocrine disruption may cause a broad range of reproductive effects, from hypospadias to ectopic pregnancies, but the most well-studied health effect is infertility.

Cannon et al., 1996

Less than one year after the publication of *Our Stolen Future,* three economists at Resources for the Future began a study to determine the value society places on avoiding the reproductive and *in utero* problems potentially caused by endocrine disruptors. The study contains valuation information on three adverse health effects associated with endocrine disruption: infertility, low birth weight, and birth defects. We discuss the valuation of infertility here, and the issues of low birth weight and birth defects in the Developmental Effects case study.

Exposure to endocrine disruptors may cause declines in male sperm count and other reproductive problems that hinder conception. These problems, generally described as infertility, lead to reductions in the probability of child-bearing primarily for couples between the ages of 15 and 44. Health scientists typically define "infertility" as the inability to conceive after twelve months of intercourse without contraceptive measures. Data on the rates of infertility and the costs of available treatment come from various sources, including the: National Center of Health Statistics' National Survey of Family Growth (conducted by the Centers for Disease Control), Society for Assisted Reproductive Technology, American Fertility Society, and the American Society for Reproductive Medicine.

Cannon et al. focus on two valuation methods, cost of illness and contingent valuation. They also discuss a revealed preference approach based on estimating the demand for fertility treatment, but conclude that this method is likely to be useful only if applied in conjunction with a stated preference survey. The cost-of-illness measure provides a lower bound on the WTP for fertility treatment because it does not address a couple's WTP to avoid the pain and suffering and inconvenience associated with reproductive health treatments.

First, Cannon et al. examined how much infertile couples typically pay for *in vitro* fertilization (IVF). Reproductive specialists use IVF to treat women with fallopian tube damage, endometriosis, male factor infertility, and couples suffering from unexplained infertility. A complete cycle of IVF treatment includes the use of fertility drugs to stimulate egg development, retrieval of eggs from the female's ovaries, fertilization of the eggs in a laboratory, and implantation of the fertilized eggs into the female's uterus. Since couples face a chance of failure at each stage of the IVF cycle, the cost per initiated cycle usually differs from the cost per completed cycle. We provide a summary of IVF cost estimates for completed cycles and successful pregnancies in Exhibit 2. Differences in the technology, procedures, and insurance coverage of the IVF treatment may limit direct international cost comparisons.

Exhibit 2		
COST ESTIMATES OF *IN VITRO* FERTILIZATION (IVF)		
Author	**Cost Estimate**	**Source of Cost Estimate**
Neumann, Gharib, and Weinstein (1994)	$8,000 per IVF cycle	Medical charges to patients as summarized in published brochures from six *in vitro* fertilization centers in the US
	$50,000 to $800,000 per delivery	
Collins et al. (1995)	$7,861 per completed IVF cycle	Survey of clinics listed in Society for Assisted Reproductive Technology database
Goldfarb et al. (1996)	$39,249 per delivery for single and twin pregnancies	Patient records maintained during 1991 and 1992 at the University Hospitals of Cleveland IVF program
	$342,788 per delivery for triple and quadruplet pregnancies	
Stern et al. (1995)	$19,267 per IVF baby	Expenditures from Hadassah University Hospital in Jerusalem
Page (1989)	$17,000 per maternity	Two Regional Health Authorities funding IVF services and a private IVF unit in the UK
Granberg et al. (1995)	$6,900 per started treatment	One private and one public IVF clinic in Sweden
	$20,300 per delivery	

Source: Cannon, M., et al., *Valuation of Developmental and Reproductive Effects: A Scoping Study*, Resources for the Future, October 1996.

Second, the authors evaluated the results of contingent valuation studies. As part of a cost-benefit analysis of IVF, Granberg et al. (1995) calculated couples' maximum willingness to pay to have a child. More than half of the survey respondents stated that they would pay at least $17,600 to have a child. In a separate study, work by Neumann and Johannesson (1994) indicated that survey respondents would be willing to pay $17,730 for IVF treatment having a ten percent chance of success.

The stated preference CV surveys suffer from significant shortcomings that may call into question the validity of the results obtained. For example, both Neumann and Johannesson (1994) and Granberg et al. (1995) used samples that were either too small or had demographic characteristics unrepresentative of the general population. In addition, Granberg et al. (1995) used an open-ended CV survey format rather than the more widely accepted dichotomous choice format. The use of an open-ended format might subject the results to anchoring bias (a condition in which the alternatives

offered influence the response). After evaluating these shortcomings, Cannon et al. (1996) concluded that, "the CV survey formats used in the studies valuing infertility treatment are not in general agreement with CV methods and protocols designed to yield reliable measures of economic value."

Discussion of Alternative Strategies

At present, there are no reliable estimates of the WTP to reduce the risks of infertility or other reproductive effects potentially linked to endocrine disruptors. Only cost-of-illness measures are available, which must be interpreted as lower bound valuations. Despite the lack of reliable empirical studies of infertility valuation, it appears that standard methods of estimating WTP, such as contingent valuation, are applicable. The main difficulty, whether WTP or COI estimates are employed, seems to lie not in valuing the adverse effects, but in linking the effects to environmental endocrine disruptors.

Until reliable WTP estimates are available and a firmer connection between endocrine disruptors and reproductive effects is found, analysts may choose to use costs of illness as lower bound estimates of the value of avoiding infertility. Stated preference methods appear to offer the best prospect for estimating WTP for improved probability of conception, while averting behavior methods may provide some insight into WTP to reduce exposure to endocrine disruptors. Finally, analysts may choose to investigate the economic theory of fertility as a framework to model both reproductive and developmental effects. Below, we discuss each of these issues and highlight the uncertainties inherent to endocrine disruption valuation.

Economic Analysis of Fertility

A well-established theoretical and empirical literature exists on the economic analysis of fertility. In this framework, the economic well-being of parents is determined by their number of children, the "quality" of each child, and family consumption of market and nonmarket goods (e.g., Becker 1993). "Quality" in its broadest sense refers to the lifetime well-being of the child, but in specific empirical analyses it may refer more narrowly to the child's health, academic success, or potential adult income.

One advantage of this model for valuation of endocrine disruptors is that it provides a unified framework for addressing both infertility and developmental effects. Infertility hinders a couple's ability to produce their desired number of children. Developmental effects harm the child's "quality," interpreted as health, academic success, or future potential.

A second advantage of the model is that it focuses on what parents presumably want: some number of children who are healthy, successful, and happy. This focus highlights the difficulty of using the WTP for fertility treatment to monetize the loss in well-being from infertility. Even if treatment is successful in producing a child, the required expense, time, and nonfinancial burdens may

cause an infertile couple to reduce the number of children they plan to have. The couple's WTP for one treatment may measure their valuation for the birth of one child, but not the full loss from infertility, which includes the WTP for the birth of each child they would choose to have if fertile.

In addition, infertile couples can consider many options, including a variety of treatments, adoption, and remaining childless. Couples select one or more options based on their preferences and circumstances; it seems implausible that those enrolled in any particular treatment represent a random sample of infertile couples. Focusing on the costs or WTP for one type of treatment may require consideration of how couples select treatment.

Cost of Illness

One cycle of IVF in the US will cost couples approximately $8,000 (Exhibit 2). Given an average success rate per cycle, economists can apply this cost estimate to the affected population of infertile couples to determine the benefits of decreased exposure to endocrine disruptors. The IVF cost estimate, however, does not include the "pain and suffering" (e.g., emotional trauma) experienced by the couples undergoing this treatment regimen.

In addition to measuring the costs of IVF, economists can calculate the costs of prescription drugs used to induce ovulation. Fertility survey analysis by Wilcox and Mosher (1993) indicates that while only two percent of women with reproductive difficulties choose IVF treatment, twenty percent of these women use fertility drugs. The dollar costs of IVF and drug treatments comprise the lower bound value couples place on successful child-bearing. Before knowing the costs of available treatment, a couple's WTP for successful child-bearing typically comprises the upper bound value.

Contingent Valuation

Contingent valuation surveys can measure the value placed on current fertility or the value placed on future fertility. Economists represent current fertility by the WTP of potential parents for an increased probability of a successful pregnancy, and future fertility by the WTP of parents for normal reproductive ability in their children (Cannon et al. 1996). Couples can express a WTP from either an *ex ante* (e.g., reduction in exposure to endocrine disruptors prior to knowing whether they are infertile) or an *ex post* (e.g., increase in probability of conception given that they are infertile) perspective.

Mosher and Pratt (1990) determined the rate of infertility for US couples between the ages of 15 and 44 as eight percent, or about one couple in twelve. This infertility statistic implies that in the presence of endocrine disruptors, couples have a 92 percent probability of successful conception. Current research efforts on endocrine disruption indicate that this probability may decrease in the future as endocrine disruptors become more ubiquitous in the environment. By contrast, an infertile couple has a near-zero probability of conception. CV surveys of infertile couples suggest a mean

WTP of $18,000 for a ten percent chance of conception (Neumann and Johannesson 1994). In addition, the survey results predict a proportionally increasing relationship between a couple's WTP and the probability of conception; though substitution effects (e.g., from adoption) may influence a couple's maximum WTP.

Ideally, health scientists could describe a dose-response function illustrating the relationship between increasing exposures to endocrine disruptors and the probability of becoming infertile. From a valuation standpoint, economists could then use the dose-response function to elicit *ex ante* (e.g., reduced exposure) and *ex post* (e.g., increased probability of conception) WTP values. This valuation process may become feasible in the future as health scientists continue to establish the dose-response function of endocrine disruptors in humans. The lack of CV studies specifically targeting endocrine disruption precludes the use of benefits transfer.

Averting Behavior

Given the relatively recent publicity of endocrine disruption as a health concern, averting behavior in the general population may not exist at observable levels. One exception that economists may explore in future valuation work concerns a consumer's choice to purchase organic produce. Among the 45 endocrine disruptors listed in Exhibit 2 in the Introduction section, 35 chemicals are pesticides. Consumers purchasing organic produce are typically well-educated on the adverse health effects associated with pesticides found on conventional produce. Since these consumers know that consuming organic produce may reduce their risks of developing certain negative health effects, economists can measure the incremental difference between the purchase price of organic and conventional produce. This difference would represent the WTP to reduce the risks of any adverse effects consumers attribute to ordinary produce.[8]

Important Caveats and Uncertainties

Two major uncertainties could potentially affect each of the valuation techniques discussed above:

! First, health scientists do not have a well-established dose-response function for endocrine disruptors. This lack of a solid relationship between varying contaminant concentrations and adverse health effects makes measuring the exposure risks difficult. Without defined exposure risks, valuation estimates derived from either CV surveys or averting behavior observations may include high degrees of uncertainty.

---

[8] In some cases, such as bacterial contamination, organic produce may not be "healthier" than conventional produce.

! Second, the success rates of different reproductive treatments exhibit considerable variation. Substantial treatment drop-out rates after each failed IVF cycle, treatment-independent pregnancies, and combination drug therapies can complicate success rate estimations. In addition, success rates may vary depending on the cause of infertility, with high rates for tubal infertility and low rates for infertility caused by male factors (Schenker, 1993). Without predictable success rates, valuation estimates derived from either CV surveys or cost of illness calculations may include high degrees of uncertainty.

ECONOMIC VALUATION OF ENDOCRINE DISRUPTION: REPRODUCTIVE EFFECTS REFERENCES

Auger, J., J.M. Kunstmann, F. Czyglik, and P. Jouannet. "Decline in Semen Quality Among Fertile Men in Paris During the Past 20 Years," *The New England Journal of Medicine* 332 (5): 281-285. February 2, 1995.

Becker, G. *A Treatise on the Family*. Enlarged Edition. Cambridge, MA: Harvard University Press. 1993.

Burger, A. "Sex Offenders." *E* 7 (2): 44. March/April 1996.

Cannon, M., R. Kopp, and A. Krupnick. *Valuation of Developmental and Reproductive Effects: A Scoping Study*. Resources for the Future. October 1996.

Carlsen, E., A. Giwercman, N. Keiding, and N. Skakkebaek. "Evidence for Decreasing Quality of Semen During the Past 50 Years." *British Medial Journal* 305 (6854): 609. September 12, 1992.

Granberg, M., M. Wikland, L. Nilsson, and L. Hamberger. "Couples' Willingness to Pay for IVF/ET." *Acta Obstetricia et Gynecologica Scandinavica* 74: 199-202. 1995.

Irvine, S., E. Cawood, D. Richardson, E. MacDonald, and J. Aitken. "Evidence of Deteriorating Semen Quality in the United Kingdom: Birth Cohort Study in 577 Men in Scotland over 11 Years." *British Medical Journal* 312 (7029): 467. February 24, 1996.

Jensen, T., J. Toppari, N. Keiding, and N. Skakkebaek. "Do Environmental Estrogens Contribute to the Decline in Male Reproductive Health?" *Clinical Chemistry* 41 (12): 1896-1901. 1995.

Mosher, W. and W. Pratt. "Fecundity and Infertility in the United States, 1965-1988." *Advance Data* Number 192. National Center for Health Statistics, US Department of Health and Human Services, Public Health Service. December 4, 1990.

Neumann, P., and M. Johannesson. "Willingness to Pay for In Vitro Fertilization: A Pilot Test Using Contingent Valuation." *Medical Care* 32 (7): 686-699. 1994.

