Final Report

VALUATION OF REDUCTIONS IN HUMAN HEALTH SYMPTOMS AND RISKS

Volume 2

COMPARATIVE ANALYSIS OF APPROACHES TO VALUING HEALTH RISKS

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VALUATION OF REDUCTIONS IN HUMAN HEALTH SYMPTOMS AND RISKS

This is Volume 2 of a four volume report. The total project undertakes an assessment and reconciliation of attempts to value reductions in human health risks, and it develops new methods and estimates for these values. Volume 2 contains a comparative assessment of work on valuing health risks. Based on the assessment, a set of interim morbidity and mortality values applicable to effects of criteria air pollutants is developed. Volume 3 reports on a study developing and applying contingent valuation techniques to the types of light symptoms often attributed to air pollution. Volume 4 reports on the design of approaches for valuing serious or life threatening illnesses.

Abstract of Volume 2

COMPARATIVE ANALYSIS OF APPROACHES TO VALUING HEALTH RISKS

Following the introduction to Volume 2, section 2.2 presents a model for valuing health risk reductions which can be used to compare alternative approaches to valuing health risks. Plausible assumptions imply that cost of illness and preventive expenditures measures are lower bounds to willingness to pay for health risk reductions. Contingent valuation, hedonic measures and other valuation approaches are compared conceptually.

Section 2.3 gives a critique of econometric evidence on the effects of environmental quality on human health. One of several concerns with comparability and reliability is how estimates are affected by avoidance measures taken by individuals in response to adverse environmental conditions. The assessment considers in detail five major empirical studies of the effects of air pollutants on mortality.

Section 2.4 is concerned with the cost of illness approach to measuring health benefits. A contribution of the present project is to put estimates of the aggregate cost of illness (medical expenditures and foregone earnings) due to morbidity on an individual per case and per day spent ill basis. Section 2.4 includes an evaluation of previous cost of illness studies.

Section 2.5 is concerned with contingent valuation studies in which interview estimates are obtained of willingness to pay for health. The three major existing contingent valuation studies of morbidity are evaluated.

In Section 2.6, a comparison is conducted of cost of illness and contingent valuation benefit measures obtained for a group of individuals for a common set of symptoms. The results indicate that willingness to pay as revealed through contingent valuation greatly exceeds cost of illness. The two measures do not move

together in any systematic fashion,

Section 2.7 considers the household production approach, in which the individual produces health by combining his own time and effort with purchased goods. Two studies are reviewed that use this framework to produce illustrative empirical estimates of willingness to pay for health improvements.

Section 2.8 reviews the housing market hedonic literature throwing light on housing price premiums for air quality. Estimates from this literature are used to obtain suggestive upper bound estimates of the value of mortality risks.

Section 2.9 brings together the foregoing results to arrive at a set of health risk values for use in environmental assessments. Interim values applicable to air pollution are developed, High, low and medium estimates are developed for morbidity conditions and mortality. Medium estimates of the value of reducing various types of acute or short term morbidity range from $25 to $125 per day. Medium estimates of the value of reduced aggravation of previously existing chronic morbidity conditions range from $60 to $150 per day. Medium estimates of the value of reduced new incidence of chronic morbidity conditions range from $800 per year for uncomplicated angina to $60,000 per year for non-fatal cancer. The medium estimates for mortality range from $2 million for an unforseen instant death to $4 million for a death due to lung cancer.

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2. COMPARATIVE ANALYSIS OF APPROACHES TO VALUING HEALTH RISKS

2.1 INTRODUCTION

A wide variety of approaches to valuing health risks or the benefits of health improvements have been proposed and in many cases implemented. Though this work has been reviewed, there is a continued need for a comparison of the various approaches, on both a theorectical and an empirical level. In particular, while the special case of valuing mortality risks alone has received a good deal of attention, the problems of valuing morbidity risks alone, or of valuing the more general case of a combination of morbidity and mortality risks has received less attention. The goal of Volume 2 is to provide a comparative review of approaches to valuing changes in health, and a synthesis of the empirical results of the various approaches..

In the next section, competing approaches are defined and briefly reviewed, but the main result is the development of a model of health investment which yields a general expression for the value of changes in risks to human health. Thus section 2.2 serves as an introduction to, and a conceptual framework for, the remainder of the volume. The contention that costs of illness and preventive expenditures are lower bounds to the preference based willingness to pay measure is carefully examined. In addition, the section explores the relationship between the value of a certain change in health, and the value of a change in health risks.

In the remaining sections, the theoretical justification and empirical results of the particular approaches are examined at greater length. The general goal of these sections is to discover what empirical estimates of the value of health exist, and to assess how accurate and complete these value estimates are likely to be.

Section 2.3 reviews health econometric results on the relationship between air pollution and health. These studies may shed light on the structure of the demand for health, and the role of avoidance practices undertaken by individuals in response to poor environmental quality. If so, the results will have important implications for measuring the benefits of improved health due to air quality improvements.

Turning to studies that have been explicitly concerned with placing monetary values on illness, section 2.4 reviews the cost of illness approach. This is the most widely usedmeasure of the value of health. Estimates from existing aggregate cost of illness studies are put on a per case of illness or per day of illness basis, to be comparable to what an individual would be willing to pay. In this way, estimates of the value of a range of health effects are developed that can be used to evaluate environmental policy changes. A careful review of the conceptual and empirical backgound of the cost of illness approach is also undertaken.

Section 2.5 examines the results of the limited number of studies that apply the contingent valuation method to valuing morbidity. This section includes the new results from the contingent valuation experiment discussed in detail in Volume 3 of this report. Consideration is given to the questions of how accurate estimates from contingent valuation may be, and to how results from the different studies compare.

Since the cost of illness approach and contingent valuation are probably the most important methods currently used to value morbidity, Section 2.6 reviews the available evidence on how these two methods compare. The most conclusive evidence on this question is from the data collected in the contingent valuation experiment of Section 3. Section 2.6 uses these data to test the hypothesis that a cost of illness measure is a lower bound to willingness to pay as revealed by contintent valuation.

Section 2.7 draws out implications for the value of health from studies of the household production of health. While relevant work is extremely limited, two studies are reviewed that yield illustrative empirical estimates of the value of acute morbidity due to air pollution.

Section 2.8 reviews work relating property values to air quality. A number of conceptual and econometric issues that have yet to be totally resolved are examined. Following this discussion, the relationship between housing values and air quality is used to imply values for mortality risks.

Section 2.9 is a synthesis of the results from the previous sections. Based on what is known about the health effects of air pollution, and on what a complete estimate of the value of health would include, a framework for estimating the value of health is reviewed. Using this framework, a table of interim values for the morbidity and mortality effects due to air pollution is developed.

2.2. FRAMEWORK FOR VALUING HEALTH RISKS

In this section we develop a model of health investment which yields a general expression for the value of changes in risk to human health. The preference based values of morbidity risks and mortality risks are ex ante dollar equivalents of changes in expected utility associated with risk changes. The values of changes in morbidity risks and and mortality risks are related to two alternative measures, costs of illness and preventive expenditures, which are thought to be lower bounds on the value of risk reductions. We demonstrate that these alternative measures are not even special cases of the more general measure and that the size relationships among the three measures are complex. Also, we derive the relationship between willingness to pay for risk changes and the consumer surpluses associated with health changes which occur with certainty.

The section begins with a review of several approaches to valuing changes in risks which are currently in use. The model of health risk behavior is developed in Section 2.2.2. In Section 2.2.3 implications for benefit estimation of the benefit measure derived from the model are discussed and concluding remarks are given in Section 2.2.4.

2.2.1. Approaches To Valuing Health Risks

2.2.1.1. Cost of Illness

The traditional approach to measuring the benefits of improved health is based on avoidance of disease damages. The damage avoidance approach, which is the form used by health professionals and some health economists, is also referred to as the cost of illness approach or sometimes the earnings expenditure approach. The cost of illness approach relies heavily on the idea that people are producers i.e., human machines. Outlays for health services are seen as investments which improve people as productive agents and yield a continuing return in the future. The yield for improvements in health is the labor product created plus any savings in health care expenditures due to any reduction in disease (see Mushkin 1962. pp. 130 and 136). The costs of health degradation are the damages caused by the disease (or accident). The health expenditures made, the value of the resources used in supplying health care, are referred to as the direct cost of illness. The loss of labor earnings due to sickness and premature death, the value of the lost product of labor, is referred to as the indirect cost of illness. The value of health improvements is the sum of the reductions in direct and indirect costs of illness. i.e., the damages which will be avoided. Studies employing the cost of illness approach include Weisbrod (1971), Cooper and Rice (1976), and Mushkin (1979).

Several deficiencies in the cost of illness approach are recognized: (1) the indirect costs are zero for retirees, ful i

time homemakers and other people who do not work in the market, (2) an arbitrary decision must be made about forgone consumption expenditures, i.e., gross or net labor earnings, (3) individuals are viewed as having no control over their health or health care expenditures and (4) there is little basis in economic theory for the use of the costs of illness in benefit-cost analysis. An attempt has been made by Landefeld and Seskin (1982) to reformulate costs of illness values to more closely approximate a theorecticallycorrect measure, but their study primarily focuses on externalities and an approach more closely tied to individual optimization seems more appropriate. Section 2.4 below examines in much greater detail the cost of illness approach as a possible source of estimates of the benefits of health risk reduction.

2.2.1.2. Willingness to Pay in Contingent Markets

The absence of a market for health as such prompted consideration of direct questioning techniques to elicit willingness to pay for changes in health risks. Through a survey interview or laboratory experiment a hypothetical market is established, and individuals are asked to purchase changes in health directly contingent upon the existence of the market. Contingent valuation of mortality risks was pioneered by Acton (1973) in his study of heart attack treatment and has been used by Loehman (1979) et al. to value morbidity related to air pollution. Currently there is renewed interest in direct questioning because it yields conceptually correct values of health risk which are difficult to estimate using other techniques.

Contingent valuation is considered in detail in Volume 3 of this Report, and empirical results applied to the value of morbidity are reviewed in section 2.5.

2.2.1.3. Household Production of Health and Preventive Expenditures

While the cost of illness approach concentrates on damages or costs following the onset of illness, individuals can and do incur costs in efforts to prevent illness from ever occurring. In Grossman's (1972) model of consumption and production of the commodity "good health", individuals combine purchased goods such as medical care and their own time to produce health capital. Willingness to pay is the value ofhealthytime and is the sum of two terms: (1) the increment in labor earnings which is possible and (2) the monetary value of the gaininutility associatedwith better health. Thus, the household production model gives a conceptual foundation for the relevance of labor earnings (indirect costs) for morbidity, but it also implies that a preference-based value will depend on the costs of producing health (preventive expenditures) and a utility, or consumption, value. An example of the household production approach is Cropper's (1981) micro study of the effect of air pollution on days lost from work due to illness. To value the health changes

she multiplies the wage rate by a factor derived from a specific production function.[1] This study and a study by Gerking and Stanley (1984) are discussed in section 2.7.

The recognition that health is partly endogenous has also spawned the idea that health improvements permit a reduction in preventive expenditures and that the savings of preventive expenditures is the value of the health improvement. This general approach has been suggested as a way to measure the benefits of reducing pollution where the expenditures prevent not only damages to human health, but also damages to property and so forth. Courant and Porter (1981) characterize the literature as having reached a limited consensus that such expenditures represent a lower bound to the total costs of pollution, a conclusion they dispute.

In a recent empirical investigation, Smith and Desvousges (1985) find that households do make adjustments to reduce the risk of exposure to hazardous wastes through drinking water. In their sample of households in suburban Boston nearly thirty percent purchased bottled water regularly to avoid hazardous wastes, while smaller fractions installed water filters and attended public meetings as ways to reduce the risks. This study provides important evidence that averting or preventive behavior in response to pollution risks can be significant. However, the relation between preventive expenditures and the benefits of improved health has received little attention. We explore this relationship.

2.2.1.4. Willingness to Pay in Implicit Markets

One implication of household production models of health is that individuals will make expenditures of money and time to improve their health and reduce risks to their health. By observing people's behavior in well-developed markets for ordinary goods and services values can be derived for health, which is not traded explicitly. Much of this type of evidence comes from the labor market in the form of estimates of compensating wage differential for jobs with extraordinarily high risks to health and survival. Most of the studies focus on implicit values of changes in the risk of a fatal accident.

Consumption activity also can involve exchanges between health and safety and other desirables. Estimates of willingness to pay have been made based on analyses of residential housing site choice, automobile seat belt use, speed of travel on highways and cigarette consumption.[2] This work, like that in the labor market, has focused on mortality risk. Inherent in this methodology of estimating implicit values of health risks is that individuals know and perceive differences. in health risks associated with various jobs and consumption activity and that they can choose among various alternatives.

Theoretical and empirical problems in viewing housing markets as implicit markets for valuing health are examined in Section 2.8. Estimates from these studies are reviewed as well.

2.2.1.6. A General Framework for Valuation

At this point there appear to be two disparate approaches to valuation of health and risks: cost of illness perhaps inclusive of preventive expenditures, and willingness to pay. Research has proceeded using one approach or the other, but only limited effort has been made to compare and reconcile the approaches. A recent paper by Harrington and Portney (forthcoming) is noteworthy in that they show that for morbidity, under certain conditions, the cost of illness values will be a lower bound on the theoretically preferred willingness to pay values. Below we develop an eclectic model with endogenous health risks and derive the preference based values for changes in health risks. The model considers morbidity and mortality and allows the probabilities of various health states and survival to be influenced by preventive activity and exogenous factors such as environmental quality. Terms for preventive expenditures and costs of illness in the benefit expression are identified for purposes of comparison with the conceptually correct willingness to pay. The model provides a framework for comparing values of health risks estimated using various techniques.

2.2.2. Human Health Risk Reduction Benefit Model

Assume a person's utility depends on the consumption of goods and services and the state of health. Utility may be expressed as

$$u = U(C,q), \tag{1}$$

where U is utility, C is consumption and q is a vector of health characteristics.[3]

A person does not know with certainty, however, what his health will be, or for a given state of health, whether or not he will survive the period in question. In order to incorporate these uncertainties into the model, we specify probability of health characteristics and probability of survival functions. The probability density function for health characteristics can be represented as

$$h(q;X,E), \tag{2}$$

where X is preventive expenditures and E is any exogenous shift variable, such as environmental change. Thus, the health characteristic probabilities are not immutable, but rather are influenced by preventive measures chosen by the individual person and exogenous changes 'such as environmental improvement.

It is reasonable to assume that the healthier a person is, the greater are the chances of survival of a given period. In other words, probability of survival can be expressed as a function of health characteristics:

$$P = p(q), \tag{3}$$

where p is the probability of surviving the period.

A final element of the model facilitates comparisons with the cost of illness approach for valuing health risk reductions. When in poor health, a person incurs cost such as medical expenditures and earnings lost due to days not worked. These costs will vary according to the degree of illness malfunction that occurs:

$$Z = f(q), \tag{4}$$

where Z is the cost incurred as a result of illness malfunctions. These expenditures reduce consumption, and provide no utility on their own.[4]

In this framework, a person chooses preventive expenditures X, in order to maximize the expected value of utility given the following income constraint:

$$M - C + x + z, \tag{5}$$

where M is money income in the absence of any' costs due to illness malfunctions,[5] Preventive expenditures influence the expected value of utility in three ways: (1) X increases the probability of being in good health, therefore increasing utility if alive; (2) at the same time, increasing the probability of being in good health also increases the probability of being alive; (3) finally, by increasing the probability of being in good health, X expenditures decrease malfunction costs Z that can be expected, increasing the amount of income expected to be left over for consumption. These benefits must be weighed against the direct loss in consumption made necessary by the preventive expenditures.[6]

More, formally, the consumer's problem can be stated as

(6) Max E(U) = the integral from negative infinity to positive infinity of

[U(C,q)p(q)h(q;X,E)dq]

subject to the income constraint (5). Reexpressing the income constraint in terms of C and substituting it into (6), the consumer's problem becomes

(7) Max E(U) = the integral from negative infinity to positive infinity of

[U(M-X-f(q),q)p(q)h(q;X,E)dq]

where U, p, and h come from equations (1), (3) and (2) respectively.[7]

The integral in (7) gives utility under different health outcomes weighted by the probability of the various outcomes. Since utility always depends upon health, the situation could be described as a continuum of state dependent utility functions, the possible states being the possible health outcomes. Different attitudes toward risk are allowed for through the shape of each state dependent utility function. When utility is expressed as U(M-X-F(q),q), it becomes apparent that preventive expenditures X directly reduce the amount of income left over for consumption. The term p(q) in (7) adjusts utility by the probability of being alive. Assuming no utility if dead, U(M-X-f(q),q) p(q) gives expected utility conditional on the state of health. A more extended analysis might consider utility of heirs as affected by bequest. The density function h(q;X,E) weights expected utility by the probabilities of different states of health. The integration over health states thus gives expected utility for the period;

The model as described does not specify fully the mechanisms available to the individual to adjust to risk such as market insurance. The only opportunity the individual has is to make ex ante preventive expednditures X that change the probabilities of the different states. V. Kerry Smith suggests that another extension of this analysis could be to carefully describe what opportunities are availabe to the individual to adjust expenditures made in each state of the world. Though these opportunities could easily be made explicit in the present model. this section retains the simpler framework in order to make the comparisons between preventive expenditures, cost of illness, and willingness to pay for risk reductions more straight forward However, in general willingness to pay values are affected by the opportunities available to adjust to risk, so it is vital to not* the simplified framework used.

The problem also becomes more tractable if a single health outcome measurable as a zero-one condition is considered. An example is occurrence of a specified type of cancer as affected by environmental irritants. Another example is occurrence of traffic accidents due to poor visibility brought on by air pollution, provided the major cost is associated with frequency of accidents, all having about the same expected severity, rather than the severity of an individual accident being importantly related to the degree of visibility. Tissue damage from contact with pollutants, such as liver damage, is another example as long as the principle effect is absence of unimpaired functioning rather than the degree of malfunctioning being associated with the degree of pollutant level.

A damage function, as might be the case for ozone, where the degree of discomfort rather the presence or absence of discomfort is related to the level of pollution, requires a more extended analysis considering probabilities for more than two states of the world. Various degrees of symptoms along with their associated probability densities have to be considered rather than just presence or absence of symptoms. The integral in (7) would not simplify as it does in the case where there is only one malfunction state.

If health is a matter only of absence or presence of a deleterious condition, the probability density function $h(q;X,E)$ is discrete rather than continuous with probability concentrated at q-l for presence of condition and q-0 for absence of condition:

$$h(q;X,E) = H(X,E) \text{ if } q\text{-}l \tag{8}$$

$$h(q;X,E) = (1 - H(X,E)) \text{ if } q\text{-}0,$$

where $H(X,E)$ is the probability of the absence of the condition.

In this case, the person decides at the beginning of the period what his preventive expenditures will be and then takes the resulting chance of what the health outcome will be for the period. A long planning period can be considered by letting consumption expenditures, illness costs, and preventive expenditures be average discounted present values, with the probabilities associated with survival and health status being averages of shorter term probabilities, possibly allowing for cumulative exposure effects.

Because of the discreteness of q when health is a matter only of the absence or presence of a condition, the integral in (7) simplifies to a sum of two discrete states corresponding to q-0 and q-l. Using (8), the consumer's maximization problem is

(9) $$\text{Max } E(U) = U_0 P_0 (1-H) + U_1 P_1 H$$

where $U_0 = U(M-X,0)$ is utility if free of the disease

$U_1 = U(M-X-Z,1)$ is utility with the disease

$P_0 = p(0)$ is probability of survival if free of the disease

$P_1 = p(1)$ is probability of survival with the disease

$H = H(X,E)$ is the probability of contracting the disease.

Equation (9) states that the expected utility to be maximized is the sum of utilities in the absence and the presence of the deleterious health condition, weighted by the probabilities of contracting and not contracting the disease and of surviving. As can be seen from the expressions for U_0 and U_1, utility depends both on the presence or absence of the disease, i.e. there is state dependence. The income constraint has been substituted into the utility function just as in equation (7). In the discrete case, this constraint can be expressed as[8]

(10)
$$C = (M - X) \text{ if } q = 0,$$
$$C = (M - X - Z) \text{ if } q = 1.$$

Differentiating equation (9) with respect to preventive expenditures X and setting the result equal to zero gives the first order condition for a maximum:

(11) $$F = U'_0 P_0 (1-H) - (U'_1 P_1 H) - (U_0 P_0 H_x) + (U_1 P_1 H_x) = 0,$$

where U'_0 and U'_1 are the marginal utilities of income when q = 0 and q-l respectively, and H_x, the change in the probability of contracting the disease resulting from an extra dollar spent on prevention. The first two terms give the decline in expected utility due to decreased consumption when an extra dollar is spent on defensive measures. The last two terms give the rise in expected utility due to decreased probability of contracting the disease as a result of the extra dollar spent on prevention. The first order condition for a maximum is that the sacrifice of consumption given by the first two terms must just offset the gain from the reduced probability of contracting the disease given by the last two terms.

In order for the consumer to obtain a maximum, the second

derivative of the expected utility function with respect to preventive expenditures must be less than or equal to zero. This second-order condition can be expressed as

$$(12)\quad \text{delta} = -U''P_0(1-H) - (U''P_0H) - (U_1P_1H_x) + (U_1P_1H_{xx}) < 0,$$

where H_{xx} is the second partial derivative of $H(X,E)$ with respect to X, and U''_0 and U''_0 are the second derivatives of utility with respect to income when q-0 and q-l respectively.

2.2.3. Valuation Of Changes In Risks To Human Health

2.2.3.1. Willingness to Pay

Expressions for the marginal willingness to pay (WTP) for an exogenous reduction in health risks can be derived from this model. The totally differentiated expected utility function must be solved for the change in income thatwouldbe required to keep expected utility constant when there is an exogenous change. The individual would be willing to pay the negative of this compensating variation for the exogenous improvements in health risks.

$$(13)\quad dE(U) = [U'_0P_0(1-H) + U'_1P_1H]\,dM + [(-U'_0P_0(1-H)) - (U_0P_0H_x) - (U'_1P_1H) + U_1P_1H_x]\,dX + [(-U_0P_0H_E) + (U_1P_1H_E)]\,dE$$

As before, U'_0 and U'_1 are the marginal utilities of income when healthy and ill, respectively. Just as with the levels of utility, these marginal utilities may differ from each other for two reasons. First, the level of consumption is higher when healthy, because of the costs incurred when ill (Z). Second, the presence or absence of a condition directly enters the utility function.

Holding expected utility constant in equation (13) by setting $dE(U) = 0$, equation (13) can be solved for the WTP measure:[9]

$$(14)\quad -dM/dE = -[(U_oP_o - U_1P_1)/m]H_E - [1 + ((U_oP_o - U_1P_1)/m)H_x]\,dX/dE.$$

The numerator of the first term is the difference in expected utility when healthy and when ill. This is divided by m = $(U'P(1-H) + U'PH)$, which is a weighted average of the expected marginal utility when healthy and the expected marginal utility when ill, with the weights being the probabilities of being healthy or ill. Thus m can be interpreted as the expected marginal utility of income.

So far, the analysis has neglected the fact that individuals choose the level of defensive expenditures so as to maximize expected utility. Rearranging the first-order condition given by equation (11) yields:

$$(15) \qquad (U_o P_o - U_1 P_1)/m = -1/H_x.$$

The left hand side is familiar from the WTP expressions. As the dollar value of the difference in expected utilities when healthy and ill, it can be interpreted as the marginal benefit of defensive expenditures that reduce the probability of illness. The right hand side is the marginal cost of defensive expenditures.

Allowing the optimal choice of defensive expenditures as individuals adjust to the exogenous changes in health risks or the environment implies that equation (14) satisfies the first order condition. Substituting the first order condition as given by (15) into the WTP expression given in (14):

$$(16) \quad -dM/dE = HE/H, + [-1 + (H_x/H_x)]dX/ = H_E/H_x.$$

This simplification allows the WTP measure to be expressed independently of the non-observable utility function, but instead in terms of the health risk function H. In particular, equation (16) gives the WTP for a change in environment as a ratio of the marginal product of the environment in reducing health risks and the marginal product of preventive expenditures in reducing health risks. This result is very similar to the findings of others who suggest WTP for an environmental improvement can be expressed solely in terms of the production function (see Courant and Porter (1981), Harrington and Portney (1983), Gerking and Stanley (1984), and Needleman and Grossman (1983)). One obvious difference is that while in these models health is deterministically a function of the environment and defensive expenditures, in our model the probabilities of being healthy or ill are a function of these variables. Another difference is that our model considers mortality as well as morbidity.

Equation (16) is the basis for one approach to obtaining

empirical estimates of willingness to pay. In principle, the health risk function H(X,E) could be estimated, yielding the marginal products necessary to compute WTP. Gerking and Stanley (1984) use this strategy to estimate WTP for ozone reductions in a model with pure morbidity under certainty. (See section 2.7 for a discussion of this study). However, Harrington and Portney (forthcoming) and Maureen Cropper emphasize the difficulties in correctly estimating a health or health risk production function.

The fundamental problem with the health production function approach is that it is hard to identify and measure all of the inputs that affect health. Harrington and Portney point out that typical epidemiological studies only explain a small fraction of the total variation in illness, suggesting that a number of important variables may have been omitted. In estimating a health production function applicable to air pollution-induced morbidity, the health outcome would be acute respiratory illness and not general health status. This could make the empirical estimation even more difficult, since respiratory health is jointly produced with other aspects of health. Finally, equation (16) only holds as a marginal condition. Bockstael and McConnell (1983) show that it may also be very difficult to use the household production approach to estimate the value of non-marginal changes. All of these problems indicate that the health production function approach to estimating WTP may be of limited usefullness. Below, other estimation strategies are investigated.

To allow for a more intuitive interpretation, equation (16) can be rewritten recalling that $H = H(X,E)$

$$dH/dE = H_x(dX/dE) + HE \tag{17}$$

or rearranging,

$$HE = (dH/dE) - H_x(dX/dE).$$

Substituting this expression for the marginal product of the environment in reducing health risks into equation (16) we have

$$\begin{aligned} -dM/dE &= [(dH/dE) + H_x(dX/dE)](1/H_x) \\ &= (1/H_x)(dH/dE) - (dX/dE). \end{aligned} \tag{18}$$

Writing this benefit expression in terms of utility by using the left hand side of the equation (15) we have

$$-dM/dE = -[(U_oP_o - U_1P_1)/m](dH/dE) - (dX/dE). \tag{19}$$

This form of the benefit expression states that a person's WTP

for an environmental improvement can be expressed as the sum of two terms. The first term is the dollar value of the expected difference in expected utilities when healthy or ill multiplied by the change in health risks due to the change in the environment or other exogenous factor. The second term is the change in preventive expenditures resulting from the exogenous change.

Our model yields an expression for willingness to pay which is ex ante in nature, i.e., before it is known whether or not the individual is sick. The value is that amount of income we have to take away from both states to keep expected utility constant. The value is defined by:

$$(20) \qquad U_0 P_0 (1-H) + U_1 P_1 H - U(M-X - dM/dE, 0) \hat{P}_0 (1-H) - U(M-X-Z\ dM/dE, 1)\ \hat{P}_0 H = 0$$

where the ^ indicates the value of a variable after a change in E. In the context of uncertainty our willingness to pay, -dM/dE, is similar to an option price (see Smith (1983)), since it is a constant payment regardless of the state of nature that actually occurs. V. Kerry Smith points out that in the model described in this section, however, the framework in which individuals can purchase state contingent contracts is not fully specified, so it is difficult to restrict the payments to be constant across the states of nature. As explained earlier, the only opportunity for individuals to adjust to risk is the purchase of preventive expenditures. These features of the model mean that the willingness to pay measure, -dM/dE, may not be consistent with conventional measures of option price. The measure is nevertheless a valid ex ante compensating variation for changes in risk.