Nichols, M. "The Sperm Scare." *Maclean's* 109 (14): 50. April 1, 1996.

Pinchbeck, D. "Downward Motility: When it Comes to Sperm, You're Half the Man Your Grandfather Was." *Esquire* 125 (1): 78. January 1996.

Schenker, J. "Medically Assisted Conception: The State of the Art in Clinical Practice." in *Tough Choices* edited by P. Stephenson and M. Wagner. Philadelphia: Temple University Press. 1993.

US Environmental Protection Agency. *Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis*. Prepared for the Risk Assessment Forum, US Environmental Protection Agency, Washington, DC. February 1997.

Wilcox, L. and W. Mosher. "Use of Infertility Services in the United States." *Obstetrics and Gynecology* 82 (1): 122-127. 1993.

ECONOMIC VALUATION OF CHILDHOOD ASTHMA

Description of the Effect

Asthma is the most common chronic disease of childhood and is the leading cause of school and work absences (US EPA 1996b). Although children constitute only 25 percent of the general population, they comprise 40 percent of all asthma cases (US EPA 1996e). Prevalence and severity of childhood asthma appear to be increasing (US EPA 1996b, Bates 1996, Halfon and Newacheck 1993), with higher rates of prevalence, morbidity and mortality among African-American and lower income children (Malveaux and Fletcher-Vincent 1996). For example, Halfon and Newachek (1993) reported that prevalence of childhood asthma in 1988 was 14 percent higher in households below the federal poverty line than in households above it, and 20 percent higher for blacks than for whites.

In addition to differences across racial and income groups, young boys are nearly twice as likely to develop asthma as girls, but this difference usually disappears in older age (ANCAAI 1997, CLA 1997). In a recent report published by the American Lung Association, 85 percent of women and 72 of men still suffered from asthma that developed when they were children (ALA 1996a). Unborn fetuses may also be at risk because uncontrolled asthma in pregnant mothers can lead to serious fetal complications (CLA 1997).

Effects and Symptoms Associated with Childhood Asthma

Asthma is an obstructive disease of the respiratory system, which is comprised of the trachea (windpipe), lungs, bronchi and bronchioles (airtubes/airways that connect the nose and mouth with the lungs), and alveoli (air sacs) (Borowitz 1996). People with asthma have extra sensitive or hyperresponsive airways (Borowitz 1996a, Boushey and Fahy 1996).

Asthma episodes occur when irritation of airways obstructs the flow of air. The main events which occur during an asthma episode are as follows.

1. Airway inflammation: the lining of airway walls swells, pushing inward.

2. Bronchoconstriction: involuntary muscles surrounding the airways contract, narrowing the airways.

3. Excess mucous production causes further blockage of airways (CLA 1997, SRCMC 1996).

Each of these factors obstructs the flow of air, and each is reversible (e.g. with medication). Figure 1 illustrates how airway inflammation and bronchoconstriction restrict the airway opening.

Figure 1
AIRWAY FUNCTION EFFECTS ASSOCIATED WITH ASTHMA

Muscle

Airway
Lining

Airway

normal airway

Airway
Lining
Swells

Airway
Shrinks

inflammation

Muscle
Tightens / Spasms

Airway
Shrinks

bronchoconstriction
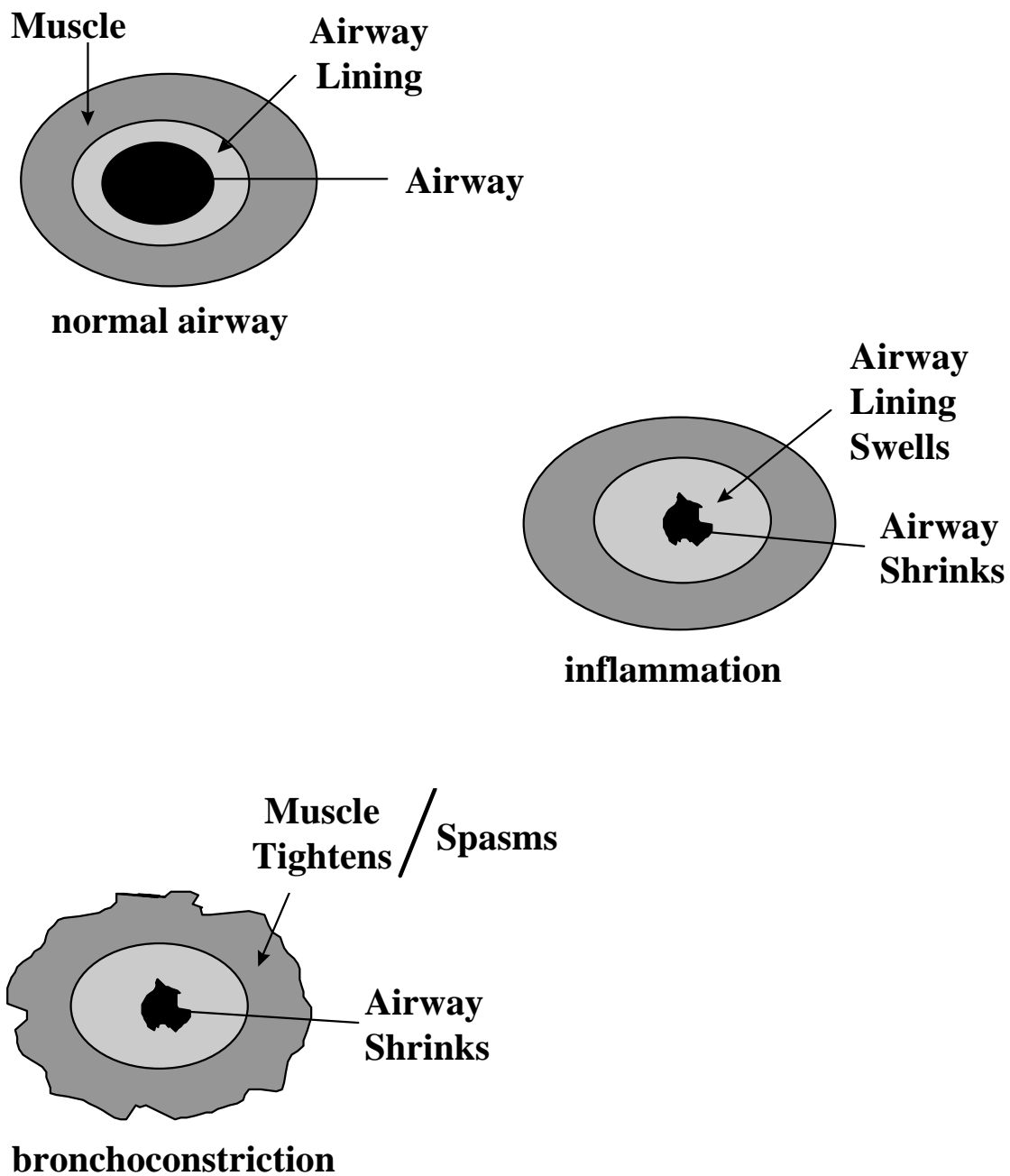
Source: Canadian Lung Association, 1997.

The wheezing sound typical of asthma results from air being forced through narrowed airways and vibrating the mucous. Other symptoms include coughing, shortness of breath, and chest tightness (CLA 1997). In an effort to breathe during an asthma attack, an individual may use accessory respiratory muscles, causing the neck muscles to contract and bulge and the nostrils to flare. Children may show flushing or perspiration, and during severe episodes their lips and nail beds may exhibit a bluish tint due to a lack of oxygen (CLA 1997). In addition, pregnant women with uncontrolled asthma may deliver babies who are premature and have low birth weight (CLA 1997).

Treatments for Childhood Asthma

An early asthma diagnosis is important because starting asthma treatment early in life may increase the chances that a child will outgrow the disease (i.e., become asymptomatic) in adulthood (Panhuysen et al. 1997). Doctors diagnose asthma by examining a child's lungs and nasal passages, through chest x-rays, spirometry, and allergy tests, and through tests of blood, sputum (mucus/saliva), and exercise capacity (CLA 1997). Children are more likely to develop asthma if they have a family history of asthma, allergies, hay fever, or eczema.

Asthma is a controllable disease (Barnes et al. 1996). Key components of control include reducing exposure to asthma inducers/triggers, daily monitoring of peak expiratory flow, and medication (SRCMC 1996). Children suffering from asthma depend on anti-inflammatory medications and bronchodilators. Anti-inflammatory medications, taken regularly, prevent asthma by preventing inflammation of the airways. Bronchodilators are taken as needed to relieve asthma symptoms quickly by relaxing the muscles around the airways, but do not reduce inflammation. Some of these medications have side-effects, but these effects are often less dangerous than uncontrolled asthma during childhood and fetal development (CLA 1997).

Asthma is often associated with long-term psychological and financial burdens due to increases in medicine usage and hospitalization (Carr et al. 1992). In addition to medical expenses and lost work and school days, asthma patients appear to suffer reduced quality of life: 95 percent of patients have impaired quality of life indexes relative other individuals of similar age (Barnes et al. 1996). Respondents to the Rowe and Chestnut (1985) survey ranked discomfort, emotional distress, and lost enjoyment of normal activities as more important effects of asthma than medical expenses and foregone income.

Types of Exposures that Cause the Effect

Asthma, once thought of as a "simple" hypersensitive reaction, is now known to be a complex condition with multiple causes and contributing factors (ALA 1996a). Although the stimuli that provoke asthma are commonly grouped into one category called "triggers", it is useful to distinguish between two types of stimuli, known as inducers and triggers. Inducers, such as allergens and respiratory viral infections, directly cause asthma because they lead to both airway inflammation and airway hyperresponsiveness. Symptoms resulting from exposure to inducers are usually delayed, less easily reversible, and last longer than those caused by triggers.   On the other hand, triggers, such as particulate matter, do not directly cause asthma because they do not inflame airways.   If inflammation already exists, airways react more quickly to triggers, resulting in bronchoconstriction. Symptoms and bronchoconstriction caused by triggers are generally immediate, short-lived and rapidly reversible (CLA 1997). Exhibit 1 provides some common examples of inducers and triggers.

Exhibit 1	
TRIGGERS AND INDUCERS THAT PROVOKE ASTHMA	
Inducers that cause asthma	**Triggers that aggravate asthma**
allergens:	tobacco smoke
- dust mites	criteria air pollutants including particulate matter, sulfur dioxide, ozone and nitrogen oxides
- cockroaches	
- animal dander, which are the dry scales shed by pets	sudden changes in weather (from mild to cold)
- pollen	exercise (mouth breathing)
- fungal spores	inhaled irritants
- molds	strong fumes
- foods, such as milk, eggs, and soy and wheat products	emotional upsets
respiratory viral infections	
Sources: CLA 1997, SRCMC 1996, Bates 1996, Etzel 1996, Koren 1996, US EPA 1997c.	

Inhaled allergens represent the most important inducer of asthma since 75-80% of young asthmatics are allergic (CLA 1997). The most common allergens are dust mites (tiny microscopic spiders found in house dust), cockroaches, pollen, molds, fungal spores, and animal dander (CLA 1997, Etzel 1996, SRCMC 1996).

Environmental tobacco smoke (ETS) is an important asthma trigger (Etzel 1996). ETS exposure increases the number of asthma episodes and severity of symptoms for 200,000 to 1 million children each year, and may cause non-asthmatic children to develop asthma (Aligne et al. 1997, US EPA and US CPSC 1995, US EPA 1992). Other indoor air pollutants affecting asthma include nitrogen dioxides and formaldehyde.

Ambient air pollutants also exacerbate asthma in some individuals, and over 25 percent of children in the U.S. live in areas that do not meet national air quality standards. Moreover, several factors associated with higher asthma incidence, such as low income and central city residence, also may be associated with greater exposure to air pollution (Mott 1996). In addition, some researchers suspect a link between air toxics and childhood asthma (U.S. EPA 1996b, Leikauf et al. 1995). U.S. EPA (2000b) provides an extensive list of toxic chemicals which may be related to asthma.

Existing Studies that Characterize Values

Despite the prevalence of asthma, there have been relatively few studies quantifying benefits of reduced incidence, or of reduced morbidity and mortality in the prevalent population. A few cost-of-illness studies have been conducted for the US, as well as several for other countries, and there has been at least one contingent valuation effort.

Cost of Asthma

Researchers have estimated costs of asthma for several countries. Exhibit 2 summarizes results from studies of direct and indirect costs of asthma for the prevalent populations of five developed countries; additional studies which are older or less comprehensive are reviewed in Barnes et al. (1996). Costs have been converted to US dollars using exchange rates. Costs per asthmatic include costs that may be shifted to others through insurance or other policies, while per capita costs represent the average financial burden of asthma on all members of society.

Exhibit 2					
TOTAL COSTS OF ASTHMA IN PREVALENT POPULATIONS OF FIVE COUNTRIES, 1990$					
Country	**Year**	**Total Costs (Millions)**	**Per Capita Total Cost**	**Asthma Prevalence**	**Per Asthmatic Total Cost**
Australia	1989	$ 209	$39.40	6%	$ 769
Canada	1990	$ 432	$17.06	Not reported	Not reported
Sweden	1975	$ 348	$40.50	3%	$1315
U.K.	1988	$1790	$31.26	3%	$1043
U.S.	1990	$6400	$25.70	4%	$ 640
Sources: Barnes et al. (1996), Krahn et al. (1996), Sullivan and Weiss (1996), Weiss et al. (1992).					