2.2.3.2 Comparisons to Preventive Expenditures and Costs of Illness

It seems natural to assume that people will pay a positive amount for an environmental improvement. This means that to keep expected utility constant in the face of an exogenous improvement in the environment, an individual's income would have to be reduced, i.e., $dM/dE < 0$ and positive willingness to pay is equal to - dM/dE. Inspection of the benefit expression given in equation (17) reveals that WTP could be positive if both terms, the utility value and the preventive expenditure value, are positive. Since the total derivatives, dH/dE and dX/dE, show how risk and expenditures change after optimizing behavior, however, the terms cannot be unambiguously signed. For the total derivatives the general and plausible results and accompanying conditions are summarized in Table 2-l.

TABLE 2-1: COMPARATIVE STATIC RESULTS OF THE HEALTH RISK MODEL

	General Result	Plausible Results	Sufficient Conditions for Plausible Results
Preventive Expenditures	$\frac{dX}{dE} \gtrless 0$	$\frac{dX}{dE} < 0$	$H_{EX} > 0$ and $(U_0P_0 - U_1P_1) > 0$ and $(U_0^1P_0 - U_1^1P_1) \geq 0$.
Morbidity Risk	$\frac{dH}{dE} \gtrless 0$	$\frac{dH}{dE} < 0$	$\frac{dX}{dE} < 0$ and $H_E > H_X \frac{dX}{dE}$. or $\frac{dX}{dE} \geq 0$.
Willingness to Pay and Preventive Expenditures [a]	$-\frac{dM}{dE} \gtrless -\frac{dX}{dE}$	$-\frac{dM}{dE} > -\frac{dX}{dE}$	$\frac{dX}{dE} < 0$ and $\frac{dH}{dE} < 0$
Willingness to Pay and Cost of Illness [a]	$-\frac{dM}{dE} \neq -Z\frac{dH}{dE}$	$-\frac{dM}{dE} \neq -Z\frac{dH}{dE}$ [b]	Many exist
Willingness to Pay and Preventive Expenditures - Pure Morbidity Case [a]	$-\frac{dM}{dE} \gtrless -\frac{dX}{dE}$	$-\frac{dM}{dE} > -\frac{dX}{dE}$	$\frac{dX}{dE} < 0$ and $\frac{dH}{dE} < 0$.
Willingness to Pay and Costs of Illness - Pure Morbidity Case [a]	$-\frac{dM}{dE} \neq -Z\frac{dH}{dE}$	$-\frac{dM}{dE} > -Z\frac{dH}{dE}$	$\frac{dH}{dE} < 0$ and $\frac{dX}{dE} < 0$ and $U(C,0) > U(C,1)$ and $U(Z)/\lambda^{**} > Z$

[a] Willingness to pay is equal to $-\frac{dM}{dE}$.

[b] It is implausible that $-\frac{dM}{dE} = -Z\frac{dM}{dE}$. A set of sufficient conditions for this result is $\frac{dX}{dE} = 0$, $U(.) \neq U(.,q)$, $U(.,Z)/\lambda^* = Z$, and $P_0 = P_1 = 1$.

Preventive Expenditures

Consider the expenditure response of the individual to a change in the environment, dX/dE. Using the first order condition, F, shown in equation (11) and the implicit function rule, its-follows that:

$$(21) \qquad dX/dE = - F_E/F_X = - F_E/delta$$

where delta < 0 from the second order condition given by equation (12). The sign of dX/dE then is the same as the sign of F_e. Differentiating F with respect to E we get:

$$(22) \quad F_E = (U'P - U'P) H - (U P - U P) H_{EX}$$
$$\qquad\quad 0\,0 \quad 11 \qquad 0\,0 \quad 11$$

which cannot be signed unambiguously. The implication is that dX/dE need not be negative in that preventive expenditures could increase with an environmental improvement. Nonetheless, under plausible conditions dX/dE will be negative. If HEX > 0, which is the case if H and E are substitutes, and if $(U_0P_0 - U_1P_1) > 0$, which is the case if expected utility when healthy exceeds the expected utility when sick, and if the difference between expected marginal utilities is small, then $F_E < 0$. If $F_E < 0$, then dX/dE < 0.

Change in Health Risk

The risk response to a change in the environment, dH/dE, depends in part on dX/dE as can be seen from equation (17). The sign of dH/dE is negative if dX/dE < 0 and if H_E is larger in absolute value than H_X dX/dE; the sign of dH/dE is also negative if $dX/dE \geq 0$. In other words, the sign of dH/dE is negative except' when dX/dE < 0 and, what seems to be unlikely, the direct effect (HE) is less than the indirect effect (H_E dX/dE). While it is possible that the indirect effect can dominate even where there is evidence of counterproductive exogenous changes, alternative explanations are offered as being more plausible, e.g. see Viscusi (1984).

The upshot of this discussion is that while the two terms in equation (19) taken together surely imply that a positive amount will be paid for an environmental improvement, it is not strictly true that the terms separately will each imply positive payments It is the case, however, that the payments for reductions in risk and preventive expenditures will be positive under the plausible conditions that X and E are substitutes and the direct effect of E on H dominating the indirect effect through dX/dE. Under these conditions the willingness-to-pay for an environmental

improvement is the sum of the utility value of the reduction in risk and the savings in preventive expenditures. Also under these conditions the savings in preventive expenditures, dX/dE, is a lower bound on willingness to pay. If the conditions described above do not hold, then dX/dE is not necessarily a lower bou-nd on WTP. Under no plausible conditions is dX/dE a special case of WTP.

Cost of Illness

On the basis of the benefit expression it is tempting to consider a value of exogenous improvement based solely on the costs of illness as special case of the general WTP measure. Indeed, there might appear to be conditions under which the expression approaches being a special case of WTP. For instance, if (1) defensive expenditures are nonexistent or unchanging, and if (2) health does not enter the utility function directly, the WTP expression shown in equation (19) collapses to the first term, and the difference in expected utilities when healthy and ill only reflects the reduced level of consumption when ill due to the costs of illness incurred, Z. Even with these severe restrictions, however,

$$(23) \qquad -Z\,dH/dE \neq \frac{U(M-X)P_0 - U(M-X-Z)P_1}{m^*}\,dH/dE$$

where $m^* = U'[P_0(1-H) + P_1H]$. For Z to equal WTP additional questionable restrictions are necessary. For example sufficient conditions are that (3) the monetary value of the utility of consumption be equal to consumption expenditures, $Z = U(Z)/m^*$, and (4) the probability of survival be equal to one, $P_0 = P_1 = 1$, see Table 2-l. In fact, there are no plausible assumptions which can be made to simplify the WTP measure to cost of illness. It is even less likely that WTP will equal Z*, the more commonly used cost of illness measure which excludes the value of lost nonwork time.

Morbidity Risk

For the sake of brevity and because considerable attention has been given to mortality risk in previous articles we focus on valuing changes in morbidity risks.[10] For the pure morbidity case, there is no possibility of death whether healthy or ill, so $P_0 = Pl = 1$. The general WTP expression, equation (19), simplifies to:

$$(24)\quad -\frac{dM}{dE}\Big|_{P_0 - P_1} = -\frac{U(M-X,0) - U(M-X-Z,1)}{m^{**}}\,\frac{dH}{dE} - \frac{dX}{dE}$$

$$= -\frac{U_0 - u_1}{m^{**}}\,\frac{dH}{dE} - \frac{dX}{dE}$$

where $m^* = U'(1+H) + U'H$ which is expected marginal utility of consumption for the morbidity case.

The relationship between WTP and preventive expenditures is again, as in the case of morbidity and mortality, complex in that neither is unambiguously larger than the other. Again, however, under similar plausible conditions dX/dE is lower bound on WTP; see Table 2-l.

As in the case of morbidity andmortality there is no reason to believe that WTP equals the savings in costs of illness, - Z dH/dE. Plausible conditions do exist however, under which - Z dH/dE is a lower bound on WTP. If $dH/dE < 0$ and $dX/dE < 0$, then WTP > - Z dH/dE because Z dH/dE. One reason is that health enters directly in the utility function and utility is enhanced by health; U(C,O) > U(C,1). Another reason is that we expect the dollar value of utility lost due to losing Z dollars of consumption to costs of illness is less than Z. This relationship between the value of the utility of consumption and consumption expenditures, or labor earnings, has been explored in depth in the "value of life" literature. Conceptually it cannot be shown, strictly, what the empirical relationship should be, see Linnerooth (1979). Still, a representative theoretical conclusion is that the value of utility of consumption or earnings will "usually" exceed their dollar value; see Bergstrom (1982). Reviews by Blomquist (1981, 1982) and Violette and Chestnut (1983) of the estimates of the value of mortality risks are consistent with Bergstrom's conclusion. The implication for our case of morbidity is that U(Z)/m** > Z dH/dE. This relationship along with U(C,O) > U(C,1) lead WTP > - Z dM/dE. If also $dX/dE < 0$, then WTP exceeds - Z dH/dE by a greater amount. So, while we cannot definitely conclude that cost of illness measures produce a lower bound for willingness to pay, the lower bound conclusion seems plausible. These results are sumarized in Table 2-l.

2.2.3.3 Comparisons to Certainty Values of Morbidity

The willingness to pay expression in the pure morbidity case is shown in equation (24). The WTP holds expected utility constant in the face of an exogenous change in health risk. This

can be compared to measures of certain changes in morbidity as follows.

Define consumer surplus (CS) as the dollar amount which holds utility constant in moving from the certainly sick to the certainly well state. For an irreplaceable commodity such as health this measure is what Cook and Graham ((1977) call a "ransom." In terms of the model, CS is thus the difference between the utility in the healthy state and sick state $(U_0 - U_1)$ expressed in dollar terms by dividing by the marginal utility of income. The expected consumer surplus associated with an exogeneous change in the environment is the product of CS and the change in the probability of the certainly well state caused by the exogenous change:

$$\text{(25)} \qquad \text{Expected CS} = -\text{CS } dH/dE.$$

$$= -\frac{(U_0 - U_1)}{\text{(marginal utility of income)}} \, dH/dE$$

Comparing equations (24) and (25), it is clear that the willingness to pay for changes in morbidity risks given by (24) is almost the expected value of consumer surplus, adjusted for changes in preventive expenditures. That is, equation (25) is almost the first term of equation (24). The only ambiguity in this comparison is that in expressing the change in utility in dollar terms in equation (24), m**, the expected marginal utility of income or money is used. Since m** is a weighted average of marginal utilities when healthy and when ill, if we assume the marginal utilities are the same, the problem is resolved. In general, it is not clear when these two marginal utilities will be equal, since differences in consumption levels and health status are involved. The relationship between the marginal utilities of income across states also depends upon the opportunities the individual has to adjust expenditures across states. For instance, with actuarially fair insurance available the individual will equate marginal utilities across states, though this will not necessarily result in full insurance in the sense that levels of utility are equal across states (see Cook and Graham (1977)). In any case, if the marginal utilities of income across states are close to each other, willingness to pay for a change in health risks is approximately equal to the expected value of consumer surplus, adjusted for changes in preventive expenditures.

Consumer surplus is what previous studes which address the pure morbidity case have measured in their valuation expressions since they have avoided the question of uncertainty. The empirical work in Volumes 2 and 3 of this report also makes use of consumer surplus, In particular, since it is difficult to

appropriately incorporate uncertainty into the contingent valuation sxperiment, we measure consumer surpluses associated with certain changes in morbidity. However, we are able to approximate willingness to pay for risk changes by the expected value of these consumer surpluses as explained above.

2.2.4 Concluding Remarks

The main purpose of this paper has been to compare preference-based willingness to pay measures for human health risk reduction with the main alternative approaches that are currently in use. After providing discussions of the various approaches, we construct an eclectic model from which we derive preference-based (WTP) values for changes in health risks, which are then compared with the alternative approaches. The model incorporates partly endogenous health, uncertainty, mortality, and morbidity. In fact pure mortality and pure morbidity, to which previous studies have been confined, are considered as special cases of the more general framework.

In the general case, we find that the preference based willingness to pay measure for reductions in health risks consists of two terms: a utility term, which reflects the cost of ilness as well as other factors; and a term reflecting preventive expenditures. It does not follow, however, that benefit measures involving the cost of illness alone or preventive expenditures alone are special cases of our general willingness to pay measure. It is difficult or impossible to specify truly reasonable assumptions under which the willingness to pay measure collapses to a cost of illness measure or a preventive expenditures measure. Our emphasis is somewhat different from that of Harrington and Portney's in that their willingness to pay measure for a reduction in morbidity is reduced to the cost of illness measure under the assumptions that there are no preventive expenditures, and health does not enter the utility function directly.

Even the weaker result that the alternative benefit measures are lower bounds to the willingness to pay measure does not necessarily hold for our model. Without additiona. assumptions, we cannot establish any general comparisons between the three measures. We do find a set of plausible assumptions under which some comparisons of the alternative benefit measures can be made. First, it is necessary to assume that the environment and preventive expenditures are substitutes in reducing health risks. Second, the direct effects of a change in the environment on health risks must outweigh the indirect effects, so $H_E > (H_X)(dX/dE)$. Third, the marginal utilities of consumption when healthy and ill must be approximarely the same.

If the above assumptions are made, for the special cases of pure mortality and pure morbidity. both the cost of illness and the preventive expenditures will plausibly be lower bounds to

willingness to pay. The cost of illness approach understates the true willingness to pay for several reasons. First, it neglects the savings of preventive expenditures. Second, it does not allow for individuals to enjoy health directly, i.e., it implies in our formulation that health q does not enter the utility function.' Third, from the "value of life" literature it seems reasonable to conclude that the value of the utility of consumption will exceed consumption expenditures, so the utility lost due to expenditures lost resulting from cost of illness is greater than the cost of illness. It should be stressed that this result directly applies to the case of mortality, but would seem to be plausible for morbidity as well.