Variations in costs per asthmatic shown in Exhibit 2 may reflect differences in methods and assumptions employed in different studies, as well as real differences in costs. Nonetheless, several common patterns emerge from these and other studies of the costs of asthma.

1. Asthma imposes significant financial costs on society, a result confirmed by other studies not listed in Exhibit 2. For example, MacKinnon et al. (1996) found that asthmatic members of an HMO incurred 83 percent higher health care costs than nonasthmatic members.

2. Direct costs of asthma are somewhat larger than indirect costs, with direct costs typically contributing between 50 and 60 percent of total costs.

3. The largest components of direct costs are for drugs and inpatient care. Inpatient, as well as emergency room, services are mainly attributable to moderate and severe cases of asthma, to children, and to lower income groups.

4. The largest components of indirect costs are morbidity costs of adult asthmatics and foregone production of parents of asthmatic children who miss school. Mortality costs are low, because asthma is rarely the cause of death.

A large share of the costs of asthma -- including most of the indirect costs as well as direct costs of hospitalizations and emergency room visits -- has been attributed to patients' failure to manage the illness properly (Weiss et al. 1992, Barnes et al. 1996). Patient compliance with therapy, particularly prophylactic therapy, appears poor. For example, perhaps as few as 15 percent of asthmatics take drugs as directed (Barnes et al. 1996). Possible explanations include the time and money costs of asthma management, and inadequate information.

Controlling asthma may consume a significant fraction of household income, particularly in poor households (Marion et al. 1985), and the greater morbidity of asthmatic children living in low income households has been attributed to the poor asthma management skills applied (Malveaux and Fletcher-Vincent 1996). Asthmatic children living below the poverty line, for example, had 40 percent fewer doctor*s visits, but 40 percent more hospitalizations, than asthmatic children above the poverty line (Halfon and Newachek 1993). Education of asthma patients has been shown to reduce hospitalizations and emergency room visits, school and work loss days, and symptoms (Krahn et al. 1994), and additional education efforts may be cost-effective. For example, the cost of one asthma-related hospitalization is roughly equivalent to the cost of three years* worth of inhaled steroids (Barnes et al. 1996).

Weiss et al. (1992)

The most comprehensive COI estimate for asthma-related illness in the U.S. is the Weiss et al. (1992) study listed in Exhibit 2. Weiss et al. estimate asthma costs in the prevalent population of 1985, and project costs forward to 1990. Data were obtained from population surveys of the National Center for Health Statistics and other sources; the 1985 data were supplemented with additional information for the five-year period 1983-87. Where permitted by available data, Weiss et al. presented separate cost estimates for children and adults.

Direct cost estimates exclude costs of diagnosis, patient education, and home equipment. Indirect cost estimates include foregone earnings and foregone household production, evaluated at the cost of hiring out household work. Indirect costs were computed for morbidity of adult asthmatics, for the lost production of adults caring for asthmatic children who missed school, and for the premature mortality of the 3380 cases in 1985 listing asthma as the cause of death. Mortality losses were discounted at four percent; the potential future loss to children missing school was not estimated.

The total cost of $6.4 billion reported in Exhibit 2 represents one percent of the cost of illness in the United States, and about nine percent of the cost of respiratory diseases. Direct costs amount to 53 percent of the total, while about one-third of total costs were attributed to children.

The Weiss et al. study provides the most comprehensive measure of the costs of asthma in the U.S. The separate analysis of children's costs, the allowance for lost production by nonasthmatic parents of asthmatic children, and the prevalence-based methodology make the study particularly useful for quantifying benefits of policies which reduce morbidity and mortality among asthmatic children.

U.S. EPA (2000b)

U.S. EPA (2000b) computed the lifetime direct costs of incident cases of asthma in 1999, but did not estimate indirect costs.   EPA aggregates costs for the following:

- **!**   office visits,
- **!**   drug therapy,
- **!**   emergency room care, and
- **!**   hospitalization.

EPA presented estimates of lifetime direct costs for asthma by patient category. Categories investigated include "average patients" and hypothetical "high-use patients." Costs were estimated using Medicare data from the Health Care Financing Administration (the largest national payer of health care services).   EPA presented results discounted at zero, three, five, and seven percent. EPA results based on zero and three percent discount rates are shown in Exhibit 3. Recent EPA guidance suggests that a discount rate of two to three percent is appropriate for regulatory analyses (see U.S .EPA (2000a).

Direct costs rise dramatically with severity. This is observable through comparison of direct costs associated with average versus high-use asthma patients; EPA estimates that the lifetime direct medical costs for asthma are roughly $49,000 for the average patient and $220,000 for the high-use patient (undiscounted 1999$) .

Exhibit 3 LIFETIME DIRECT COSTS FOR ASTHMA, 1999$		
Patient Category	**Undiscounted**	**3%**
Average Patient	$49,099	$22,447
High-use Patients	$220,026	$101,459
High-use Patients After Intervention	$109,281	$50,041
Source: US EPA (2000b)		

EPA also presented their estimates of annual direct costs, which can be compared to the Weiss et al. (1992) annual direct cost estimates. The total annual direct costs for an average patient in the EPA study are presented by age: $761 for ages four to five, $905 for ages six to 17, and $889 for ages 18 to 75. The Weiss et al. direct cost estimate, in contrast, is $509 per asthmatic per year after converting to 1999 dollars using the medical care component of the Consumer Price Index. Thus, the EPA estimate exceeds the Weiss et al. estimate by a factor of between 1.5 and 1.8.

Part of the gap between the two direct cost estimates can be explained by EPA inclusion of cost categories excluded from Weiss et al., such as diagnosis (the average total cost for diagnosis is estimated to be $617.87 per case). The remaining difference may be attributable to methodological differences between the prevalence-based study of Weiss et al. and the incidence-based study of EPA.

The EPA study is useful in analyzing direct costs separately by severity. Although the estimates are less comprehensive than measures including indirect costs, the incidence-based methodology is suitable for quantifying benefits of policies that reduce incidence or delay onset of asthma.

Contingent Valuation of Asthma Morbidity

Rowe and Chestnut (1985, 1986)

Rowe and Chestnut (1985, 1986) applied contingent valuation to estimate WTP to reduce asthma-related illness. Eighty-two subjects, including 64 asthmatic adults and 18 parents of asthmatic children, were recruited from 90 subjects in an ongoing study by the UCLA Schools of Medicine and Public Health. All subjects lived in Glendora, California (a community east of Los Angeles), and data were collected during the fall of 1983. Three survey instruments were used: the UCLA daily diary on asthma severity, respiratory status and medication use, a daily diary of perceptions about asthma and defensive behavior, and a general questionnaire on activities and WTP.

Respondents to the general questionnaire were asked to choose a value from a payment card that best represented the maximum tax increase they would be willing to pay for a 50 percent reduction in the number of "bad asthma days." After deletion of protest and inconsistent bids, WTP to avoid a single bad asthma day was estimated from 65 observations using a WTP regression model including variables for the total number of days reduced, severity, income, and other variables. Separate estimates for reductions in children's asthma were not presented. Results are summarized in Exhibit 4.

Exhibit 4		
WILLINGNESS TO PAY TO AVOID ONE "BAD ASTHMA DAY		
Severity	**1983 Dollars**	**1990 Dollars**
No symptoms	$ 9	$ 11.81
Very mild symptoms	$19	$ 24.93
Mild symptoms	$30	$ 39.37
Moderate symptoms	$41	$ 53.80
Source: Rowe and Chestnut (1985, 1986).		

This study provides the most comprehensive information on WTP for reductions in asthma morbidity. Its results were used by EPA in the cost-benefit analysis of the Clean Air Act to value acute asthma (U.S. EPA 1997a). Specifically, EPA computed a central estimate of $32 (1990 dollars) per day of acute asthma avoided, based on the arithmetic average of the WTP figures presented for the four severity levels in Exhibit 4.

Other Valuation Information

Additional valuation information is available for endpoints which may be related to asthma but which are suffered by other populations as well. For example, U.S. EPA (1997a) reports unit valuations for respiratory symptoms, including shortness of breath and wheezing, respiratory hospital dmissions, and incidence of chronic obstructive pulmonary disease (defined as ICD codes 490-496 and thus including asthma, code 493).

Discussion of Alternatives for Valuation Strategy

Three major obstacles complicate valuation of childhood asthma.

1. Limited information is available on the value of reducing asthma morbidity in children. There have been no estimates of WTP to reduce childhood asthma separately from adult asthma. Cost of illness studies have analyzed children's and adults' costs separately, but provide less than comprehensive estimates of value. For example, there is no generally accepted methodology for quantifying the economic loss to children from missed school, and Weiss et al. evaluate lost school days based only on the foregone production of adult caregivers. EPA also estimates costs for children, but with direct costs based on Medicare charges, and no indirect cost estimate at all. In addition, the cost

of illness is not a comprehensive measure of value and does not account for asthma symptoms which do not lead to medical costs or foregone production. The lack of a comprehensive, separate value for childhood asthma is important because it need not be true that reduced asthma in children and adults generates equivalent private or social benefits.

2. Relatively limited information is available on dose-response relationships between environmental contaminants and childhood asthma. Although the case of childhood asthma and criteria air pollutants is something of an exception, in general most analyses of environmental health effects focus on adult subjects.

3. The link between endpoints of dose-response functions and asthma endpoints monetized often is weak (see the general discussion in Chapter 5). Rowe and Chestnut estimate values for "bad asthma days," as subjectively defined by each respondent, while dose-response estimates often focus on lung function or symptoms. A similar problem affects cost of illness studies to a lesser degree. For example, the Weiss et al. estimates of annual costs must be converted to an estimate of the cost savings from environmental improvement. This may require several dose-response functions linking a contaminant to separate sources of costs, such as hospitalizations, emergency room visits, and work loss.

Valuing Reduced Incidence

A key step in valuing childhood asthma is distinguishing between policies which may reduce incidence, or delay onset, and policies which reduce morbidity or mortality among asthmatic children. At present the causes of asthma have not been delineated clearly. Causal links between air pollution and morbidity among asthmatics are more solidly established than any links between environmental contaminants and incidence of childhood asthma. There is correspondingly little information relevant to valuation of reduced incidence or delayed onset of asthma.

The incidence-based cost of illness study conducted by U.S. EPA (2000b) is suitable for monetization of reduced incidence or delayed onset of asthma, in adults or children. The direct cost estimates presented by EPA must be supplemented with measures of indirect costs. As a preliminary estimate of the order of magnitude of indirect costs, the prevalence-based studies reviewed estimate that indirect costs are 40 to 50 percent of total costs (47% in the Weiss et al. study for the U.S.).

If a clearer connection between incidence and environmental contamination can be established, then analysts may choose to estimate WTP for reduced risk of childhood asthma in the general population. Specifically, analysts may use stated preference methods to estimate parents' WTP for reducing the risk that their children would contract asthma. The risk-risk and risk-dollar tradeoff methods used by Viscusi et al. (1991) and Krupnick and Cropper (1992) for chronic bronchitis would appear to be applicable for valuation of asthma. The study might be designed to insure adequate representation of demographic groups who may be at high risk, including low-income, minority residents of central cities.

Valuing Reduced Morbidity in the Prevalent Population

In the case of asthma morbidity in the prevalent population, the link to environmental contaminants, especially criteria air pollutants, is relatively firmly established. To value reductions in morbidity among asthmatic children, analysts may apply a joint stated preference/revealed preference (averting behavior) approach.

The averting behavior approach is promising because there is clear evidence that many asthmatics monitor their disease closely and take preventive action as appropriate (Pope et al. 1991, Rowe and Chestnut 1985). At least some preventive actions, such as increased use of medication, would provide few benefits apart from control of asthma, thus avoiding the joint production problem common in averting behavior studies. The difficulties of estimating WTP using averting behavior alone have been discussed in Chapter 3 and other case studies, however, and the method is best employed as a supplement to contingent valuation of childhood asthma. Contingent valuation estimates, in turn, are more easily defended if tied to actual behavior.

Valuation efforts might be directed toward determining the WTP of parents for reductions in asthma-related morbidity of children. An economic model of family decision-making, similar to the models presented for valuation of endocrine disruption, could provide a useful framework for the analysis. Finally, in view of the environmental justice issues raised by the disproportionate impact of asthma on disadvantaged children, the research could include a large and diverse enough sample to analyze benefits separately for different demographic groups.

As an interim valuation strategy, an analyst might apply the Rowe and Chestnut CV estimates and the Weiss et al. COI estimates for valuation of morbidity in asthmatic children. Rowe and Chestnut provide the only comprehensive WTP estimates, and while not focused exclusively on children, their sample did include some (parents of) asthmatic children. The Weiss et al. estimates can be applied to value additional endpoints like emergency room visits and hospitalizations.

ECONOMIC VALUATION OF CHILDHOOD ASTHMA REFERENCES

Aligne, C., J. Stoddard. "Tobacco and Children: An Economic Evaluation of the Medical Effects of Parental Smoking." *American Journal of Diseases of Children* 151:648-653. 1997.