Preventive expenditures also are likely to be a lower bound to willingness to pay. The preventive expenditures are not a complete measure of the benefits of health risk reduction to an individual because the individual enjoys gains in expected utility as well as the savings of expenditures. Our model does not suggest any necessary relationship between the cost of illness and preventive expenditures measures.

One additional result is that the benefit of an exogenous change that improves both mortality and morbidity risks is not the simple sum of the benefits of mortality risk reduction and the benefits of morbidity risk reduction.

Our results'come from a model of individual maximizing behavior which considers the private costs and benefits. Thus, our results cannot be immediately generalized to social costs and benefits. However, we are able to draw some conclusions. For instance, we find in the case of pure mortality that private WTP and private cost of illness are unrelated since the latter does not matter to an individual if he dies. Only if we were to build in bequests, or to impose some constraint on the amount of debts thatcouldbe left at death, would costofillness enter the pure mortality framework. But we know costs of illness are not necessarily zero for society. So society's willingness to pay for a reduction in mortality risk may exceed the willingness to pay of the individual.

Empirical research on mortality risks has tended to confirm the prediction that benefit measures based on cost of illness will be lower bounds to benefit measures based on a willingness to pay approach. Further empirical work is needed to substantiate or refute the theoretical result that for morbiditv the cost of illness will be smaller than the willingness to pay Work.along these lines is reviewed in Section 2.6. In addition. future empirical work could shed some light on the case where both mortality and morbidity risks are present. Data which contain contingent value estimates of willingness to pav. estimates of direct and indirect costs of pollution related illness, and also pollution related preventive expenditures could be highly useful. These data would enable us to further investigate the questions examined in this section.

2.2.5 Footnotes

1. Cropper (1981) does obtain estimates of valuation of health changes, she does so only under very specific assumptions. Gerking and Stanley (1984) do so more generally, estimating the value of a change in health as the cost of preventive activity times an estimated ratio of marginal products of inputs in the heatlh production function.

2 For a review of labor market studies see Smith (1979). For a comprehensive survey of the literature on willingness to pay and fatality risks see Blomquist (1982).

3 C consists of both expenditures on market goods and services and on time, combined in fixed proportions. If the value of time is constant at the market wage rate, then consumption time expenditures are simply the product of the wage and the amount of time spent in consumption activities. Preventive expenditures (X) and costs of illness (Z) introduced below are also assumed to consist of expenditures on time and market goods combined in fixed proportions.

4 Typically, the cost of illness approach only includes earnings lost or the value of time lost from work and excludes the value of time lost from consumption activities. Define $Z^* = Z - c_L$, where c_L is the value of time lost from consumption. In our comparisons of the cost of illness and willingness to pay approaches in section 2.6 we will employ the more widely used Z* definition of the cost of illness.

5 M is the sum of nonlabor income and potential earnings. Assuming the wage rate is constant, potential earnings are simply the product of the wage rate and the total time in the period. The individual's problem can be expressed in terms of the choice of X, rather than its goods and time components, because of the fixed proportions assumption for X, C, and Z.

6. Just as with Z expenditures, X expenditures provide no utility directly by themselves.

7. Although the consumer's problem as expressed in equations (6) and (7) is single period in nature, it can be generalized to allow for multi-period planning as has been done by Crooper (1977). In particular,' suppose the probability density function, the probability of survival function, and the utility function all vary over time. Assuming an infinite planning horizon, the consumer's problem can be restated as

MAX E(U) = the integral from T to infinity of the integral

from negative infinity to positive infinity of

$$U(M_t - X_t - F(q_t), q_t; t)p(q_t, t)h(q_t, X_t, E_t, t)dqdt.$$

8. Note that for any given individual, Z is fixed once the disease is contracted. In a more extended analysis, Z could be made to depend on other variables such as the price of medical care. Z could be made endogenous in the current framework if it were specified as a function of preventive expenditures.

9. Terms involving the partial derivative of U with respect to q, disappear, since these terms are multiplied by dq, and dq = 0 since q is set at either 0 or 1. Similarly, recalling that the costs of illness Z are given by Z = f(q), dZ = f|(q) dq = 0, since again dq = 0.

10. Although we concentrate on morbidity risk we should note another implication of our model for the cost of illness approach. Typically COI studies separately estimate the morbidity costs and the mortality costs and simply add them together, e.g., see Mushkin (1979, p. 385). From our model it is evident that willingness to pay for combined morbidity and mortality risks is not the sum of the willingness to pay for the special cases alone.

2.2.6 References

1. Acton, Jan Paul. Evaluating Public Programs to Save Lives: The Case of Heart Attacks. Rand Corporation R-950-RC, January 1973.

2. Becker, Gary S., Human Captial. Columbia University Press, New York, 1964.

3. Bergstrom, Theodore C. "When is a Man's Life Worth More than his Human Capital?" in Michael Jones-Lee, ed. The Value of Life and Safety Amsterdam: North-Holland Publishing Co., 1982.

4. Blomquist, Glenn. "The Value of Human Life: An Empirical Perspective" Economic Inquiry 19, January 1981. pp. 157-164.

5. Blomquist, Glenn. "Estimating the Value of Life and Safety: Recent Developments" in Michael Jones-Lee, ed., The Value of Life and Safety. North-Holland Publishing Company, Amsterdam, 1982.

6. Cook, P.J., and Graham, D.A. "The Demand for Insurance and Protection: The Case of Irreplaceable Commodities." Quarterly Journal of Economics, 1977, pp. 143-156.

7. Cooper, B. S. and Rice, D. P. "The Economic Cost of Illness Revisited". Social Security Bulletin 39, February 1976. 21-36 pp.

a. Courant, Paul N. and Porter, Richard C. "Averting Expenditure and the Cost of Pollution". Journal of Environmental Economics and Management, 8, December 1981. 321-329 pp.

9. Cropper, M. L. "Health, Investment in Health, and Occupational Choice". Journal of Political Economy. 85, December 1977. 1273-1294 pp.

10. Cropper, M. L. "Measuring the Benefits from Reduced Morbidity". American Economic Review 71, May 1981. pp. 235-240.

11. Gerking, Shelby and Stanley, Linda. "An Economic Analysis of Air Pollution and Health: The Case of St. Louis." Mimeo. University of Wyoming, May 1984.

12. Harrington, Winston and Portney, Paul R. "Valuing Health Benefits of Environmental Improvements." Journal of Urban Economics, forthcoming. Future, May, 1983.

13. Linnerooth, Joanne. "The Value of Human Life: A Review of the Models". Economic Inquiry, 17, January 1979. pp. 52-74.

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

15. Mushkin, Selma J. "Health as an Investment". Journal of Political Economy, 70 Supplement, October 1962. pp. 129-157.

16. Mushkin, Selma J. Biomedical Research: Costs and Benefits. Ballinger, Cambridge, Mass, 1979.

17. Needleman, Herbert and Grossman, Michael. "Health Econometric Methods for Multimedia Pollutants." Workplan for U.S. EPA Cooperative Agreement. (September 1983).

18. Smith, Robert S. "Compensating Wage Differentials and Public Policy: A Review". Industrial and Labor Relations Review 32, April 1979. pp. 339-352.

19. Smith, V. K. "Option Value: A Conceptual Overview," Southern Economic Journal, January 1983, pp. 654-68.

20. Smith, V.K. and Desvousges, W.H. "Averting Behavior: Does it Exist?" Vanderbilt University Department of Economics Working Paper, September 1985.

21. Viscusi, W. Kip. "The Lulling Effect: The Impact of Child-

Resistant Packaging on Aspirin and Analgesid Ingestions" American Economic Review 74, May 1984. pp. 324-327.

22. Weisbrod, Burton A. "Costs and Benefits of Medical Research: A Case Study of Poliomyelitis." Journal of Political Economy-, 79, May/June 1971. pp. 527-544.

2.3. HEALTH ECONOMETRICS: AN ASSESSMENT

2.3.1. Introduction and Overview

The purpose of this assessment is to determine what the empirical evidence is with regard to effects of environmental quality on human health. The focus is on cross-sectional studies measuring the relationship between mortality rates and ambient air quality measures. A primary concern is whether or not these studies taken separately or as a whole can shed light on the structure of demand for health, not just net responses to changes in environmental characteristics on health measures. In this regard a fundamental consideration is the role of avoidance practices made by individuals in response to adverse health conditions in specification, estimation, and inference from econometric models. One reason for such concern is that impacts on health of differences or changes in climatic conditions, environmental quality, and other influences reflect the net effect of these differences after avoidance has taken place in response to what otherwise would have been adverse health effects.

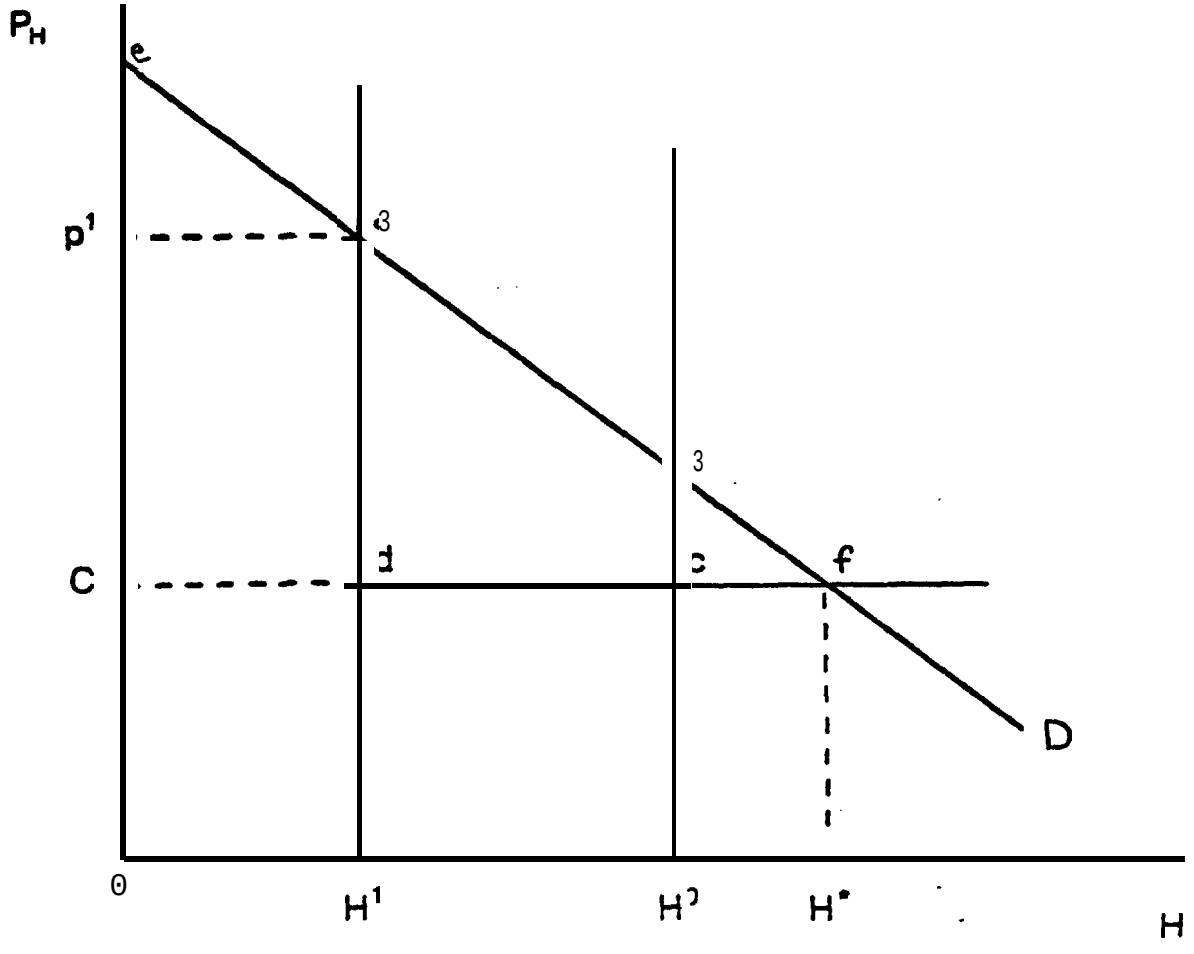
An illustration is presented in Figure 2-l where D is the demand for health, H, and there are two sources of health production: that from local amenity and environmental conditions and that produced by individual behavior. An extreme case is where with environmental quality Q_0 health status on average would be H^0 in the absence of other behavioral responses (e.g. defensive or avoidance measures). The supply of health from Q_0 is thus inelastic at H^0. At a similar extreme, suppose that avoidance procedures are perfect substitutes for environmental conditions and can be produced by an individual at constant cost C. Then, as depicted in Figure 2-l health status would be H* with defensive or avoidance expenditures given by $C (H^* - H^0)$. Consumer surplus is given by the area inside $oefcH^0$.

Now suppose that instead of Q_0, environmental quality was given by Q_1 which is less than Q_0. The supply of health from such conditions is now Hl which is less than H^0 yet the difference in health status can be offset by additional avoidance procedures at a cost of $C (H^0 - H^1)$. Consumer surplus in this case is given by the area $oefdH^1$ which is less than that previously by exactly $C (H^0 - H^1)$.

In the above example the correlation between observed health status (averaging H*) and environmental conditions would be zero even.though benefits of environmental improvements from Q^1 to Q^8 would be $C \times (H^0 - H^1)$. On the other hand, in a stochastic setting, regression of H^* (or more realistically, variations of actual health status around H^*) on Q and expenditures (or the level) of avoidance would result in biased estimates of causal effects of pollutants on health quality because expenditures are endogenous (affected by health status in their absence) However, controlling for the feedback effect (e.g. through use of instruments for health expenditures in the econometric

FIGURE 2-l

ENDOGENEOUS HEALTH AND ENVIRONMENTAL QUALITY



specfication of health status) the pollutant effect on health is essentially that which would occur without responding avoidance supply effects. In the extreme, the effect of an environmental quality change from Q^0 to Q^1 would lead to a change in health from H^0 to H^1, appropriately holding health expenditures constant.

More generally, differences in environmental conditions faced will be reflected in differences in health status even after avoidance procdures. The resulting calculation of benefits due to improvement in environmental conditions needs to consider not only cost savings (from a reduction in avoidance expenditures) but also the value of the increased health that would result.

With this in mind the assessment considers the results from five empirical studies of the effects of environmental pollutants on mortality: Lave and Seskin (1977), Crocker et al (1979), Chappie and Lave (1982), Mendelsohn and Orcutt (1979), and Schwing and McDonald (1976). The purpose of this assessment is not to duplicate the critiques of such analyses as presented in the EPA's "Air Quality Criteria for Particulate Matter and Sulfur Oxides." Rather it is to determine if estimated effects in these studies are robust in light of the ways in which avoidance and other measures are treated.

2.3.2 Study Summaries

L.Lave and E. Seskin, Air Pollution and Human Health (Baltimore: Johns Hopkins University Press), 1977.

This analysis compares mortality rates across 117 SMSAs in 1960 related to sulfates and particulates and 69 SMSAs in 1969 considering the effects of SO_2, NO_2, and NO3 also. Classical least squares estimation techniques are applied with control for effects of population density, percent of population over age 65, percent of non-white population, and the percent of households with income less than poverty level. Measure's of avoidance or defensive activities are not explicitly included.

T. Crocker, W. Schulze, S. Ben-David, and A. Kreese, Methods Development for Assessing Air Pollution Control Benefits, Vol. I. (Washington, D.C.: Environment Protection Agency) EPA-600/5-79-001a, 1979

This analysis compares mortality rates across 60 cities in 1970 and relates these to SO_2, TSP, and NO_2. Other exogenous variables included in the study are measures of population that was non-white, median age of population, living space density,

cold temperature, cigarette consumption, and three dietary variables. Also included as an explanatory variable is a measure of physicians per capita. An instrument for the latter was employed in estimation of the mortality rate specification in order to control for its potential endogenity with respect to mortality rates.

M. Chappie and L. Lave, "The Health Effects of Air Pollution: A Reanalyses," Journal of Urban Economics, 12 (1982), pp.346-376.

Data for 104 SMSAs in 1974 are employed in this analysis. Many variants of the previous Lave and Seskin model are examined which add to the set of control variables many dietary variables, as well as cigarette and alchohol consumption measures. In addition the effect of physicians per capita are examined (taking into account its potential endogeneity).

R. Mendessohm and G. Orcutt, "An Empirical Analysis of Air Pollution Dose-Response Curves," Journal of Environmental Economics and Management, 6 (1979), pp.85-106.

Mortality rates in 1970 for 404 county groups in the contiguous U.S. are examined in this study. Pollutants considered are sulfates, nitrates, SO_2, NO_2, CO, TSP, and Ozone. Many control variables are employed in estimating age-sex-race mortality rates. These include demographic characteristics for the age-sex-race group, the county group, as well as climatic condition and region specific characteristics. The estimation techniques is weighted least squares.

R. Schwing and G. McDonald, "Measures of Association of some Air Pollutants, Natural Ionizing Radiation and Cigarette Smoking with Mortality rates", in The Science of the Total Environment 5, (1976), pp.139-169. ------- -- ---

Mortality rates in 46 SMSAs in 1960 are considered in this study. The pollutants considered are SO_2, SO_4, NO_2, NO_3, and hydrocarbons. In total 23 explanatory variable (climatic conditions, pollutants, cigarette smoking. and natural ionizing radiation) are employed to study total and disease specific mortality rates. Three alternative estimation techniques are applied to these data: ordinary least squares, ridge regression, and sign constrained (with respect to pollutants) least squares.

2.3.3. Assessment

2.3.3.1. Pollutant Effect Comparison

Table 2-2 shows the effects of a 1 microgram/meter^3 increase- in various pollutants on the mortality rate (deaths/100,000) implied by estimates from the five studies outlined above, Comparison between studies of single pollutant effects are made somewhat difficult by the differences in the pollutants considered in any particular study. Correlation between included and excluded pollutants thus hamper the validity of inference based on effects of single pollutants. However, except for the estimates from Crocker, et.al. effects of sulfur oxides (SO_2 and SO_4 are positive and often substantial. The sign of effects of TSP are not consistent across studies. Except for the results in Mendelsohm and Orcutt, effects of Nitrogen oxides appear positive.

2.3.3.2. Study Design and Estimation Approach

Besides differences in the sets of pollutants considered in each study a variety of study design and estimation approach differences are relevant for assessment of these studies. A first consideration is that the Lave and Seskin and Mendelsohm and Orcutt studies do not control for such factors as smoking behavior or dietary characteristics of the population group considered. Correlation between these measures and the pollutant variables would serve to bias the estimated pollutant effects making serious inference from these two studies suspect. The Schwing and McDonald study suffers similarly from lack of inclusion of many of these potentially important variables.

The Chappie and Lave and Crocker, et.al studies, however, are very similar in that they include smoking and dietary varibles as well as consider the role of physicians per capita in affecting mortality rates. Yet, the implications for pollution effects differ substantially. To understand the reason for these differences more fully Table 2-3 presents the estimated coefficients on the other explanatory variables (for deaths/100,000) employed in these two studies. The demographic variables employed differ except for the percent of the population that is non-white. The coefficients on this variable are similar, andifthe piece of a package of cigarettes averaged slightly less than $1.00, the effect of population smoking characteristics is similar between these two studies. Effects of physicians per capita are also very similar between the two studies.

Substantially larger effects of per day protein consumption on mortality rates are found in the Crocker, et.al study compared to those in Chappie and Lave. Moreover, these effects are more precisely estimated in the Crocker, et.al. study. This suggests a potentially important influences of

correlation between dietary characteristics and the various pollutants considered in each study. Other than this, the reasons for the differences in pollution effects may be solely due to the difference between the effects of sulfates and the effect of SO_2.

2.3.3.3. Overall Design Consideration

Both the Crocker, et.al and Chappie and Lave studies address the endogeneity of physicians per capita on mortality rates within a cross-sectional setting. Such would be expected as demand for physician services may be one result of avoidance or averting behavior with respect to health problems. However, this is only one factor that may be important. Avoidance behavior may also be reflected in dietary, smoking, and alchohol consumption which needs to be seriously treated in further empirical work.

Avoidance or averting behavior in place, such as described above, is but one avoidance alternative. A second may be avoidance through changing residence location in response wo what would otherwise be adverse health conditions in an area. One implication of this would be that individuals may locationally sort themselves in accordance with differences in environmental quality among areas with those least affected living in relatively low quality areas. If such is the case, estimates of mortality rates differences between areas as a function of pollution would likely understate the effect of changes in overall pollution levels (especially those occuring in high pollution areas to begin with). Secondly, individuals may change location in response to what would otherwise be continued ill-health effects of pollution in one area. In such a case persons adversely affected by pollution might end up dying (and increasing the mortality rate) in low pollution areas. This would also lead to an understatement of the true effect of pollutants on mortality rates such as those based on the existing cross-sectional analysis.

Table 2-2

Estimated Effects of 1 Microgram Per Cubic Meter Increases in Selected Pollutants on the Mortality Rate

(Deaths/100,000)

Pollutant	Study					
	Lave and Seskin[a]	Lave and Seskin[b]	Chappin and Lave[c]	Crocker et.al.	Mendelsohm and Orcutt[d]	Schwing and McDonald[e]
so2		2.64		-.313	1.02	2.01
Sulfates (SO4)	5.418	-1.02	13.052		16.0	18.0
TSP	.619	-.022	-.322	.107	-.051	
NO2		.17	.082	-.082	-1.09	
Nitrates (NO3)		.035			-.059	2.3
CO(milligram/per cubic meter)					7.04	
03					.58	

[a] From Lave and Seskin (1977), Regression 7.1-3

[b] From Lave and Seskin (1977), Regression 7.8-10

[c] From Chappie and Lave (1982), Regressions 6-9

[d] Based on implied effects of 1 microgram per cubic meter change using estimates in Table III and pollutant means in Table Al in Mendelsohm and Orcutt (1979), 1970 age characteristics of the population for creation of adult population mortality rate effects.

[e] Schwing and McDonald present estimated elasticities of'pollutant effects on mortality rates. The estimates in Table 1 are based on elasticities for the pollutant at its primary standard level or, in the case of nitrates, at the average level presented in Mendelsohm and Orcutt (1979). Results are based on the constrained least squares elasticity estimates for total mortality rates given in Schwing and McDonald (1976).

Table 2-3

Comparison of Crocker, et.al. and Chappie and Lave Estimation Results (deaths/100,000)

Explanatory Variable	Crocker, et. al.	Chappie and Lave
Percent of population non-white	5.63 (4.56)	3.61 (3.47)
Median age of population	6.59 (11.54)	
Percent of households with greater than 15 persons/room	31.77 (2.35)	
Number of days with temperature below 0°	1.44 (2.91)	
Packages of cigarettes/year/ capita	2.2 (2.81)	
Per capita expenditures on smoking items		2.512 (1.92)
Per capita expenditures on alchohl		1.255 (2.45)
ln (population)		-42.59 (1.98)
Median family income		- . 036 (2.78)
ln (population/sq.mile)		41.98 (1.90)
Grams/day/capita of protein	70.1 (3.55)	8.42 (0.21)
Gram/day/capitaof carbo-hydrates	-2.92 (1.36)	.146 (0.20)
Grams/day/capita of saturated fatty acids	14.6 (1.45)	-2.222(0.12)
Physicians/10,000 population	-.53 (4.35)	-.64 (3.79)

2.3.4. Concluding Comments

All of the empirical findings cited in the studies reviewed in Section 2.3.2 suggest that pollutants can be related to measures of human health. The data sets employed and the statistical techniques employed differ, often substantially, in these analyses. Yet, one is very much left with the feeling that little is known regarding the relevance of the empirical findings for estimation of benefits of health status improvements associated with reductions in average pollutant levels, pollutant mix, or changes in pollution dispersion over, for example, a one-year period of time. One problem that arises is that multiple pollutants are often correlated in ambient air characteristics, which potentially reduces the information that can be gained regarding one particulare pollutant's impact on health isolated from those of other pollutants. This problem, however, is one that methodological approaches using ambient air quality measures can only hope to acknowledge and minimize using appropriate methods of inference from empirical results. Three more serious problems arise (some of which are addressed in the literature) which are of concern for current purposes. These are outlined below.

If the demand curve for health were known, in the extreme setting considered in Figure 2-l comparison of pollutant effects on mortality rates not holding constant and holding constant the endogeneous avoidance behavior of individuals in response to adverse health status should indicate the difference $H^0 - H^1$. Clearly, the health econometric studies examined do not yield reasonsable means of doing so. This information is quite useful in that it would allow for estimation of area H^1abH^0 if D were known. Indeed, the inf rmation that is missing but needed is an estimate of area H^1dcH^8, the amount of avoidance costs incurred to offset the decline in environmental quality. An important piece of information could thus be gained by regressing health avoidance costs (or at least those measurable) on environmental quality, giving an indication of this area. In more complicated avoidance cost situations where C is, for example, an increasing function of $(H - H^i)$ or shifted as a function of H^1, this type of avoidance cost information would still be needed in order to determine true benefits of pollution reductions. Regardless, structural estimates of not just the human health specifications are needed in order to get an appropriate measurement of the benefit function for reduced pollution. A need in this regard is thereby to investigate the opportunities available in estimating the full set of simultaneous relationships involved. Two potentially important areas in which to extend even further empirical analysis in this regard are discussed below.

2.3.4.1. Location Change Complications

In one very relevant sense, the level of pollution faced by an individual are subject to choice. Of relevance for current

purposes is whether or not individuals respond to ill effects of pollutants on 'human health (or health production) by migrating to areas with better environmental quality if they do and if past period pollutant experiences affect future health conditions, in an extreme case a negative partial correlation between current health status and currently faced environmental conditions is not only expected but is also a measure of the severity of the pollutant's impacts on health preservation.

Endogeneity of location choice and thus environmental quality means that feedback between current health status and current pollutant levels needs to be explicitly incorporated into health econometric studies. It is not sufficient to simply include a net migration variable into mortality or morbidity rate specifications. In any case, only health induced migration would be of concern regarding correlation of the migration measure and the error term in the health specification.

More generally, effects of exposure to pollutants may be lagged or cumulative. It is important to deal more adequately with exposures faced by individuals over longer periods of time (controlling for location changes) than has heretofore been attempted. This would be especially relevant in attempting to measure differences in impacts on health of fluctuation-s in environmental conditions and long-term differences in exposure.

2.3.4.2. Population Heterogeneity

Almost all of the health econometric studies acknowledge likely differences in effects of pollutants on individuals. In fact, even in its most random form where pollutants equally affect everyone's probability of a certain health effect, some individuals are spared the impact which others are not. Controlling for differences in measured demographic characteristics of the population allows for alleviation of some of the problems involved with heterogeneity in susceptibility. Still, the problem of heterogeneity in unmeasured characteristics poses a measurement problem.

One way of starting to deal with this is to consider measurement of changes in health status of a panel sample of individuals. Effects of pollutants may then be related to the actual health status of individuals in prior years to help address the question of susceptibility. In conjunction with this,the role of migration in response to deterioating health and its impact on location of, for example, death, relative to pollution levels could be more fully examined.