American College of Allergy, Asthma & Immunology (ANCAAI). *Asthma-What Is It and Who Gets It?* Document obtained from an internet web page at this address: http://www.injersey.com/Living/Health/Asthma/asthma.html. Web page visited September 1997.

American Lung Association (ALA). *Childhood Asthma: A Matter of Control.* Pamphlet. 1997a.

American Lung Association (ALA). *Fact Sheet: Particulate Matter Air Pollution.* Document obtained from an internet web page at this address: http://www.lungusa.org/noframes/global/news/report/viron/virmaterfac.html. 1997.

American Lung Association (ALA). *Study Indicates Food Allergies May Be a Factor in Some Children's Asthma.* Document obtained from an internet web page at this address: http://www.lungusa.org/noframes/global/news/medical/medallergies.html. February 1996.

American Lung Association (ALA). *Study Links Dust Mite Allergy to Asthma Severity in Children.* Document obtained from an internet web page at this address: http://www.lungusa.org/noframes/global/news/medical/four.htm. 1995

Barnes, P.J., B. Honsson, and J.B. Klim. "The Costs of Asthma." *European Respiratory Journal* 9: 636-642. 1996.

Bates, D. V. "Observations on Asthma." *Environmental Health Perspectives* 103: 243-247. September 1995b

Borowitz, S.M. University of Virginia Medical School. *What is Asthma*? Document obtained from an internet web page at this address: http://galen.med.virginia.edu/~smb4v/tutorials/asthma/whatis.htm. September 1996.

Borowitz, S.M. University of Virginia Medical School. *Why Does Asthma Occur and What Happens During an Asthma Attack?* Document obtained from an internet web page at this address: http://galen.med.virginia.edu/~smb4v/tutorials/asthma/why does.htm. September 1996.

Boushey, H.A. and J.V. Fahy. "Basic Mechanisms of Asthma." *Environmental Health Perspectives* 103 (Suppl 6): 229-233. September 1995.

Canadian Lung Association (CLA). *Asthma*. Adapted from *Asthma-1995* by Dr. Donald Cockcroft. Document obtained from web pages linked to the CLA's Asthma homepage at this address: http://www.lung.ca/asthma/asthma1.html. Web page visited September 1997.

Carr, W., L. Zeitel, and K. Weiss. "Variations in Asthma Hospitalizations and Death in New York City." *American Journal of Public Health* 82(1): 59-65. January 1992.

Etzel, R.A. "Indoor Air Pollution and Childhood Asthma: Effective Environmental Interventions." *Environmental Health Perspectives* 103(Suppl 6): 55-58. September 1995.

Gergen, P. and K. Weiss. "Changing Patterns of Asthma Hospitalization Among Children: 1979 to 1987." *Journal of the American Medical Association* 264: 1688-1682. October 1990.

Halfon, N. and P.W. Newachek. "Childhood Asthma and Poverty: Differential Impacts and Utilization of Health Services." *Pediatrics* 91(1): 56-61. January 1993.

Koren, H.S. "Associations between Criteria Air Pollutants and Asthma." *Environmental Health Perspectives* 103: 235-242. September 1995.

Krahn, M. "Issues in the Cost-Effectiveness of Asthma Education," *Chest* 106(4): 264S-269S (October Supplement). 1994.

Krahn, M., C. Berka, P. Langlois and A.S. Detsky. "Direct and Indirect Costs of Asthma in Canada, 1990." *Canadian Medical Association Journal* 154 (6): 821-830. March 15, 1996.

Krupnick, A. and M. Cropper. *Valuing Chronic Morbidity Damages: Medical Costs, Labor Market Effects, and Individual Valuations.* Report to the Office Policy, Planning, and Evaluation, US Environmental Protection Agency. Resources for the Future, Washington, DC. February 1989.

Leikauf, G.D., S. Kline, R.E. Albert, C.S. Baxter, D.I. Bernstein, J. Bernstein, and C. R.Buncher. "Evaluation of a Possible Association of Urban Air Toxics and Asthma." *Environmental Health Perspectives* 103 (Suppl 6): 253-271. September 1995.

Malveaux, F.J. and S.A. Fletcher-Vincent. "Environmental Risk Factors of Childhood Asthma in Urban Centers." *Environmental Health Perspectives* 103 (Suppl 6): 59-62. September 1995.

Marion, R.J., T.L. Creer, R.V.C. Reynolds. "Direct and Indirect Costs Associated with Management of Childhood Asthma." *Annals of Allergy* 54: 31-34. January 1985.

Mott, L. 1995. "The Disproportionate Impact of Environmental Health Threats on Children of Color." *Environmental Health Perspectives* 103: 33-35. September 1995.

Panhuysen, C. et al. "Adult Patient May Outgrow Their Asthma." *American Journal of Respiratory and Critical Care Medicine* 155: 1267-1272. 1997. Document published by the American Lung Association (ALA) and obtained from an ALA internet web page at this address: http://www.lungusa.org/noframes/global/news/medical/medast.html. April 17, 1997.

Pope, C.A. III, D.W. Dockery, J.D. Spengler and M.E. Raizenne. "Respiratory Health and PM_{10} Pollution: A Daily Time Series Analysis." *American Review of Respiratory Disease* 144: 668-674. 1991.

Rowe, R.D. and L.M. Chestnut. *Addendum to Oxidants and Asthmatics in Los Angeles: A Benefits Analysis*. 1986.

Rowe, R.D. and L.M. Chestnut. *Oxidants and Asthmatics in Los Angeles: A Benefits Analysis*. 1985.

Scottish Rite Children's Medical Center (SRCMC). Asthma Education Center. 1996.

Strand, V., S. Rak, M. Svartengren, G. Bylin. "Nitrogen Dioxide Exposure Enhances Asthmatic Reaction to Inhaled Allergen in Subjects with Asthma." *American Journal of Respiratory and Critical Care Medicine* 155: 881-887. 1997.

Sullivan, S.D. and Weiss, K.B. "Assessing Cost-effectiveness in Asthma Care: Building an Economic Model to Study the Impact of Alternative Intervention Strategies." *Allergy* 48: 146-152. 1993.

Thurston et al., G.D. "Summertime Haze Air Pollution and Children with Asthma." *American Journal of Respiratory and Critical Care Medicine* 155: 654-660. 1997.

Timonen, K.L. and J. Pekkanen. "Air Pollution and Respiratory Health Among Children with Asthmatic or Cough Symptoms." *American Journal of Respiratory and Critical Care Medicine* 156: 546-552. 1997.

US Environmental Protection Agency (US EPA). *Air Quality Criteria for Ozone and Related Photochemical Oxidants*. Office of Research and Development. July 1996c.

US Environmental Protection Agency (US EPA). *Air Quality Criteria for Particulate Matter*. Office of Research and Development. April 1996d.

US Environmental Protection Agency (US EPA). *The Benefits and Costs of the Clean Air Act, 1970 to 1990.* Draft Report to Congress. April 1997c.

US Environmental Protection Agency. *Guidelines for Preparing Economic Analysis.* Final Draft. 2000a.

US Environmental Protection Agency (U.S. EPA). *Cost of Illness Handbook: Review Copy,* Prepared for Office of Pollution Prevention and Toxics by Abt Associates. Prepared by Abt Associates. 2000b.

US Environmental Protection Agency (US EPA). *Fact Sheet: EPA's Revised Ozone Standard.* Document obtained through an internet web site at this address: http://ttnwww.rtpnc. epa.gov/naaqsfin/o3.htm. July 17, 1997b.

US Environmental Protection Agency (US EPA). *Fact Sheet: EPA's Revised Particulate Matter Standards.* Document obtained through an internet web site at this address: http://ttnwww.rtpnc. epa.gov/naaqsfin/pmact.htm. July 17, 1997a.

US Environmental Protection Agency (US EPA). *Fact Sheet: Health and Environmental Effects of Ground-Level Ozone.* Document obtained from an internet web page at this address: http://www.epa.gov/r10earth/offices/air/o3health.html. November 29, 1996a.

US Environmental Protection Agency (US EPA). *Fact Sheet: Health and Environmental Effects of Particulate Matter.* Document obtained from an internet web page at this address: http://www.epa.gov/r10earth/offices/air/pmhealth.html. November 29, 1996e.

US Environmental Protection Agency (US EPA). *Environmental Health Threats to Children.* Office of the Administrator. September 1996b.

US Environmental Protection Agency (US EPA). *Respiratory Health Effects of Passive Smoking: Lung Cancer and Other Disorders.* Office of Air and Radiation. December 1992.

US Environmental Protection Agency (US EPA) and the US Consumer Product Safety Commission (US CPSC). *The Inside Story: A Guide to Indoor Air Quality.* April 1995.

Viscusi, W.K., W. Magat and J. Huber. "Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk-Dollar Trade-offs for Chronic Bronchitis." *Journal of Environmental Economics and Management* 21 (1): 32-51. 1991.

Weiss, K.B., P.J. Gergen, T.A. Hodgson. "An Economic Evaluation of Asthma in the United States." *The New England Journal of Medicine* 326 (13): 862-866. March 26, 1992.

ECONOMIC VALUATION OF CHILDHOOD LEAD POISONING

Description of the Effect

Lead, a well-studied toxin that has no biological function, causes negative health effects, especially in children. It enters the body through inhalation, ingestion, and dermal contact with lead (US EPA 1997a). Upon reaching the bloodstream, lead affects blood cells and the central nervous system. It distributes itself through the organs, including the brain (US EPA 1997j). Lead alters the blood's hemoglobin by preventing the synthesis of heme, which helps the blood distribute oxygen throughout the human body. Inhibition of heme synthesis severely disrupts the functioning of many organs and results in an accumulation of protoporphyrin in cells, which may be indicative of anemia[9] (US EPA 1997k, US EPA 1985, Mathtech 1987).

Lead poisoning is defined to occur when blood lead levels exceed 10 micrograms per deciliter (ug/dl) of blood[10] (Schettler et. al 1996, US EPA 1997k). Some children may experience lead poisoning effects below this level, while other children may physically appear healthy even if they have high blood lead concentrations (US EPA 1997e). Doctors assess lead concentrations in the body through blood testing, urine testing, and X-ray fluorescence of bone (Schettler et. al 1996)

Children under the age of seven and fetuses are most susceptible to lead poisoning, which has long-term and often irreversible effects (US EPA 1997a). According to the American Academy of Pediatrics, an estimated three to four million children in the US under the age of six have blood lead levels that could impair development, and an additional 400,000 fetuses face a similar risk (US EPA 1997k).

The growing bodies and tissues of small children easily absorb lead, especially on an empty stomach or if the child does not have enough dietary calcium and iron (The Arc 1997, US EPA 1997j). Blood lead levels in the fetus are up to 90 percent of those in the pregnant mother since lead readily crosses the placenta. In addition, lead accumulates in bone tissue and may be released from bone during pregnancy, leading to fetal lead poisoning. The effects of lead exposure on a fetus

---

[9] Heme is the prosthetic, oxygen-carrying, color-furnishing constituent of hemoglobin, which is the iron-containing protein pigment occurring in the red blood cells of vertebrates that transports oxygen from the lungs to the tissues of the body. Protoporphyrin, along with iron, forms the heme of hemoglobin. Anemia indicates a lack of red blood cells and hemoglobin in the blood (Webster's Medical Dictionary).

[10] The US EPA established this threshold concentration level (Schettler et al. 1996, US EPA 1997k).

include low birth weight, birth defects, and slow/abnormal development (US EPA 1997d). At high levels of exposure, lead causes spontaneous abortions and stillbirths, and was used to induce abortions in the past (Schettler et. al 1996).

The symptoms of lead poisoning include headaches, poor appetite, trouble sleeping, crankiness, and vomiting. Exhibit 1 lists the effects of lead exposure on children and fetus. Figure 1 illustrates the relationship between lead poisoning effects and blood lead levels. The levels of lead in the bloodstream can be classified as mild (10-19 ug/dl), moderate (20-44 ug/dl), severe (45-69 ug/dl), and acute medical emergency (over 70 ug/dl) (The Arc 1997).

Exhibit 1
ADVERSE EFFECTS OF LEAD ON CHILDREN AND FETUS
Neurobehavioral - Decreased Intelligence - Developmental Delays - Behavioral Disturbances - Seizures (at very high levels) - Coma (at very high levels)
Growth - Decreased Stature
Endocrinologic - Altered Vitamin D Metabolism
Hematologic - Elevated Erythrocyte (Red Blood Cell) Protoporphyrin Levels
On the Fetus - Decreased Gestational Age - Decreased Gestational Weight - Miscarriage and Stillbirth (at very high levels)
Source: US DHHS and CDC, 1991.

Figure 1

THE EFFECTS OF ELEVATED BLOOD LEAD LEVELS

Children	Lead Concentration in Blood (μg Pb/dL)	Adults

150

Death ►

100 ◄ Encephalopathy

Encephalopathy ►
Nephropathy ►   ◄ Frank Anemia

Frank Anemia ►

◄ Decreased Longevity

Colic ►

50 ◄ Hemoglobin Synthesis ▼

Hemoglobin Synthesis ▼ ►   40 ◄ Peripheral Neuropathies / Infertility (Men) / Nephropathy

Vitamin D Metabolism ▼ ►   30 ◄ Systolic Blood Pressure (Men) ▲ / Hearing Acuity ▼

◄ Erythrocyte Protoporphyrin (Men) ▲

Nerve Conduction Velocity ▼ ►   20

◄ Erythrocyte Protoporphyrin (Women) ▲

Erythrocyte Protoporphyrin ▲ ►
Vitamin D Metabolism (?) ▼

Developmental Toxicity ►

IQ ▼
Hearing ▼ ►   10 ◄ Hypertension (?) ▲
Growth ▼

Transplacental Transfer ►

▲ Increased function   ▼ Decreased function

Source: Schettler et al., 1996.