2.4. COST OF ILLNESS APPROACH

2.4.1. Introduction

The cost of illness (COI) approach focuses on those aspects of the value of health that may be fairly directly measured: medical expenditures and foregone earnings due to illness. The basic idea of many COI studies is simply to convey in some quantifiable way the impact of illness on the U.S. economy. These studies range from comprehensive studies of the cost of all illness in the U.S. for a given year to studies dealing with a specific disease or group of diseases. The COI approach is also frequently used as a way to measure the benefits of a program or any change that improves health, for use in benefit cost analysis. The reasoning is clear: if illness imposes the costs of medical expenditures and foregone earnings, a reduction in illness yields benefits equal to the costs saved.

Researchers have used the COI approach as away to value the health benefits resulting from a change in air pollution levels. For instance, Lave and Seskin (1976) combine their data with the Cooper and Rice (1976) estimates of the total cost of illness in the U.S. to find a value for a hypothetical change in pollution levels. This section is mainly concerned with using cost of illness estimates as a source for empirical estimates of the value of health effects linked to air pollution, though a fairly general appraisal of 'the approach is also undertaken.

The appeal of the COI approach is its seemingly straightforward estimation of clear, well-defined and observable quantities. There is a large amount of information collected on medical expenditures and foregone earnings due to illness, and the sources are often good quality, national data bases. Since the COI approach does not place a value on the more intangible aspects of health, notably pain and suffering, the approach is intuivively seen as estimating a lower bound to the true value of health. As alternative willingness to pay estimates for the value of reductions in mortality risks have become available, the COI approach is less frequently used to value these risks. However, alternative estimates for the value of morbidity are just becoming available, and the range of morbidity effects valued is still quite limited. The quality of the alternatives to COI values of morbidity is also questioned. For these reasons, the COI approach remains an attractive source of estimates for the values of a wide range of morbidity effects. In this section the COI approach is mainly applied to morbidity; mortality is discussed only incidentally.

A drawback to the COI approach as usually implemented is that it produces estimates of the total medical expenditures and foregone earnings due to illness in the U.S. However, the data linking air pollution to morbidity are on an individual basis. For example, air pollution can be related to the days an average individual spends ill inayear. There are two ways to conduct a benefit cost analysis of air pollution using aggregate cost of

illness estimates and individual links between air pollution and health. First, the data linking individual health effects and air pollution could be used to extrapolate the total amount of illness caused by air pollution in the U.S. This aggregate quantity of illness could then be valued using an existing COI estimate. (This is the procedure used by Lave and Seskin (1976)). An alternative route is to derive from the existing aggregate COI studies estimates of an individual's cost of illness. These individual estimates could then be directly combined with the data linking individual health effects and changes in air pollution. If the objective is to estimate the aggregate cost of illness due to air pollution, it would be necessary to make assumptions about the distribution of individuals and link them to the micro relationships. As V.K. Smith points out, this "bottom up" approach is probably intuitively more appealing to many economists. To implement this approach, estimates of individual cost of illness are required.

Estimates of an individual's cost of illness are desirable for several other reasons, The theoretical models that suggest cost of illness measures may be a lower bound to the conceptually correct measure of the value of health apply to individual and not aggregate values. In addition, alternative approaches to valuing morbidity produce estimates of an individual's value of health. At present, direct comparisons of these individual willingness to pay estimates and the aggregate cost of illness estimates can not be made.

The goal of this section is to express existing COI approach estimates on a basis that relates to what an individual would be willing to pay for a change in health. Section 2.4.5 puts a number of studies' estimates on a per case and a per day basis. This procedure is not necessarily ideal, since a "top down" approach is still used in estimating the individual's costs of illness: the process begins with the aggregate costs and uses these to imply the individual costs. This approach was originally proposed as a means to avoid serious double-counting of costs (Rice (1966)). Since the relative performances of the "top down" versus "bottom up" approaches is an open issue, some estimates based on individual observations of costs are also presented. Additional information on individual costs was obtained in the survey described in Volume 3, and reported in section 2.6 below.

Preceding the presentation of the empirical results obtained from existing COI studies (section 2.4.5), a general assessment of the usefulness of the COI approach is undertaken. Section 2.4.2 discusses the relationship between the COI approach and the conceptually correct willingness to pay approach. Section 2.4.3 extends this discussion to consider differences between individual and societal willingness to pay for health improvements. While this distinction is made in the context of the cost of illness approach, the difference between individual and societal values is important for all attempts to value the benefits of health improvements. Following these discussions of

conceptual issues, section 2.4.4 is a critical evaluation of the standard methodology of COI studies.

2.4.2. Linking the Cost of Illness Approach to Willingness to Pay

Researchers using the cost of illness approach have noted a number of shortcomings of the approach for benefit cost analysis. For instance, the COI approach makes no attempt to measure the benefits of reduced pain and suffering associated with health improvements, as noted above, but concentrates on more easily measured aspects of the cost of illness. Thus benefit cost analysis using this approach to valuing benefits may indicate that fewer resources should flow into cancer research, for example, than the public might desire because of the relatively high costs in terms of pain and suffering of cancer. (This example is suggested by Cooper and Rice (1976).) Another general problem is that little value is placed on activities outside of the marketplace, since the approach considers only foregone earnings. While recent studies have attempted to make adjustments to allow for value to be placed on the time of those individuals keeping house, leisure time in general, and thus much of the time of retired individuals in particular, is implicitly not valued at all. Programs that reduce the illnesses of the older members of society might be very difficult to justify using benefit cost analysis, if the benefits are measured using the COI approach. Programs aimed at improving the health of another segment of the population, the very young, may also show few benefits from the COI approach. Since future earnings are discounted, at a fairly typical discount rate of 10 percent earnings that start 20 years in the future have a relatively small present value. This list of troubling implications of benefit cost analysis using a COI approach could be extended, which suggests that the benefits of improved health that most people actually perceive may not be well estimated by the COI measures.

The fundamental problem with the COI approach is that though the quantities the studies estimate are clearly important aspects of the benefits of improved health, the methodology originally was not founded on any rigorous theoretical basis. This point is forcefully made by Mishan (1971), who particularly emphasizes changes in mortality risks -- the "value of life." He points out that benefit cost analysis is based on the proposition that an action is judged by whether it represents a potential Pareto improvement, that is, whether the gains resulting from the action can be distributed so that at least one person is made better off, and no one is made worse off. To use this criterion, it is necessary to look at the sum of what each member of society is willing to pay or accept for the change. The problem with the COI approach to measuring the "value of life" is that there is no a priori reason to believe that an individual's future earnings

will be related to his willingness to pay for a reduction in mortality risks. Studies based on individual preferences for such reductions are now usually said to follow the willingness to pay (WTP) approach.

In response to Mishan's and others' criticisms, a good deal of attention has focused on theoretically relating discounted future earnings to what an individual would be willing to pay for a small reduction in the risk of death. Two conclusions emerge from the theoretical work. First, there is no necessary relationship between future earnings and willingness to pay (see Linnerooth, (1981), or Rosen (1981)). Second, however, under certain restrictive conditions future earnings may be a lower bound to the willingness to pay measures. (Usher (1971), Conley (1976)).

Comparisons of empirical work following the COI approach to work following the WTP approach support both of these theorectical conclusions. Blomquist (1981) in his review of existing empirical studies concludes that while "there is no close association of value of life with future earnings....there is a strong indication that the value of life is greater than future earnings." Thus, there is some theoretical and empirical justification for one element the COI studies estimate: the foregone earnings due to premature mortality. It must be stressed that the justification is weak. At best, these foregone earnings are only a lower bound to the conceptually correct WTP measure, so there is no reason to believe the measures will be close to each other.

Much less attention has been paid to justifying the remaining elements of the COI estimates: medical expenditures, and foregone earnings due to morbidity. Ideally, the cases of mortality and morbidity should be considered together, to allow for possible interactions (see section 2.2). The expressions derived from such a model are fairly complicated, but it is possible to show that for the case of pure morbidity, under certain plausible assumptions, the cost of illness will be a lower bound to the WTP measure.

In short, theoretical models suggest that WTP reflects four components: 1) lost wages: 2) additional medical expenses; 3) the dollar-value of the disutility of additional illness; and 4) the change in defensive expenditures. This can be seen in the willingness to pay expression derived in section 2.2 for the case of pure morbidity:

$$(24)\quad -\frac{dM}{dE} = -\frac{U(M-X,0) - U(M-X-Z,1)}{P_0 - P_1}\,\frac{dH}{dE} - \frac{dX}{dE}$$

$$m^{**}$$

The first three components of willingness to pay for a reduction in the risks of morbidity are reflected in the expected difference in utility when healthy and when ill valued in dollars

(the first term on the right hand side). The difference in utility when healthy and when ill depends upon both the cost of illness term Z and the absence or presence of the condition (0 or 1 as the second argument in the utility function U). cost of illness Z is defined to include the value of time lost due to illness, reflecting both foregone earnings and the value of leisure time, and all the out-of-pocket medical expenditures necessitated by illness. Willingness to pay also depends upon the change in defensive or preventive expenditures brought about by the reduction in risks (the second term dX/dE). (For a more complete discussion and definition of all variables, see section 2.2.)

In contrast, the COI measure only includes the lost wages (often called the indirect costs) and the additional medical expenses (the so-called direct costs). The amount an individual would be willing to pay is largerthanthe COI measure as long as the omitted quantities of the WTP measure are positive. People will always pay a positive amount to avoid the disutility of illness. Whi'le Courant and Porter (1981) emphasize that defensive expenditures may either increase or decrease in response to an decrease in pollution, the normal cases is that a decrease in pollution saves defensive expenditures, and so these savings are a positive part of the WTP measure. In this case., the COI measure of the benefits of a reduction in morbidity is a lower bound to the theoretically correct WTP measure. However, as shown in section 2.2, there are no plausible conditions under which the cost of illness measure is a special case of WTP.

The theoretical model does not suggest how close the COI measure will be to the WTP measure. Rigorous comparisons of these measures are undertaken in section 2.5. Some idea of the difference between the measures can be gained by considering the aspects of benefits the COI measure neglects: the disutility of illness and the savings in defensive or preventive expenditures. While illness may decrease utility in many, possibly subtle, ways, probably the most important effect is the pain and suffering caused by illness. Mushkin (1979) attempts to estimate a dollar value on the total pain and suffering due to illness, basing her estimates partly on market revealed preferences, such as expenditures on painkillers, expenditures for medical care due to a pain symptom, and so forth, and partly on value's given to pain and suffering in court awards. Her estimates for 1975 range from $25.8 billion to $228.6 billion, compared to a traditional COI measure of $322.6 billion. That is, allowing for pain and suffering could represent an increase of 8 to 70 percent in the COI measures of the benefits of improved health.

Unfortunately, no comprehensive estimates could be found of the total defensive expenditures due to illness. The household production models of health (Grossman (1972)) do suggest that a wide variety of activities and goods may play a role in the production of health, so the change in defensive expenditures is possibly large. As reported below (section 2.6), as part of the contingent valuation experiment information was collected on

individuals' purchase of items for health reasons (air conditioner and humidifiers) and it was found that non-trivial proportions of the sample had made such purchases. In relation to pollution induced health risks, Smith and Desvousges (1985) find that households do make adjustments to reduce the risks of exposure to hazardous wastes through drinking water, but are not able to measure the value of these actions, This evidence indicates that the change in preventive expenditures may be a significant determinant of how much individuals are willing to pay for a reduction in health risks. Thus, consideration of the elements of the WTP measure the COI measure neglects suggests a tentative conclusion that the COI measure seriously underestimates true willingness to pay for an improvement in morbidity.

The general conclusion of the work comparing the COI approach to valuing improvements in mortality and morbidity to the WTP approach is that the COI benefit measure is a lower bound to the WTP benefit measure, but not necessarily a very good approximation of it. Almost all three elements of the COI measure can be related to what an individual would be willing to pay for an improvement in health: medical expenditures due to morbidity, foregone earnings due to morbidity, and foregone earnings due to premature mortality are all elements of a theoretically derived measure. The omission is that medical expenditures due to fatal illnesses have not been related to the willingness to pay for a reduction in the probability of such an illness. In a nonrigorous argument, this seems plausible, since an individual will not value these expenditures if he is not alive to pay them. The possibility of a bequest motive, though, implies that an individual does derive utility from his heirs' consumption possibilities, and so if the medical expenditures due to a fatal illness reduce the amount of the bequest, the individual may be willing to pay to avoid these costs. Other possible justifications for including the medical expenditures due to fatal illnesses arise from the consideration of societal, rather than individual, willingness to pay. The question is similar to the problem of whether "premature" funeral costs are of interest in valuing reductions in mortality risk.

A secondary problem stemming from the medical expenditures due to fatal illnesses is that in many studies where medical expenditures are used in benefit cost analysis, all medical expenditures are implicitly asumed to be due to morbidity. The impact of this incorrect assumption is difficult to assess. Clearly, most illness does not result in death; simple calculations show, for instance that less than 1 percent of the total cases of pneumonia in a year result in death (Vital and Health *Statistics*, various issues). On the other hand, the treatment of a fatal case is certainly likely to be more expensive than the treatment of a nonfatal case (unless the fatal illness is very short), so fatal illnesses may still account for a significant proportion of medical expenditures. In this case, using total medical expenditures as an estmiate of the benefits of reducing morbidity alone would overstate these benefits.

2.4.3. Individual Versus Societal Willingness to Pay

The analysis so far has focused on COI measures as approximations of an individual's willingness to pay for improvements in his own health risks, but society might also have an interest in the individual's health. The problem of which viewpoint to use, individual or societal, has received attention in the cost of illness literature. Some early researchers, for instance, reported foregone earnings net of consumption, on the grounds that it is the net earnings that society lost due to an individual's morbidity and mortality (see, for instance, Weisbrod (1961, 1971)). The common practice currently is to estimate total earnings fore-gone, which is justified by the relation between total earnings and individual willingness to pay, as discussed above. In other ways, however, the COI studies have continued to try to consider the societal viewpoint. This can be seen in further details of the calculation of foregone earnings. Earnings are estimated gross of taxes, reflecting the value to society of the taxes that would be paid in the absence of illness, though what most likely matters to the individual's utility is his net of tax income. Non-labor income is not included in COI measures of foregone earnings, on the other hand, because though the individual does consume it, it would not be lost to society if the individual suffers morbidity or mortality. In general, the present status of the COI approach might be described as an uneasy compromise between the individual and the societal viewpoints.