Types of Exposures that Cause the Effect

Description of Toxin

Lead is a heavy, bluish-gray metal that naturally exists as lead oxide, lead salts or as organic salts. It has been mined for thousands of years (Schettler et. al 1996). Before the adverse health effects of lead exposure were known, manufacturers commonly used lead because of its desirable characteristics, including low melting point, high density, ease of fabrication, acid and corrosion resistance, and chemical stability (US EPA 1997b).

Levels of Exposure: Dose-Response Relationship

The US EPA established the National Ambient Air Quality Standard for lead and its compounds at 1.5 microgram/cubic meter[11] (CFR Section 50, part 12). According to the US EPA, this standard represents the threshold concentration above which negative health effects may occur (US EPA 1997f). Higher doses of lead produce more severe symptoms (US EPA 1997i). In particular, a number of recent studies have examined the lead-IQ dose-response relationship (Schwartz 1994).

Direct Sources of Lead in the Environment

The major sources of lead in the environment are dust, soil, water, paint, and food. Leaded paints and corrosive lead water pipes have resulted in residential lead poisoning. Lead enters the environment during its mining, ore processing, smelting, refining, recycling or disposal. According to the Toxics Release Inventory, lead compound releases to land and water between 1987 and 1993 totaled nearly 144 million pounds, with lead smelters contributing the largest share (US EPA 1995). The combustion of municipal solid waste and landfill leachate often release lead-contaminated ash to the environment (Rugg 1989). The widespread use of resource recovery ash in structural materials also poses a threat of lead poisoning (Korzun and Heck 1990). Until its ban in 1986, leaded gasoline contributed to lead in the ambient air, in dust, soil, and food. The phaseout of lead in gasoline, industrial emissions standards, and the fact that lead solder is no longer used in commercial food canning has significantly reduced lead exposures, but much of the lead still remains in the soil near heavily trafficked and urban areas (US EPA 1997c, US EPA 1997k, Schettler et. al 1996, Brunekreef

---

[11] The National Ambient Air Quality Standard is based on the maximum arithmetic mean averaged over a calender quarter (CFR Section 50, part12).

1984). Lead can also contaminate food, and is still present in many non-food products, otherwise known as "Adventitious Sources " (Fergusson 1986). Exhibit 2 provides a comprehensive description of the sources of lead in the environment.

Complicating Social Factors

Complicating biological and social factors make children under the age of seven at high risk of lead poisoning. Children have a tendency to put inedible objects and their hands into their mouth, which can be dangerous if they have been playing with lead-contaminated paint (Brunekreef 1984). This problem is exacerbated with children suffering from 'pica,' which is an abnormal craving for non-food objects, especially since lead paint compounds have a sweet taste (Sturges and Harrison 1985). Correlations exist between children who either lack parental care, have parents with low incomes and educational levels, or who live in substandard housing (Brunekreef 1984). Minority children tend to have higher blood lead levels than the national averages: almost 22 percent of black children one to two years old currently have blood levels over the 10 ug/dl threshold level (Schettler et. al 1996).

Existing Studies Characterizing Values

Since at least the mid-1980's EPA has been developing and refining methods for assessing childhood health effects from lead.[12] Estimates of the value of avoiding lead exposures have been developed and refined over the same period. EPA's landmark study of the costs and benefits of removing lead additives in gasoline (US EPA 1985) was an important effort not only because of its identification of a ubiquitous source of lead exposure but also because it provided a well-documented and established starting point for development of monetized benefits. The lead in gasoline study employed a direct cost-of-illness approach for childhood health effects and developed an indirect cost of illness estimate for compensatory education. In the first case, they estimated direct costs of medical treatment on a per-child basis using thresholds of blood lead levels to measure increasing severity of effect. Subsequent valuation efforts have developed these categories of effects further and extended the scope of monetized effects to include characterization of reduced educational attainment levels and reduced lifetime earnings of the exposed children.

---

[12] Note that this section excludes discussion of the valuation of health effects associated with adult exposure to lead. This is also a well-developed literature on valuation of lead-induced adult health effects, which include stroke, hypertension, and heart attacks. See US EPA 1997 for a good summary of the available literature and valuation techniques.

	Exhibit 2
	THE MAJOR SOURCES OF CHILDHOOD LEAD POISONING
Routes of Exposure	**Description**
Inhalation of Ambient Air/Dust	Lead smelters, incinerators of municipal solid waste and other industries contribute to airborne lead. Until leaded gasoline was banned in January 1986, as much as 70-90 percent of lead that was burned in gasoline ended up as particulate matter in the air (US EPA 1997c). Superfund sites also pose a potential threat (US EPA 1990). The chief source of airborne lead indoors is from paint (US EPA 1997k). Lead-based paint, inhaled as dust or ingested as paint chips, represents the most common high-dose source of lead nationwide (US EPA 1997i). Lead was added to paint to make it dry faster and be corrosion resistant (US EPA 1997b). Leaded paint is estimated to be present in 75% of houses in the US built before 1978 (The Arc 1997). Exterior lead paint that is often used on steel structures, such as bridges and elevated railways, and on street markings, may contain as much as 90 percent lead by weight. While flakes of paint that fall pose a serious health threat to children, scraping lead paint off of a structure, in a process known as de-leading, may increase the amount of lead in the air (Schettler et. al 1996). Children may also be poisoned by lead dust brought home by parents from the workplace (The Arc 1997).
Ingestion of or Dermal Contact with Soil	Most of the lead in soil comes from lead-based paint chips flaking from the exterior of homes (US EPA 1997d). Smelters, incinerators of municipal solid waste, landfill leachate and other industries are also major contributors to lead in soil (The Arc 1997). Although lead additives in gasoline have been banned since January 1, 1996, much of the lead burned in gasoline still remains in the soil near heavily trafficked highways and urban areas (US EPA 1997c, US EPA 1997k). Lead binds to soil, which poses a health risk if the soil is tracked into the house. Children expose themselves to lead if they ingest or play in contaminated soil (US EPA 1995).
Ingestion of Water	The US EPA estimates that drinking water is the source of about 20 percent of Americans' lead exposure (The Arc 1997). Under the Safe Drinking Water Act, the EPA established 15 ppb as the lowest acceptable concentration of lead in drinking water (US EPA 1997l). Lead in drinking water results from corrosion of lead pipes, lead solder used to join copper pipes, or from faucets and brass fittings which contain lead. Plumbing installed before 1930 most likely contains lead; plumbing that is less than five years old may also leach lead because mineral deposits that prevent corrosion have not yet formed inside the pipes (US EPA 1997l).
Ingestion of Food	Lead-containing dust can settle on food. Vegetables grown in city gardens may contain lead. Lead can also leach from ceramic or crystal dishes that contain lead (US EPA 1997e, US EPA 1997d)
Other Types of Exposures	In addition to paint, ceramic glazes, and water plumbing, lead is still commonly found in many products, including: batteries, pigments, varnishes, solders, ammunition, cable coverings, fishing sinkers, bearings, caulking, stained glass, plastics, electronic devices, medical and scientific equipment, radiation shields, tank linings, pipes and equipment which handle corrosive materials, bronze/brass/steel alloys, imitation pearls, insecticides, lubricants, and even in some crayons and miniblinds (US EPA 1997b, US EPA 1997c). Some folk remedies, "health foods" and cosmetics may contain lead (US EPA 1997k, The Arc 1997).

The lead-in-gasoline study's direct cost of illness estimate focused on medical costs avoided by preventing blood lead levels from reaching the 25 ug/dl level. A subsequent direct cost of illness estimate conducted by Mathtech for EPA included medical costs for such treatments as chelation therapy as well as costs incurred in screening and education programs to identify high lead exposure and the opportunity cost of time spent by parents in caring for their children. Both sets of estimates were developed on a per-child basis and employ an *ex post* incidence based methodology, and both leave out welfare losses for such components of willingness to pay as the coincident adverse health effects and pain and suffering associated with chelation therapy treatment, as well as the long-term effect of impaired cognitive development during the developmental years. Exhibit 3 summarizes the results of these two major efforts. Note that the Mathtech results were developed based on CDC risk class definitions, and so provide a more detailed characterization of the distribution of costs across severity levels as well as costs for treatment of elevated blood lead levels that nonetheless remain below the 25 ug/dl level.

Exhibit 3			
Benefit Estimates for Reductions in Childhood Lead Poisoning: Direct Cost of Illness Studies			
Types of Costs Associated with Childhood Lead Poisoning	**Source Study**	**Benefit**	**Notes**
medical costs avoided by preventing children's blood lead levels from rising to 25 ug/dl or above	Schwartz 1994 CDC 1991	$1300/child (1989 dollars)	Estimates update costs of US EPA 1985 study using the medical-care component of the Consumer Price Index.
	US EPA 1985	$900/child (1985 dollars)	Conservative estimate because does not include welfare losses, such as opportunity costs of parents; adverse health effects of chelation therapy, or pain from treatment.
out-of-pocket medical costs, costs borne by screening and education programs, and the opportunity costs of parents	Mathtech 1987	CDC Risk Class IV: $2,742/child	In CDC Risk Class IV, the blood lead level is above 40 ug/dl and the erythrocyte protoporphin level is above 53 ug/dl. Children are at urgent risk and require immediate treatment.
		CDC Risk Class III: $1,369/child	In CDC Risk Class III, either the blood lead level above 40 ug/dl when the erythrocyte protoporphin (EP) level is between 35-53 ug/dl; or, the blood lead level is between 21 and 40 ug/dl when the EP level is above 53 ug/dl.
		CDC Risk Class II: $633/child	In CDC Risk Class II, the blood lead level is between 21 and 40 ug/dl when the erythrocyte protoporphin (EP) level is between 33 and 53 ug/dl.
		CDC Risk Class Ib: $267/child	In CDC Risk Class Ib, the blood lead level is between 21 and 40 ug/dl when the erythrocyte protoporphin (EP) level is between 0 and 32 ug/dl.
		CDC Risk Class Ia: $352/child	In CDC Risk Class Ia, the blood lead level is between 0 and 20 ug/dl when the erythrocyte protoporphin is above 33 ug/dl. Children in this category have elevated EP levels and should be tested for anemia.
		CDC Risk Class I: $267/child	In CDC Risk Class I, the blood lead level is between 0 and 20 ug/dl when the erythrocyte protoporphin is between 0 and 32 ug/dl. Children in this category are at low risk but costs reflect potential future damage.

Indirect cost of illness estimates for compensatory education were developed for the lead-in-gasoline study by estimating the cost of such education for three years. Those estimates were applied assuming that 20 percent of the children with blood lead levels in excess of 25 ug/dl would require compensatory education. EPA's most recent estimate of compensatory education costs (US EPA 1997) uses a more specific definition of the affected population of children (those with IQ levels less than 70, statistically among the lowest 2.5 percent of children in terms of cognitive ability), and also employs an assumption of 11 years of required compensatory education. These estimates are presented in Exhibit 4.

An additional category of benefits associated with prevention of developmental effects from lead is the long-term effect of developmental impairment on lifetime earnings of exposed children. EPA's report on the costs and benefits of the Clean Air Act (US EPA 1997) estimates effects on lifetime earnings by first estimating the effect of high blood lead on IQ, then the effect of lowered IQ on educational attainment, and then the effect of educational attainment on labor force participation and earnings. The welfare loss that this method attempts to capture is the lifetime loss of cognitive potential; lifetime earnings provides a ready revealed preference method for estimating this effect, but nonetheless it is not without difficulties and complexities. For example, this careful tracing of effects acknowledges that the educational attainment to earnings link must consider the net effect of educational attainment on earnings, rather than the gross effect. While increased educational attainment demonstrably increases earnings, additional years of education come at a cost that includes both the cost of schooling (e.g., tuition) and the opportunity cost of time spent in school rather than employed full-time. EPA's estimate subtracts these costs from the overall estimate and nonetheless arrives at an average estimate of roughly $3000 per lost IQ point. Estimates of indirect cost of illness are summarized in Exhibit 5. Note that all of these estimates claim to underestimate the true value of avoiding IQ decrements because they employ conservative assumptions about future productivity growth and labor participation rates. These estimates also do not capture parents' willingness to pay for their child to avoid being mentally handicapped, a component of the value of avoided lead exposure that could be substantial in severe instances lead poisonings. Assumed discount rates are also a critical factor in estimating the present value of a long-term effect that occurs over the lifetime of individuals exposed during the first six years of their life.

Another category of non-cancer morbidity that is associated with lead exposures is manifest through infant mortality. Maternal lead exposure during pregnancy leads to a measurable increase in the rate of infant mortality. Existing estimates of the WTP to avoid increases in the risk of infant mortality have used values for avoided mortality risk from wage-risk studies of working adults, rather than parents' or society's willingness to pay to reduce the risk of infant mortality. Arguments can be made that the societal willingness to pay to avoid infant mortality is larger than that expressed by adults for their own avoidance of mortality risk (based, for example, on the increased number of life years lost, the pain and suffering of the parents, and society's expressed willingness to pay to save or extend infant's lives through extraordinary medical procedures). There is also some evidence that society does not choose to invest as heavily in the avoidance of infant mortality, particularly in reducing infant mortality rates through prenatal care programs. Further theoretical and empirical work is necessary if estimates of WTP to avoid infant mortality are to be refined.

		Exhibit 4	
		Benefit Estimates for Reductions in Childhood Lead Poisoning: Indirect Cost of Illness Studies	
Types of Costs Associated with Childhood Lead Poisoning	**Source Study**	**Benefit**	**Assumptions and Notes**
net cost of compensatory education for children whose IQ are less than 70	US EPA 1997	$52,700/child (for 11 years in 1990 dollars)	Estimates for children with IQs less than 70. Conservative estimate. Costs reflect children attending regular school, not a special education program.
net cost of compensatory education due to decrease in IQ level and cognitive abilities	Schwartz 1994	$3,320/child with blood levels over 25 ug/dl (for 3 years in 1989 dollars)	Assume that 20 percent of children with blood levels above 25 ug/dl will require compensatory education. Effects on hearing, balance, hyperactivity, and perceptual and attention disorders are not included in these estimates.
	CDC 1991	$3,331/child (for 3 years in 1991 dollars with last two years calculated with five percent discount rate)	Assume that 20 percent of children with blood levels above 25 ug/dl will require compensatory education.
	US EPA 1985	$2,600/child (for 3 years in 1985 dollars)	Assume only 20 percent of all children over 25 ug/dl will have compensatory education.

Exhibit 5			
Benefit Estimates for Reductions in Childhood Lead Poisoning: Indirect Cost of Illness Studies: IQ decrements			
value of lifetime earnings lost per child per IQ point from reducing lead poisoning	US EPA 1997	$2,957/IQ point (1997 dollars with five percent discount rate)	This values is the average of the $2,500/IQ point estimate based on Schwartz (1994) and $3,400/IQ point estimate based on Salkever (1995). It accounts for both the direct effects of lead on IQ decrements and on the indirect effects on lower educational attainment and reduced labor force participation (subtracting from indirect benefits the costs of additional education and associated opportunity cost).
value of lifetime earnings per child per one ug/dl (or 0.25 IQ points) increase in blood lead level	CDC 1991	$1,147/ one ug/dl	CDC estimates do not provide values for preventing lead's effects on children's stature, hearing, vitamin D metabolism, and blood production. It also does not value the contribution of lead to juvenile delinquency, the administrative costs of personal injury lawsuits, the improvement in property values from improved housing conditions resulting from abatement.
	Schwartz 1994	$1300/ 1 ug/dl	Estimate applies to each child in the cohort turning 6 years of age each year. This estimate is an underestimate because it assumes a low productivity growth, a high discount rate, and low female participation.

Discussion of Alternative Valuation Strategies

The preceding discussion demonstrates that there are a wide range of available estimates to characterize the monetary benefits of avoiding childhood lead exposures. Most of the analyses cited above, particularly EPA's lead-in-gasoline analyses and EPA's analysis of the costs and benefits of the Clean Air Act, have been extensively reviewed by EPA staff and peer reviewers and can therefore be considered among the more defensible estimates available. Nonetheless, even the above cited work does not adequately characterize all the hypothesized effects on children of lead exposure. Lead poisoning, as is the case with many developmental impairments, has a wide range of effects. In addition, use of the above strategies requires some attention to the units of analysis. In consideration of these factors, analysts may choose to undertake the following two measures in valuation efforts for childhood lead exposures:

1. ***Pay special attention to units of analysis.*** Some of the estimates cited above are based on per-child estimates for ranges of blood lead levels, at least one of the recent measures is based on lost IQ points, and the compensatory education estimates are based on estimation of the numbers of children that, as a result of lead exposure, are left with IQ levels that drop below 70. It is important in application of these estimates to ensure that the health science supports measurement of these units of analysis for the particular exposure scenario of interest.

2. ***Characterize other effects that may not be monetized.*** For example, in addition to the above health effects, the health science literature also notes that lead exposure can lead to: fetal effects from maternal exposure, including diminished IQ; other neurobehavioral and physiological effects (e.g., the CDC cites effects on hearing, balance, hyperactivity, and perceptual and attention disorders, not all of which would be reflected in estimates of compensatory education necessary for low IQ children); and sociological effects such as delinquent or anti-social behavior.

Some future regulatory actions may be addressed towards less ubiquitous exposures than the lead-in-gasoline rule and other aspects of the historical Clean Air Act. In the case of exposure scenarios that are dominated by a relatively small number of acute exposures (e.g., for ingestion of contaminated soil at a particular site or small set of sites) the fact that the cost-of-illness estimates presented above ignore the pain and suffering component and parental willingness to pay to avoid health effects in their children may be more problematic. Additional attention paid to the general issue of the willingness to pay of parents to avoid health effects in their children may help to better characterize this potentially large benefit component.

ECONOMIC VALUATION OF CHILDHOOD LEAD POISONING REFERENCES

The Arc. *The Arc's Q&A on Lead Poisoning: Childhood Lead Poisoning Prevention*. Document obtained from an EPA Internet web page following address: http://thearc.org/faqs/leadqa.html. August 1997.

Brunekreef, B. "The Relationship Between Air Lead and Blood Lead in Children: A Critical Review." *The Science of the Total Environment* 38: 79-123. 1984.

Centers for Disease Control (CDC). *Strategic Plan for the Elimination of Childhood Lead Poisoning*. February 1991.

Cropper, M. Outline: *Benefits Estimation Seminar: Valuing the Health Impacts of Water Pollution*. January 23, 1997.

Fergusson, J.E. "Lead: Petrol Lead in the Environment and Its Contribution to Human Blood Levels." *The Science of the Total Environment* 50: 1-54. 1986.

Korzun, E.A. and H.H. Heck. "Sources and Fates of Lead and Cadmium in Municipal Solid Waste." *J. Air Waste Manage. Assoc.* 40(9):1220-1226. September 1990.

Mathtech, Inc. *Final Report: Methodology for Valuing Health Risks of Ambient Lead Exposure*. Prepared for the US EPA, Office of Air Quality Planning and Standards. December 1987.

Mielke, H.W., J.C. Anderson, K.J. Berry, P.W. Mielke, R.L. Chaney, and M. Leech. "Lead Concentrations in Inner-City Soils As A Factor in the Child Lead Problem". *American Journal of Public Health* 73(12):1366-1369. 1983.

Rugg, Mack. *Reducing the Lead and Cadmium Content of Municipal Solid Waste and Ash Residue*. New Jersey: Camp Dresser & McKee, Inc. February 1989.

Salkever, D. "Updated Estimates of earnings Benefits from Reduced Exposure of Children to Environmental Lead." *Environmental Research* 70: 1-6. 1995.

Schettler, T., G. Solomon, P. Burns, M. Valenti. *Generations at Risk: How Environmental Toxins May Affect Reproductive Health in Massachusetts*. Greater Boston Physicians for Social Responsibility (GBPSR) and the Massachusetts Public Interest Research Group (MASSPIRG) Education Fund. 1996.

Schwartz, J. "Societal Benefits of Reducing Lead Exposure." *Environmental Research 66*: 105-124. 1994.

Sturges, W.T. and R.M. Harrison. "An Assessment of the Contribution From Paint Flakes to the Lead Content of some Street and Household Dusts." *The Science of the Total Environment* 44: 225-234. 1985.

US Department of Health and Human Services (US DHHS) and Centers for Disease Control and Prevention (CDC). *Strategic Plan for the Elimination of Childhood Lead Poisoning*. February 1991.

US Department of Housing and Urban Development (US HUD). *Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing*. A Report to Congress. December 7, 1990.

US Environmental Protection Agency. *The Benefits and Costs of the Clean Air Act, 1970 to 1990*. Draft Report Prepared for US Congress. April 1997.

US Environmental Protection Agency. *Criteria Pollutants*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/ttncaaa1/title1/bgilbert/greenbk/o3co.htm. August 1997f.

US Environmental Protection Agency. *Comprehensive Review of Lead (Pb) in the Environment Under the Toxic Substances Control Act*. Draft Report. July 26, 1990.

US Environmental Protection Agency. *Costs and Benefits of Reducing Lead in Gasoline: Final Regulatory Impact Analysis*. February 1985.

US Environmental Protection Agency. *EPA Region 1: Healthy Beginnings*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/region01/eco/lead/t_lppunit.html. August 1997d.

US Environmental Protection Agency. *Human Health Technical Committee Reports: 9. Lead*. Arizona Department of Environmental Quality. Phoenix, Arizona. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/oppeinet/oppe/futures/risk/crexamples/examples/Arizona/html. August 1997i.

US Environmental Protection Agency. *Indoor Air Pollution: An Introduction for Health Professionals*. Document obtained from an EPA Internet web page at the following address: http://www/epa.gov/iedweb00/pubs/hpguide.html. August 1997k.

US Environmental Protection Agency. *Lead Basic Facts taken from The Inside Story-A Guide to Indoor Air Quality*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/iedweb00/lead.html. August 1997j.

US Environmental Protection Agency. *Lead-Based Paint: Public Health Threat*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/reg5foia/pb/threat.html. August 1997a.

US Environmental Protection Agency. *LEAD- General Information and Region 3 Highlights*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/reg3artd/indoor/lead.htm. August 1997h.

US Environmental Protection Agency. *Lead in Drinking Water: Actions You Can Take To Reduce Lead in Drinking Water*. Office of Water. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/watrhome/pubs/lead1.html. August 1997l.

US Environmental Protection Agency. *Lead Poisoning and Your Children*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/iedweb00/pubs/lead.html. August 1997g.

US Environmental Protection Agency. *Lead (Pb) - The Mineral*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/reg5foia/pb/mineral/html. August 1997b.

US Environmental Protection Agency. *National Primary Drinking Water Regulations*. Office of Water. October 1995.

US Environmental Protection Agency. *OPPT Annual Report FY95: 3. Reducing Risk to the Public from Chemicals; Promoting Life Cycle Management*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/opptintr/ar95/opptch03.htm. August 1997e.

US Environmental Protection Agency. *Product Matrix: Lead*. Document obtained from an EPA Internet web page at the following address: http://www.epa.gov/grtlakes/seahome/housewaste/house/lead.htm. August 1997c.

US Environmental Protection Agency. *Strategy for Reducing Lead Exposures.* Final Draft. September 26, 1990.

ECONOMIC VALUATION OF KIDNEY DISEASE

This case study provides information on valuation of avoided kidney disease resulting from environmental factors. We first provide a description of kidney disease and treatment options. The second section discusses what is known about environmental linkages to kidney disease, including environmental pathways and dose-response relationships. The third section provides an overview of existing kidney disease studies that may be used to develop values related to nephropathy. The final section provides guidance for kidney disease valuation.

Description of the Effect

Human kidneys function in a highly complex manner to clean blood of wastes, and are of critical importance for maintaining a healthy physiological system. Kidneys play a large role in maintaining fluid levels, electrolyte balance, many hormone levels, and nutrient status. As a result, damage to the kidneys can affect most organ systems in the body (US EPA 1997). When the blood filtering process fails, the body retains fluid, experiences high blood pressure, accumulates wastes, and fails to produce a sufficient number of red blood cells (NIH 1997).

Kidney disease is a debilitating condition that causes numerous adverse physical and emotional conditions of varying severity. People suffering from the disease experience increased morbidity, including mobility effects, muscle cramps, hypotension, or infections. Kidney disease can have many lifestyle impacts, including diet changes, daily schedule disruptions, and sleep disturbances. Kidney disease may cause an increase in emotional stress. For example, patients may experience depression, anxiety, pain, loss of energy, or changes in their social and personal relationships (NIH 1997). In addition, kidney disease increases patient mortality and survival rates. The USRDS reports that the death rate during the first year of incidence was 25.5 percent in 1992. For those that survived the first year, the death rate during the second year of the disease was 21.4 percent (NIH 1995).

To better understand kidney damage, it is important to have a basic understanding of how kidneys function. Each kidney consists of many "nephrons" which receive extra water and wastes from blood capillaries and work to empty them from the body. As shown in Figure 1, each nephron is made up of a Bowman's capsule and tubule; the "glomerulus" of each capsule carries out the substance exchange and discharges it into the tubule. The nephron tubules empty waste into collecting tubules which lead to the central cavity of the kidney, and eventually to the urinary bladder (Keeton 1980).

Kidney disease and its progression to kidney failure, or end-stage renal disease, may result from a variety of physiological conditions. For example, tubular damage from an environmental contaminant exposure eventually progresses to direct kidney damage through inflammation of the glomerulus (US EPA). In addition, several health conditions may cause glomerulonephritis, a kidney disease that inflames and scars the kidneys to the point where they are unable to remove wastes and excess water from the blood to make urine (NIH 1997a).[13] Other physiological conditions leading to kidney deterioration include hypertension and polycystic kidney disease. Hypertension may damage the blood vessels in the kidneys, resulting in the kidneys not removing wastes and extra fluid from the body (NIH 1997b). Polycystic disease is a genetic disorder where fluid-filled cysts grow in the kidneys, eventually replacing kidney mass, decreasing kidney function, and leading to kidney failure (NIH 1997d).