Some attempts have been made to reconcile the differences between the individual and the societal viewpoints in measuring the benefits of improved health, though these seem to have concentrated on the case of mortality risks. Landefeld and Seskin (1982) develop an adjusted process to calculate foregone earnings, allowing for the individual's perspective in that earnings are computed net of tax, non-labor income is included, an individual discount rate is used (as opposed to the social discount rate), and a risk-aversion factor is applied. These adjusted foregone earnings estimates are closer theoretically and empirically to the measures estimating individual willingness to pay for a reduction in mortality risks directly. Working in the opposite direction, Bailey (1980) attempts to adjust individual willingness to pay measures to allow for benefits to other persons from the reduction in the risk of an individual's death, and in some ways his methodology is closer to the methodology of the COI approach. He modifies a WTP measure to allow for future direct taxes on labor and future indirect business taxes on labor that would be lost due to an individual's premature mortality, and to allow for direct costs associated with a fatality not borne by the family of the victim.

From the perspective of benefit cost analysis, however, many of the deeper conceptual problems in measuring the differences between individual and societal perceptions of the benefits of

health improvement are not resolved, and in fact seem to have received very little attention in this context. A number of problems involve the role of medical expenditures in benefit estimation when considered from an individual versus a societal point of view. In addition, the existence of paid sick leave allows the possibility of a difference between individual and societal valuations of foregone earnings due to morbidity. Finally, pure altruism plays a part when considering how society in general values an individual's health risks. Each of these problem areas is discussed below, but not at the length or with the rigorous analysis they deserve. It should also be noted that in keeping with the general purpose of this section, only the case of morbidity is considered.

The role of medical expenditures in benefit estimation would be much clearer if the market for medical care were the textbook ideal of a competitive market in the absence of distortions. In this situation, Harberger's basic postulates for benefit cost analysis would apply; in particular it could be assumed that: "(a) the competitive demand price for a given unit measures the value of that unit to the demanders;" and "(b) the competitive supply price for a given unit measures the value of that unit to the supplier" (Harberger (1974)). For the last unit bought and sold, the price observed in the market will be the demand price and the supply price, in this ideal setting. So for a marginal change in the quantity of medical care, the market price represents the value both demanders and suppliers place on that unit, and the change in medical expenditures (price times quantity) is the value of that change appropriate for use in benefit cost analysis, from either an individual or the societal point of view. However, the medical care sector is far from the ideal non-distorted competitive market: there are reasons to believe the market price will not be a good approximation of the value of the last unit to demanders; and there are also reasons to believe that the market price of medical care may diverge from the value of the last unit to the supplier, i.e., the value of the next best alternative use of the resources involved in the production of medical care.

The most obvious reason that the market price of medical care may not reflect the value demanders place on the last unit consumed is the existence of third party payments. Recent figures show that over two thirds of all personal health care expenses are paid for by third parties, including private health insurers, governments, private charities, and industry (Gibson, et al., (1983)). Third party payments drive a wedge between the demand price (the price the demander or consumer sees) and the market price. With third party payments, the value the consumer of medical care places on the last unit may be fairly low, depending upon the portion of the cost he pays. The benefits of an improvement in health to the individual demander will relate only to the possibly small reductions in medical expenses he actually sees in the presence of third party payments. Following the COI approach to measuring benefits, however, all medical expenditures are counted, not just those expenses the individual

incurs. This means that a COI measure may not be comparable to a measure based on individual willingness to pay, unless the savings to a third party payer resulting from an individual's reduced health risks are somehow passed on to the individual, as could be the case if healthier individuals receive reductions in their health insurance premiums. Even if the individual does not perceive the total savings in medical expenditures, though, as a first approximation the COI benefit measure may represent the societal viewpoint, since the third pary payer, or whoever does realize the savings in costs (such as other purchasers of health insurance), do benefit. The sum of the savings to the individual directly involved and the savings to these others will equal the total medical expenditures estimated in the COI approach. This first approximation misses the more subtle effects of the wedge third party payments drive between the demand price and the market price involving optimizing behavior on the part of the demanders. These effects can not be successfully evaluated without developing a more rigorous analytical model of the demand and supply of medical care.

Other ways in which the medical care sector deviates from the ideal competitive market are the importance of non-profit organizations in providing hospital services, and the complicated role the physician plays as both a supplier of medical care, and one who has a possible influence on the quantity of medical care demanded by the patient. In the absence of the profit motive, hospital administrators may pursue other goals, such as a reputation for high quality medical care. If this is the case, hospitals may provide a higher quality, and higher priced, good than the demanders would prefer. The role of the physician could similarly result in the patient consuming more medical care than he would judge optimal if he had full information. So both of these aspects of the medical care sector may drive further wedges between the value of the medical care to the demander, and the market price. Again, a more rigorous analysis is required to make any conclusions about the importance of these possible effects.

A fairly standard analysis can be used in evaluating the importance of one final aspect of the medical care sector: the possible lack of competition in the supply of physician services. Various features of the market for physician services suggest that physicians may have a substantial degree of market power: the effective restriction of entry through the American Medical Association's control of the supply of medical students; the increases over time in the incomes of physicians relative to the incomes of what seem to be comparable professionals; and so forth. In this situation, the market price of medical care will be above the value of the next best alternative use of the resources used in the production of medical care. The difference is an economic rent, or monopoly profit, that is gained by the physicians. Now, a reduction in medical expenditures due to an improvement in health will release resources (physicians) that go to a use valued at less than the market price of medical care. The result is a reduction of the rents received by physicians.

Thus, the decrease in medical expenditures is partly a transfer from physicians to patients. That this tranfer is not a welfare gain for society as whole using the criterion of a potential Pareto improvement described earlier is clear: the gains by the demanders of health care are offset by the losses suffered by physicians. Distributional effects could be relevant, however.

To summarize the preceding discussion of the medical care sector, aspects of the demand and supply of medical care suggest that there may be differences in how the individual and how society value reductions in medical expenditures. Many of the effects are unclear, in the absence of a rigorous analytical model. The clearest result is that if physicians do have some degree of market power, part of the reduction in medical expenditures will represent a transfer of income, and not a gain to society as a whole.

Another case for which the value of a health improvement may be different depending upon the individual or societal viewpoint is the analysis of lost time due to illness if the individual receives paid sick leave. This case has been analyzed by Harrington and Portney (1983) as a variant of their general model. As they note, as a first approximation it might seem that lost time due to illness, though no longer a cost to the individual, still represents a cost to society as a whole: with paid sick leave the employers would perceive the costs associated with a worker's illness. Then if the COI approach estimates foregone earnings without allowing for paid sick leave, the COI benefit measure will diverge from the individual WTP measure, but it will still approximate society's willingness to pay for a health improvement. However, the presence of paid sick leave changes the individual's optimizing behavior, in particular it changes his optimal choice of defensive expenditures, and his ability to trade off leisure time and time spent working. As a result, the formal analysis of Harrington and Portney concludes that with paid sick leave, the COI measure is no longer necessarily a lower bound to the WTP measure. (This is the type of subtle effect that must be considered in a complete analysis of the issues raised earlier involving third party payments and other distortions in the medical care sector.)

The final difference between individual and societal willingness to pay for a reduction in morbidity that will be considered is the possibility of pure altruism. In this case, other members of society are willing to pay for an improvement in an individual's health, and these amounts should be added to the individual WTP measure. Altruistic motives are clearly important, and in particular family members may be willing to pay a great deal to improve the morbidity risks of other members of the family. This explanation may relate to the values placed on improving the morbidity risks to children, infant mortality risks, and even pre-natal care,

2.4.4. Quality of Cost of Illness Estimates

The analysis of sections 2.4.2 and 2.4.3 suggests there may be conceptual problems with the cost of illness approach, because costs of illness may not be closely related to either individual or societal willingness to pay for improved health. Despite these objections, the cost of illness approach remains widely accepted as a standard approach to valuing health. Often, this acceptance is justified by the argument that theoretical considerations aside, the COI benefit measures are easily and reliably estimated in practice. This section addresses directly the issue of the quality of cost of illness estimates, as usually implemented.

The most recent attempt to make a comprehensive estimate of the total costs of illness in the U.S. is the study by Paringer and Berk (1977), for the Fiscal Year 1975. In addition, a comprehensive estimate of personal health expenditures by disease category has been completed by Hodgson and Kopstein (1984), for the year 1980. The health care expenditure estimates of the Hodgson and Kopstein study, combined with the estimates of foregone earnings due to morbidity from the Paringer and Berk study will be an important source of estimates for possible use in benefit cost analysis. (see section 2.2.5, below). For this reason, a review of the quality of these estimates is in order. In addition, since these studies use a standard methodology, their weaknesses and strengths will be shared by a majority of the COI studies.[1]

First, the quality of the estimates of health or medical expenditures due to different diseases is reviewed. Following this is a discussion of the estimates of foregone earnings due to morbidity.

2.4.4.1. Estimates of Health Expenditures

To evaluate the quality of the COI estimates of health expenditures by disease category, it is necessary to review the methodology behind these estimates. The comprehensive studies such as that of Paringer and Berk follow fairly closely the methodology developed by Rice (1966). The starting point is a measure of total health sector expenditures for a given year, E. Then, expenditures are broken down by type of service purchased, i.e. hospital care, physicians' services, etc. Letting E_i represent expenditures in the i^{th} service category, where $i=1,\ldots,n$, note that the sum of the E_i equals E. Estimates of the E_i are available from the Health Care Financing Administration (HCFA). (Before 1978 these estimates were prepared by the Social Security Administration.) Next, the COI studies must estimate a series of weights, v^j_i, which represents the percentage of expenditures in service category i accounted for by disease j. A variety of sources is used to estimate the different v^j_i. Finally, the expenditures necessitated by disease j, E^j, can be computed as the sum of the expenditures

necessitated by disease j.in each of the n service categories. The principle advantage of this methodology is that double counting is avoided, since total expenditures are simply distributed to the different disease categories.

For the purpose of benefit estimation, it is the expenditures necessitated by a particular disease, E^j that are of interest. Since in general the weights for the j^{th} disease will vary across the service categories, proper estimation of the expenditures by service category and the weights is required. In a recent review, Scitovsky (1982) finds problems in both parts of the estimation process.

A serious problem exists in the HCFA definitions of the service categories. The major categories of expenditures are: 1) hospital care, 2) physicians' and other health professionals' services, 3) drugs and medical sundries, 4) nursing home care, and 5) nonpersonal health care services, such as the prepayment and administrative expenses of insurance, medical construction, etc. Currently, the HCFA estimates of hospital expenditures include salaries and other payments to health professionals on hospital staffs, and the expense of drugs dispensed in hospitals. So expenditures for hospital care are overstated, while expenditures for health care professionals' services and for drugs and medical sundries are understated. A similar problem arises in estimating expenditures on nursing home care: these estimates include the costs of drugs dispensed in nursing homes. Redefining the service categories to correct for these problems, Scitovsky presents conservative estimates of the errors in the 1978 HCFA estimates of health care expenditures by service category. She finds that expenditures for hospital services were overstated by 12.4 percent, and expenditures for nursing home care were overstated by 3.5 percent. Expenditures for dentists' services were understated by 1.8 percent, expenditures for physicians' services were understated by 9 percent, and expenditures for drugs and medical sundries were understated by 50 percent.

Scitovsky mentions other problems with the estimation of the size of the service categories, but could not estimate the magnitude of these problems. For instance, expenditures for physicians' services may be further understated, since the estimates are based on tax returns of physicians. Particularly for physicians in private practice, both the opportunity and a strong incentive to underreport income are present, so this is a source of potentially serious error. Another problem is that Scitovsky feels the quality of the data used to estimate expenditures for nursing home care is poor. Hodgson and Meiners (1982) point out a third problem: double-counting of costs may be included in the estimates of expenditures for non-personal health care services. As an example, the costs of construction of new hospital facilities should be reflected in the prices charged for hospital care, so counting these costs in both categories is incorrect. This type of error is necessarily small, however, since expenditures for nonpersonal health care

make up only a small percentage of total expenditures.

One category of expenditures is typically omitted: expenditures in the nonhealth sector necessitated by illness, such as transportation to and from medical providers, special diets, and so forth. These expenditures are conceptually medical expenses, not preventive expenditures, because they follow the incurrence of a disease and do not prevent or lessen the probability of illness. It would be quite difficult to make a comprehensive estimate of these expenditures, since so many different types of goods and services could be involved. In an admittedly incomplete attempt to estimate some of these costs, Mushkin (1979, pp. 384-5) has estimated that including the nonhealth sector costs of illness would increase total expenditure estimates by 10 to 16 percent.

The problems encountered in the estimation of the expenditures by service categories (the Ei) are probably not as serious as the problems of estimating the weights used to assign expenditures to specific illnesses. Based on the criticisms of Scitovsky (1982) and others, the most important problems seem to be those concerning the allocation of the two largest expenditure categories: hospital services and physicians' services.

Most hospital expenditures are for community hospitals. These expenditures are distributed by days of care for each diagnostic group, as estimated from the Hospital Discharge Survey, weighted by expense per patient day. However, several studies by the Institute of Medicine (1977) show that the hospital diagnosis data are imprecise, so the estimate of the days of care by diagnostic group will be imprecise. Another problem is that the inpatient/outpatient mix is not accounted for in the allocation of expenditures. All expenditures are allocated on the basis of days of inpatient care, but these expenditures include a substantial amount of outpatient care. To the extent that the case mix of outpatient care differs from that of inpatient care, costs will be misallocated: the weights v_1, where 1 = hospital expenditures, will be estimated incorrectly.