Figure 1
HUMAN KIDNEY AND NEPHRON[1]

Human Kidney

Nephron

[1]Adapted from Keeton (1980).

---
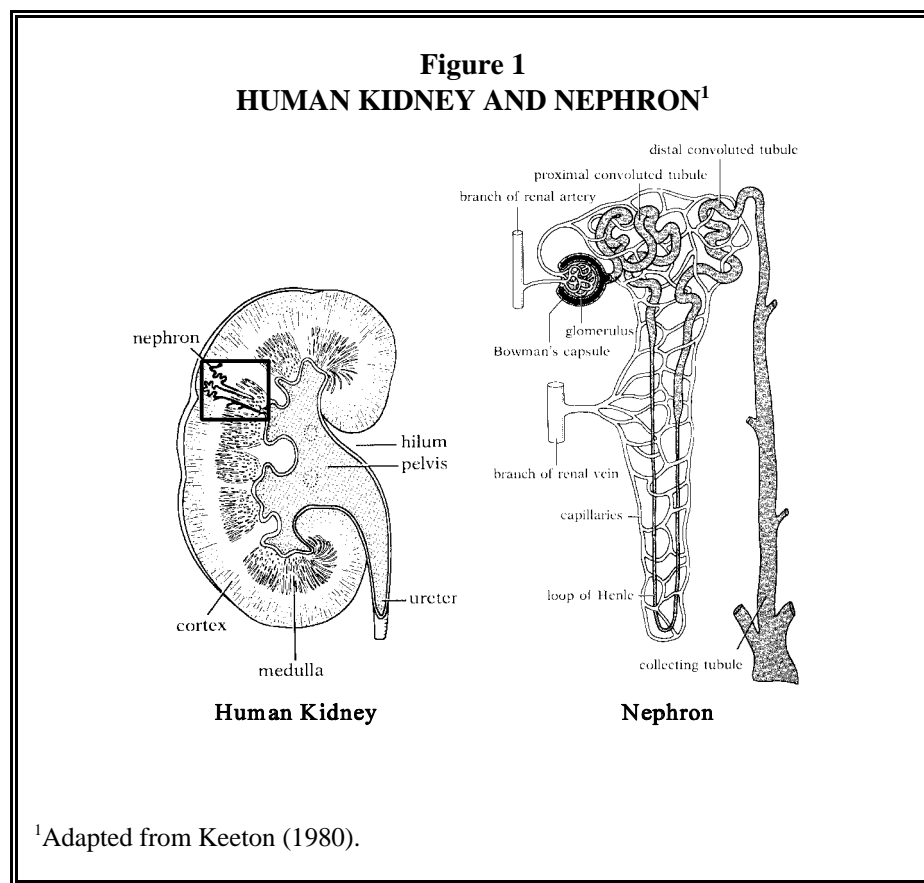
[13] Diabetes, the leading cause of end-stage renal disease, is a type of glomerulonephritis. IgA nephropathy is thought to be a genetic condition ultimately resulting in glomerulonephritis. Lupus nephritis, a kidney condition arising from genetic conditions, infections, viruses, or air pollution, also results in glomerulonephritis (NIH 1997c).

The treatment options for end-stage renal disease (ESRD) include hemodialysis, peritoneal dialysis, and kidney transplantation. Treatment options are at the discretion of the ESRD patient and are not necessarily linked to the initial source of kidney dysfunction. Hemodialysis is a vascular treatment procedure that cleans and filters the blood by ridding the body of wastes, extra salt and fluids (NIH 1997). Peritoneal dialysis is a treatment procedure that removes extra water, wastes, and chemicals from the body by using the lining of the abdomen to filter blood (peritoneal membrane). Several types of peritoneal dialysis are available, including continuous ambulatory peritoneal dialysis (CAPD), continuous cyclic peritoneal dialysis (CCPD), and intermittent peritoneal dialysis (NIH 1997). These peritoneal dialysis options vary by the frequency of drainage, the materials needed to filter the blood, and whether the dialysis is a form of self-treatment. ESRD patients may receive transplant kidneys from living-related donors, however, many patients await kidneys from cadaver donors. Since there are not enough cadaver donors for every person who needs a kidney, patients are placed on a waiting list and receive dialysis treatment in the meantime.

ESRD incidence increased in the period from 1986 to 1995 (NIH, *USRDS*, 1997). The US Renal Data System reports there were an estimated 260,000 cases of ESRD in the US on December 31, 1995 (NIH 1997e). This report also indicates approximately 69,000 new cases of ESRD developed in the US during 1995. From 1993 to 1994, growth of the incident dialysis cases in Medicare patients rose 14.7 percent. The US Renal Data System reports that in 1995, the mean age fore ESRD incidence was 60 years of age. Exhibit 1 shows that prevalence and incidence rates increase with age, with ESRD affecting the 65 to 74 age group population the most substantially (NIH 1997e). In addition, over the time period 1993 to 1995, USRDS reports the prevalence and incidence rates peak between 70 and 80 years of age. Despite the fact that incident and prevalence rates are highest among the elderly, these data show a substantial number of younger, wage-earning individuals contract ESRD (i.e., approximately 166,000 individuals between the ages of 20 and 64 suffered from kidney disease on December 31, 1995).

Exhibit 1						
TREATED MEDICARE ESRD POINT PREVALENCE AND INCIDENCE COUNTS AND RATES						
	Prevalence on 12/31/95			Incidence during 1995		
Age	Count	Percent of Total	Rate per Million	Count	Percent of Total	Rate per Million
0-19	4,658	1.8	60	1,087	1.6	13
20-44	68,327	26.6	648	11,666	16.9	109
45-64	97,670	38.0	2,120	23,225	33.7	508
65-74	54,163	21.1	3,273	19,217	27.9	1097
75+	32,448	12.6	2,587	13,675	19.9	1035
Source: (NIH 1997e)						

Kidney Disease from Environmental Exposure

Toxicological data indicate exposure to environmental contaminants may put humans at risk for contracting renal effects. To establish a non-cancer health risk, such as kidney disease, for a given contaminant, risk assessors compare an estimated exposure level to a benchmark exposure level that is likely to be without an appreciable risk of adverse health effects. This benchmark exposure level is referred to as a reference dose (RfD) and is designed to be protective for even sensitive subgroups of the population. Exposures above RfDs are potentially unsafe, while exposures below RfDs are not expected to pose any appreciable risk. In developing RfDs, toxicologists evaluate critical and prevalent effects of exposure to contaminants.[14] For several contaminants, kidney disease is either the critical health effect or one of several prevalent health effects resulting from inhalation, oral, or dermal exposure.

An analysis of 32 contaminants of concern for hazardous waste management identified kidney disease to be the critical effect for nine contaminants and to be a prevalent health effect for six contaminants (US EPA).[15] The nine contaminants identified as having a kidney disease as the critical health effect include: cadmium, pentachlorophenol, methylene chloride, toluene, pyrene, fluoranthene, ethylbenzene, nitrobenzene, and pentachlorobenzene. The six contaminants identified as having kidney disease effects at higher than RfD levels include: cadmium, tetrachloroethylene, mercury, pyrene, methyl ethyl ketone, and pentachlorobenzene.

The Agency for Toxic Substances and Disease Registry (ATSDR) reports on pathways leading to renal effects for some of the 32 contaminants examined for the hazardous waste management activity studies. For chemicals covered by ATSDR, the most frequent pathway to renal effects identified with human evidence is inhalation, followed by oral, and then dermal contact. Human-based studies indicate inhalation of cadmium, pentachlorophenol, toluene, tetrachloroethylene, or mercury have had adverse renal effects. Studies also indicate ingestion of cadmium, toluene, or mercury may also lead to kidney dysfunction.

Because the traditional RfD approach provides no information on the potential magnitude of the risk associated with exposures at different levels (see discussion in Chapter 5), EPA is

---

[14] The critical effect is the health effect observed to occur at the lowest dose and serves as the basis for the RfD. A prevalent effect is one that occurs at higher doses of the contaminant. More than one prevalent effect is likely to be associated with a given contaminant.

[15] The Environmental Protection Agency's Office of Solid Waste (OSW) conducted analyses on 32 contaminants to evaluate the human health effects that may result from regulations governing corrective action at hazardous waste management facilities and a contaminated media rule as part of the Hazardous Waste Identification Rule project. OSW chose 32 contaminants having a significant non-cancer health effect impact for the corrective action rule.

investigating methods for quantifying non-cancer risks. In one effort, EPA demonstrates a prototype method using a contaminant linked to kidney disease. In a draft report, EPA develops a dose-response relationship for cadmium, a contaminant noted as causing tubular damage leading to ESRD (US EPA). The report evaluates available toxicological data on non-cancer health effects associated with cadmium exposure, and uses these data to develop a quantitative model of the dose-response relationship for kidney disease. The report combines exposure estimates from a general model of Superfund-related exposure with the dose-response equations to estimate individual and population risks. The results are quantitative estimates of the incremental risks of kidney disease from exposure to cadmium at a hypothetical Superfund site and estimates of the non-cancer risk reduction benefits of remedial action at a site (i.e., the reduced number of kidney disease cases in a lifetime due to Superfund site remediation) (US EPA). This method shows promise as a way to better quantify risk estimates, but is not yet approved for use in EPA risk assessments.

Studies Characterizing Costs of Kidney Disease

Existing economic studies of kidney disease use the cost-of-illness approach to estimate costs for various kidney-related diseases. While a variety of older literature exists, this section discusses the most recent literature providing cost estimates for kidney diseases.[16] As discussed in the cost-of-illness section of Chapter 3, the present value per-case lifetime cost approach (i.e., the incidence approach) is most appropriate for evaluating policies which would reduce incident cases (see Held et al. 1992 below). Alternatively, the annual cost of prevalent cases (i.e., the prevalence approach) is useful for policies which would ameliorate existing cases (see Rice 1985 below).

Held et al. (1992) use the cost-of-illness incidence approach to calculate the adjusted lifetime present value of charges by treatment type for ESRD patients by age, race, and primary cause of renal failure. The lifetime estimates include Medicare-allowed charges and exclude lost wages. The authors estimate charges using two methods. One method ("intent to treat") calculates lifetime charges based on the treatment the patient was undergoing 181 days following the onset of ESRD. The other method ("transplant history") adjusts charges to account for patients who undergo transplant after 181 days following the onset of ESRD. Exhibit 2 below provides adjusted lifetime present value charges by age group for in-center hemodialysis, transplant (when it occurs before day 181), transplant (when it occurs after day 180), two methods of calculating continuous ambulatory peritoneal dialysis costs (CAPD), continuous cyclic peritoneal dialysis (CCPD), and home hemodialysis. These values represent the "transplant history" methodology for the youngest three

---

[16] For reference, Hu and Sandifer (1981) provide a review of 21 genitourinary system cost-of-illness studies conducted between 1969 and 1979.

age groups. Since the elderly (i.e., ages 65 to 74) less frequently obtain transplants, the authors calculate charges for this age group using only the "intent to treat" method. The reported charges represent the median expected charges associated with the first 50 percent of the patients to die (i.e., 50th percentile), weighted across gender and primary cause of renal failure.[17]

Exhibit 2
ADJUSTED LIFETIME PRESENT VALUE OF CHARGES BY KIDNEY DISEASE TREATMENT TYPE FOR ESRD PATIENTS[1] (Thousands of 1990 dollars)

Treatment Type	Ages 25-35 (number of obs.)[2]	Ages 40-50 (number of obs.)	Ages 55-64 (number of obs.)	Ages 65-74 (number of obs.)
In-Center Hemodialysis	$161 (7508)	$139 (11366)	$98 (20732)	$81 (28112)
Home Hemodialysis	$116 (276)	$161 (346)	$112 (601)	$88 (776)
CAPD (method 1)	$160 (1229)	$146 (1466)	$93 (2193)	$73 (3177)
CAPD (method 2)	$202 (346)	$142 (397)	$105 (580)	$81 (869)
CCPD	$154 (97)	$50 (90)	$95 (149)	$73 (197)
Transplant before day 181	$143 (1852)	$128 (1174)	$96 (328)	n/a
Transplant after day 180	$215 (4083)	$174 (3707)	$130 (1638)	n/a

[1] Costs calculated with a discount rate of three percent.
[2] The number of observations represent the total number of survival days in each age/treatment group.
Source: Held et al. 1992

---

[17] An analysis of lifetime kidney disease costs incorporates charges and number of survival years for a given sample of patients. To identify the sample, the analyst compiles the number of survival years for the first X percent of the patients to die (i.e., the Xth percentile). For example, Held, et al. calculate costs at the 85th percentile (i.e., the sample determined after 15 percent of the patients have died) and the 50th percentile (i.e., the sample determined after 50 percent of the patients have died). The analyst may calculate several lifetime cost figures by altering the choice of percentile.

The Held et al. values indicate that, as expected, lifetime costs are higher for younger patients. The transplant costs are the highest among treatment options ranging from $96,000 to $215,000 depending on age group (1990 dollars). CAPD costs range from $73,000 to $202,000 depending on the cost calculation methodology and age group. Hemodialysis charges range from $81,000 to $161,000. Finally, CCPD charge estimates are the lowest, ranging from $50,000 to $154,000. In 1995 the US Renal Data System Annual Data Report (NIH 1995) began conducting analyses of the cost and cost-effectiveness of ESRD treatments. The 1995 report presents per-case lifetime costs associated with alternative hemodialysis treatment options using techniques similar to Held (1992). The study reports that expected lifetime hemodialysis charges of the first 60 percent of the patients to die (i.e., 60th percentile) range from $70,000 to $72,800 (1992 dollars). These costs include Medicare and patient charges, and vary with type of hemodialysis treatment and primary cause of renal failure. Similar to the 1995 report, the 1997 Annual Report presents cost analyses, however these costs represent only Medicare spending for two particular procedures used in hemodialysis treatment (NIH 1997e). This study also reports Medicare reimbursements for different treatment options (i.e., CAPD, CCPD, hemodialysis, transplant) per time at risk. Because these results do not account for varying survival rates among treatment options and do not represent lifetime charges, they are inappropriate for valuing either existing or incident cases.

A study by Dor et al. (1992) uses the cost-of-illness approach to provide annual cost estimates associated with "free standing" dialysis facilities using 1987 data. The authors provide total annual cost estimates for dialysis facilities providing hemodialysis, CAPD, and CCPD treatment options, and for dialysis facilities that provide only hemodialysis services. These charges exclude costs associated with in-hospital dialysis facilities. In addition, the authors use a statistical cost function to estimate the average and marginal costs associated with hemodialysis and CAPD treatment options. The study estimates per-treatment costs for in-center hemodialysis, at-home hemodialysis, and at-home CAPD; however, these costs do not represent costs for either incidence or prevalence cases.

Showstack (1989) uses data collected between 1982 and 1986 to determine hospitalization costs for cadaveric and living-related donor kidney transplantation. This study presents the number of hospitalization days and total costs of cadaveric kidney transplant patients one year after surgery. These cost-of-illness figures are not appropriate for valuing incident or existing cases of ESRD.

Garner and Dardis (1987) calculate the cost per life-year gained for at-home dialysis, in-center dialysis, and kidney transplant treatment options.[18] The authors provide treatment costs that include and exclude output gains from market and nonmarket activities, but they recommend use of the more complete estimates that include measures of output gains. The study provides low and high estimates of treatment costs based on survival probabilities and earnings assumptions. The authors estimate costs using five and ten percent discount rates, and evaluate treatment modes over a 5-, 10-, 15-, and 20-year period by gender. Using a ten percent discount rate and 20-year treatment period, the study reports low and high estimates do not differ for at-home dialysis or in-center dialysis, but they do vary

---

[18] Garner (1984) provides a similar assessment in her 1984 dissertation.

for transplant options. The authors estimate at-home dialysis costs to be $25,000 per life-year gained, and in-center dialysis costs to be $32,000 per life-year gained (1981 dollars). Transplants from living-related donors range from $17,000 to $22,000 per life-year gained. Transplants from cadaveric donors range from $23,000 to $31,000 per life-year gained.

Rice (1985) uses health sector costs and earnings to estimate annual costs associated with genitourinary diseases for the US. The study reports health care costs of genitourinary diseases to be approximately $12 billion per year. Using an estimate of 154,000 total person-years lost to productivity due to genitourinary diseases, the authors also estimate morbidity damages to be approximately $1.8 billion per year (1980 dollars),

Because the cost-of-illness approach does not estimate individual willingness-to-pay to avoid the disease or its symptoms, it does not include the values associated with reduced quality of life associated with kidney disease. Economic studies of ESRD patients indicate several subjective measures not captured by the cost-of-illness approach may enter into kidney disease values (i.e., measures that reflect the emotional status of patients). A study by Gudex (1995) indicates that patients with ESRD experience a lower quality of life compared with the general population. The study reports that many factors contribute to this reduced quality of life, most notably uncertainty about the future and lack of energy. Comparing quality of life factors across treatment alternatives, the study indicates that transplant recipients experience a higher health-related quality of life than dialysis patients. Analyzing objective and subjective quality of life measures for ESRD patients, Evans, et al. (1985) note that transplant recipients had a higher objective quality of life than dialysis patients (i.e., measures that reflect the physical status of patients). In terms of functional impairment and ability to work, the study indicates transplant patients function closer to normal levels than dialysis patients. This study also indicates that transplant patients have a higher quality of life in terms of life satisfaction, well-being, and psychological effect than dialysis patients.

Discussion of Alternative Valuation Strategies

The first step in kidney disease valuation is to assess whether exposure has a significant adverse impact on the renal system. The links between contaminant exposure and kidney disease are not explicitly determined for many contaminants. Toxicological data will indicate if kidney disease is the critical health effect associated with contaminant exposure. In these cases, the RfD is the dose at which a population is put at risk for kidney disease, and depending on exposure levels, prevalent health effects may also be present. In cases where kidney disease is a prevalent health effect for a given contaminant, risks of kidney disease would be accompanied by risks to other adverse effects. Determining the dose-response relationship in this situation helps to assess whether

kidney disease effects are significant compared to other prevalent health effects. Examination of the health effects literature, perhaps with the intent of employing an incremental risk methodology similar to that used by EPA in the cadmium analysis (US EPA), will help to clarify the effect of exposure.

Once dose-response links have been established, the next step is to estimate the number of individuals likely to contract the disease. The traditional RfD measures indicate whether an exposed population is at risk for contracting kidney disease; they do not assign probabilities to a given dosage. One way to determine case numbers is to develop hypothetical scenarios of percentages of the exposed population who contract the disease. Unfortunately, there are no guidelines for determining such risk numbers. This hypothetical exercise would not be part of the primary valuation effort; however, it would provide an indication of whether kidney disease values could play a critical role in an analysis.

The third step in kidney disease valuation involves appropriately applying the per-case costs from the kidney disease literature. The literature indicates that cost estimates will vary with treatment type, age, gender, race, and primary cause of disease (e.g., see Dor et al. 1992; Held et al. 1992; Garner and Dardis 1987; Rice 1985). In addition, the choice of treatment type is also likely to vary with age (Held 1992). As a result, to the extent possible, it is important to consider the characteristics of the affected populations when applying cost-of-illness estimates.

Analysts should recognize that the cost-of-illness approach does not include some aspects of the effects associated with kidney disease. As previously noted, the literature takes a cost-of-illness approach to estimate the value of avoided effects, and this approach does not represent willingness-to-pay values to avoid the disease, pain and suffering associated with the disease, or values related to different qualities of life associated with various treatment options. Acknowledging that the full costs of kidney disease will be greater than a treatment charge calculation, and considering how these subjective measures may vary with the exposed population characteristics, contributes to a more accurate cost assessment. For example, as Gudex (1995) and Evans (1985) note, subjective cost measures are likely to vary among ESRD patients because some treatment options are associated with a lower quality of life than others.

Large differences between WTP and cost-of-illness (COI) estimates may exist also because of demographic or medical reasons. If kidney disease strikes people predominantly near or beyond the end of their working lives, there is little loss of productivity, making COI estimates small relative the value for avoiding the disease. In addition, an ESRD patient would be willing to pay more to avoid kidney disease if there is a chance a preferred treatment option would be denied. For example, transplant waiting lists are long and living related donors are not always available to patients. It is likely that the elderly would have a greater WTP than measured by COI because they are less likely to receive a transplant. In addition, younger ESRD patients on transplant waiting lists who might die waiting for a kidney would also be likely to have a greater WTP.

Since willingness-to-pay to avoid the disease (WTP) may be well in excess of the cost-of-

illness estimates, it may be valuable to adjust the cost-of-illness (COI) estimates for adverse quality of life conditions or attempt to estimate WTP. Similar to the Miller, et al. methodology (1989), an analyst may be able to use the quality of life indices reported in Evans, et al. (1985) to estimate quality-adjusted life years (QALYs) measures. Applying the QALYs measures to the value of a statistical life-year would provide a rough, but potentially informative, estimate. Alternatively, analysts could estimate the WTP to avoid kidney disease using stated preference methodologies discussed in Chapter 3 (i.e., the contingent valuation or risk-risk tradeoff approach). Similar to chronic bronchitis studies, analysts could use the risk-risk tradeoff method to estimate values. An application to ESRD would be similar to chronic bronchitis because in both cases patients live with the disease for their lifetime.

ECONOMIC VALUATION OF KIDNEY DISEASE REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). *ATSDRs Toxicological Profiles on CD-ROM.* Boca Rato, LA: CRC Press. 1997.

Aranzabal, J., L. Perdigo, J. Mijares, F. Villar. "Renal Transplantation Costs: An Economic Analysis and Comparison with Dialysis Costs." *Transplantation Proceedings* 23 (5). October 1991.

Croxson, B.E. and T. Ashton. "A Cost Effectiveness Analysis of the Treatment of End Stage Renal Failure." *The New Zealand Medical Journal* 103 (888). April 1990.

Dor, A., P.J. Held, M.V. Pauly. "The Medicare Cost of Renal Dialysis." *Medical Care* 30 (10). October 1992.

Evans, R.W., D.L. Manninen, L.P. Garrison, Jr., L.G. Hart, C.R. Blagg, R.A. Gutman, A.R. Hull, E.G. Lowrie. "The Quality of Life with End-State Renal Disease." *The New England Journal of Medicine* 312 (9). 1985.

Garner, Thesia I. "Economic Analysis of End-Stage Renal Disease Treatments." Dissertation, University of Maryland. 1984.

Garner, Thesia I. and Rachel Dardis. "Cost-effectiveness Analysis of End-stage Renal Disease Treatments." *Medical Care* 25 (1). January 1987.

Gudex, C.M. "Health-related Quality of Life in Endstage Renal Failure." *Quality of Life Research* 4. 1995.

Held, P.J., M.N. Turenne, R.R. Bovbjerg, R.A. Wolfe, F.K. Port. "Cost Effectiveness of ESRD Treatment Modalities." Final Report Vol. 1. 1992.

Hu, T.W. and F.H. Sandifer. *Synthesis of Cost of Illness Methodology*. Report to the National Center for Health Services Research, Department of Health and Human Services. 1981.

Karlberg, I. "Cost Analysis of Alternative Treatments in End-Stage Renal Disease." *Transplantation Proceedings* 24 (1). February 1992.

Keeton, W.T. *Biological Science.* Third Edition. New York: W. W. Norton & Company, Inc. 1980.

Miller, T.R., S. Luchter, C.P. Brinkman. "Crash Costs and Safety Investment." *Accident Analysis and Prevention* 21(4). 1989.

National Institutes of Health (NIH), National Institute of Diabetes and Digestive and Kidney Diseases. *End-Stage Renal Disease: Choosing a Treatment That's Right for You.* Document obtained from an internet web page at this address: http://www.niddk.nih.gov/endstagerenaldisease/endstagerenaldisease.html. 1997.

National Institutes of Health (NIH), National Institute of Diabetes and Digestive and Kidney Diseases. *Glomerulonephritis.* Document obtained from an internet web page at this address: http://www.niddk.nih.gov/ kusums/glomneph.htm. 1997a.

National Institutes of Health (NIH), National Institute of Diabetes and Digestive and Kidney Diseases. *High Blood Pressure and Kidney Disease.* Document obtained from an internet web page at this address: http://www.niddk.nih.gov/ kusums/hypotens.htm. 1997b.

National Institutes of Health (NIH), National Institute of Diabetes and Digestive and Kidney Diseases. *Lupus Nephritis.* Document obtained from an internet web page at this address: http://www.niddk.nih.gov/ kusums/lupuneph.htm. 1997c.

National Institutes of Health (NIH), National Institute of Diabetes and Digestive and Kidney Diseases. *Polycystic Kidney Disease.* Document obtained from an internet web page at this address: http://www.niddk.nih.gov/polycystic/pkd.htm. 1997d.

National Institutes of Health (NIH), National Institute of Diabetes and Digestive and Kidney Diseases, US Renal Data System. *USRDS 1997 Annual Data Report.* Bethesda, MD. 1997e.

National Institutes of Health (NIH), National Institute of Diabetes and Digestive and Kidney Diseases, US Renal Data System. *USRDS 1995 Annual Data Report.* Bethesda, MD. 1995.

Rice, D.P., T.A. Hodgson, A.N. Kopstein. "The Economic Costs of Illness: A Replication and Update." Health Care Financing Review. 1985.

Showstack, J. "Service Use and Costs Associated with Kidney Transplant." Agency for Health Care Policy and Research. Rockville, MD. Report #AHCPR-92/29. May 1989.

US EPA. "Toward a Method for Quantifying Human Non-Cancer Health Risks: Risks of Superfund-related Exposures and Potential Risk Reduction Benefits of Site Remediation." Draft Report prepared for US Environmental Protection Agency, Office of Policy Planning and Evaluation by Industrial Economics, Inc. (IEc) and Abt Associates, Inc. August 1997.

US EPA. "Noncancer Health Effects and Ecosystem Effects Valuation Bibliographies." Memorandum to Yvette Hopkins, Office of Solid Waste, US Environmental Protection Agency, from Beth Snell and Lisa Robinson, Industrial Economics, Incorporated. April 1994.

INDEX