Computing the weights for allocating expenditures for physicians' services is also problematic. These weights are based on the distribution of physician visits by diagnosis, based on the National Disease and Therapeutic Index, a continuing survey of private medical practice in the U.S. The quality of these diagnostic data is questionable. Scitovsky feels that these data are even less reliable than the similar data for hospitals, while the Institute of Medicine (1981, p. 89) describes the data as more reliable, but less precise due to the smaller sample used in the survey.

A larger problem is that the studies implicitly assume equal charges for all types of physician services. Since in fact a routine office visit is much less expensive than a visit requiring more extensive services or surgery, the weights will be incorrectly computed, and thus the costs of different illnessess

incorrectly estimated. That this is a potentially serious problem can be seen by comparing several estimates of the expenditures due to cancer. Rice and Hodgson (1978) modify Paringer and Berk's assumption of constant costs by breaking down physicians' services into four types with four different costs. Using this procedure, they reach an estimate 85 percent higher than Paringer and Berk's, and they feel that their result is still an understatement. Based on actual observation of patients, Scitovsky and McCall (1976) estimate physicians' services for breast cancer as costing three times more than the Rice and Hodgson estimate, While it is not clear which is the best estimate, there is certainly a very large range in this case. In general, it must be concluded that the estimation of this set of weights, the v_m where m = physicians' services, is also quite imprecise.

Problems also exist in the allocation of expenditures in the remaining smaller service categories: drugs and medical sundries, nursing home care, and nonpersonal health care services. Early studies' treatment of the expenditures for drugs and sundries is poor. The original Rice (1966) study does not allocate these expenditures at all, and the Cooper and Rice (1976) update allocates expenditures without distinguishing between prescription and non-prescription drugs. However, the Paringer and Berk study does make this distinction (see Berk, et al., 1978). Without knowledge of the detailed methodology used in the Hodgson and Kopstein study, it is impossible to assess the accuracy of their estimates of the weights used in the allocation of expenditures for drugs and medical sundries. Scitovsky (1982) found no evaluation of the data in general, and so could not express an opinion regarding its reliability. On the other hand, Scitovsky does judge the data used in allocating expenditures for nursing home care as poor, so the estimates of that set of weights are suspect. Finally, some remaining personal health care expenditures may not be allocated at all; Hodgson and Kopstein were able to allocate all but 5.6 percent of these expenditures. However, no attempt is made to allocate expenditures for nonpersonal health care to specific disease categories. For 1980, this means that an additional 16 percent of total health care expenditures are left unallocated. In effect, this final set of weights, v_n where n = nonpersonal health care, have been arbitrarily set to zero. Hodgson and Meiners (1982) in particular emphasize that these expenditures are a cost of illness and should be allocated by disease category (to the extent they do not represent double-counting, see above).

A serious problem that affects the estimation of all of the weights is the treatment of multiple conditions. The procedure is to allocate all of a patient's expenditures to his primary diagnosis, even though multiple conditions may be present. Multiple conditions seem fairly common. Scitovsky (p. 479) reports studies that 52 percent of hospital patients has multiple conditions, 85.7 percent of all residents in nursing homes has more than one chronic condition, amd 49.5 percent of the civilian noninstitutionalized population reported one or more chronic

conditions, and the average number of conditions per person with a chronic condition was 2.2.

In the context of benefit cost analysis, the proper treatment of multiple conditions will depend upon the exogeneous change being-considered.' For example, Rice (1966) finds that cardiovascular conditions are often secondary causes of disability, and as such increase the costs of treating other illnesses by necessitating longer hospital stays, etc. Counting these extra expenditures as part of the costs of cardiovascular disease would add around 5 percent to Rice's original estimate. For a program that prevented or cured cardiovascular conditions, the savings of the expenditures due to cardiovascular complications would be a legitimate part of the benefit measure. However, a program that prevented the primary illness might also prevent some of the secondary expense, so the expenditures saved could be counted as part of the benefit of that program also. Careful consideration of each program is necessary, to capture all the relevant benefits, but to avoid double-counting of benefits.

Proper treatment of the problem of multiple conditions is also necessary in the estimation of the lost wages caused by illness, since these are commonly assigned only to the primary diagnosis as well.

Taken together, the above criticisms imply that the estimates of health expenditures by disease category are subject to numerous, possibly large, errors. Many of the different categories of expenditures, the E_i, are estimated incorrectly, as are the weights placed on the categories. The fact that several categories are omitted form the final estimate of expenditures by disease might be taken to implythatthe estimates as a whole are conservative lower bounds. It is true that the estimates will sum to less than a true estimate of total expenditures.. However, this does not imply anything about how the individual E^J as estimated will compare to the ideal true value. It is impossible to make any general statements even about the sign of the errors, much less estimate the magnitudes. Consider as an example the estimate of health expenditures created by a chronic illness, that requires a great deal of routine care, but little hospitalization or surgery. Expenditures will be understated, since such a condition would require relatively large non-health sector costs, such as transportation. On the other hand, since the care would be routine, the cost of each office visitwouldbe overstated by the assumption of constant costs for all office visits. Considering the presence or absence of multiple conditions, whether or not the disease necessitates expenditures drugs, nursing home care, and so on further complicates the the issue. All that can be concluded is that the estimate of the expenditures due to such an illness may be incorrect, but by how much or in what direction would be difficult to guess.

2.4.4.2. Estimates of Foregone Earnings

The estimation of foregone earnings due to different diseases is somewhat more straightforward than that of medical expenditures. The methodology of the Paringer and Berk (1977) study is fairly typical. First, the population is broken down into four groups losing wages due to illness: 1) currently employed individuals; 2) individuals keeping house; 3) non-institutionalized individuals unable to work because of ill health; and 4) the institutional population. Within each group, detailed information is used to estimate the amount of earnings foregone, and to allocate these losses to specific diseases.

A general problem of the foregone earnings estimates is that, following the human capital approach, the COI studies focus on output or production lost, be it market, or non-market household production. Thus, the studies attempt to measure days lost from work, or days lost from house-keeping, as a result of illness. This measurement does not capture all the costs that an individual would be willing to pay to avoid. As in the models disucssed above, an individual can be thought of spending his time working, at leisure, or ill. Utility maximizing behavior implies that work and leisure will be traded off until at the margin leisure time is just as valuable as working time. Additional time spent ill, whether it comes out of leisure time or is lost from work, is valued at the wage rate by the individual. By only 'valuing the time actually lost from work or housekeeping, the COI measure of foregone earnings implicitly values leisure time at zero. Compared to the conceptually correct measure, COI estimates like Paringer and Berk's are incomplete.

There are also problems specific to the estimation of the foregone earnings of each of the four groups. The estimation of the foregone earnings due to illness of those currently in the work force is probably the most problem free. The Paringer and Berk study uses unpublished National Center for Health Statistics (NCHS) data on the number of work-loss condition days by age, sex, and diagnosis for individuals in this group. As the NCHS data is based on the the National Health Survey, a household survey, the first set of problems involves the accuracy of these estimates. In their general comments on the quality of data from the Survey, NCHS cautions that the estimates are based on a sample, and not the entire population, so they are subject to sampling error, but adds that sampling errors for most of the estimates are small (see Vital and Health Statistics, various issues).. Another problem is that the results of the Survey depend, of course, on how the respondents report their health status. While the National Health Survey is undoubtedly well-designed, this type of problem is to some extent impossible to eliminate. Cooper and Rice (1976) conclude that the use of Survey data in estimating foregone earnings due to morbidity "undoubtedly results in conservative estimates for some diseases and overstatements for others," because of incorrect identification of the conditions actually present in the

respondents.

A second set of problems encountered in the estimates of the foregone earnings of the currently employed is that it is the number of "condition days" that is reported. A condition day of work-loss is a day of work loss associated with a certain condition, so if an individual reports that he missed a day for two conditions, this would be reported as two condition days of work-loss. In general, the sum of condition days of work-loss may exceed the total number of person days of work-loss. To avoid double counting of work-loss days, Paringer and Berk scale down all work-loss condition days by a constant, so the sum of adjusted work-loss condition days equals the total of person days of work-loss. As they note, "this procedure may create a bias in the estimates of morbidity costs by disease class, since certain classes are more likely to be primary causes of work-loss or bed-disability than others." (Paringer and Berk, 1977, p. 9).

A final source of error in the esimation of the foregone earnings of the currently employed is the specificity of the data used. While the data is age- and sex- specific, the Institute of Medicine (1981, p 91) argues that even more specific data would be desireable. Consider their example that the better educated, who generally have higher earnings, may be healthier than the less well educated, and less likely to fall ill from an exogeneous threat such as pollution. Failure to control for education will result in an overstatement of the foregone earnings due to an increase in illness, since the poorly educated with below average earnings for their age/race/sex group will be affected disproportionately. Variables other than education may also be important, so additional bias may be present in the estimates of the earnings lost by those currently employed.

The estimation of the "foregone earnings" of individuals keeping house is less precise than the estimation for the currently employed. The Paringer and Berk study uses unpublished NCHS data on the number of bed-disability condition days for women keeping house, by age groups. Again, problems may be encountered because of the possible inaccuracies of the Survey data. In addition, the bed-disability condition days are scaled down, so the estimates may be biased as with the work-loss condition days discussed above. Finally, the same biases may result because education and other possibly important variables are not controlled for.

There are further problems with the estimates of the value of housekeeping services. First, the procedure used to value these services is questionable. The values are based on what the Institute of Medicine (1981, p. 91) describes as a "relatively small outdated sample." In addition, time spent housekeeping is valued according to the wage rates of workers in the marketplace performing similar services. What is relevant to the individual keeping house, however, is the wage rate she is giving up by staying out of the market. The IOM suggests that this might be estimated "based on the earnings of working women with similar

characteristics as housewives". Finally, the value of time spent by all individuals keeping house, not just women, should be estimated. While Paringer and Berk (pp. 11-12) make a strong case that this should be done, they only estimate the value of men's housekeeping services (or household production in general) for the case-of mortality. Estimates of the loss of household production due to morbidity are limited to estimates of women's loss.

There is less to say about the estimation of the foregone earnings of those unable to work because of illness and the institutional population. The key assumption made is that these groups would have had the same work and housekeeping experiences as the currently employed, controlling for sex and age. Whether this is a good approximation is not clear, but it is also not clear if any better assumption could be made. This assumption does imply that any biases in the estimation of the foregone earnings of the currently employed and of those keeping house will aslo exist in the estimates of the foregone earnings of those unable to work and the institutional population.

A recent study by Salkever (1985) includes several methodological refinements in the estimation of foregone earnings due to morbidity and so avoids some of the problems outlined above. Salkever develops estimates for foregone earnings for non-institutionalized males age 17 to 64 by combining data from the Health Interview Survey (HIS) and the 1976 Survey of Income and Education (SIE). To compute the earnings loss for each work loss day reported in the HIS, a synthetic estimate of the respondent's hourly wage was computed. This entailed inserting data on the respondent's personal character-istics from the HIS into an hourly wage regression estimated with SIE data. The independent variables included measures of the individual's education, presence or absence of a chronic condition, region and urban or rural character of residence, industry where person was employed and average earnings for the occupation in which the person was employed. Using such specific data on the individuals who suffer work loss days implies that Salkever's estimates of foregone earnings are much less likely to suffer the bias problems the Institute of Medicine described. To return to the IOM example, since education differences are controlled for in Salkever's estimates, foregone earnings will not be overstated even if the better educated earn more and are less likely to be sick, as the IOM suggests.

Salkever also estimates the earnings losses for persons unable to work because of illness. As in earlier studies, he assumes these persons lose income equal to the earnings of similar individuals without chronic health problems. Specifically, these foregone earnings were computed as the average earnings by persons in the SIE data, without chronic health problems, classified by age group, education level, race and region of residence. Just as for valuing work loss days, using more specific data on the individuals unable to work because of illness means that Salkever's estimates are less

likely to be biased.

Salkever's estimates of foregone earnings due to morbidity represent important improvements in methodology, which should be relfected in improved accuracy. However, since Salkever only develops estimates for males age 17 to 64 for certain conditions, his estimates are not directly comparable to the more comprehensive estimates of earlier studies reported below. As a result, it is difficult to judge the empirical importance of either Salkever's refinements or the inaccuracies implied by the earlier methodology.

In conclusion, the estimation of the foregone earnings due to illness may be straightforward, but the estimates still are not necessarily very close to the ideal true values. Most of the errors tend to understate foregone earnings due to morbidity, so in this case, unlike the health expenditures estimates, the existing estimates can be considered as conservative lower bounds to the true values.

2.4.5. Empirical Estimates of the Cost of Illness

In this section, estimates of medical expenditures and foregone earnings due to illness are presented, to be used as a measure of the value of improved morbidity risks. Particular emphasis is placed on the cost of illness estimates for diseases and disease categories that might be related to environmental quality. In section 2.4.5.1, some estimates from existing COI studies of the total medical expenditures and foregone earnings to morbidity related to different disease categories are presented. In section 2.4.5.2, these estimates are put on a per case basis, and additional per case estimates are presented. In section 2.4.5.3, for certain conditions, the costs are also expressed on a per day of illness basis.

2.4.5.1. Total Medical Expenditures and Foregone Earnings Due to Morbidity

Reported in Table 2-4 are total figures for medical expenditures and foregone earnings due to morbidity caused by various diseases or disease groups. The totals have all been updated to August 1984 dollars, using the medical care component of the CPI to adjust the medical expenditures, and the general CPI to adjust foregone earnings. It is recognized that this procedure may introduce errors in the estimates, due to relative price changes in health care services and relative wage changes for different age/sex/race groups.

In addition to the comprehensive estimates of the cost of all illnesses of the Paringer and Berk and the Hodgson and Kopstein studies, Table 2-4 also reports the results of studies that estimate the costs of a specific illness or group of

illnesses.[2] These studies are useful in two ways. First, the expenditures and earnings lost. due to a specific illness (e.g. emphysema) can be found. Comprehensive studies only provide estimates relating to more general categories (e.g., all respiratory diseases). Second, the specific illness studies may employ a different methodology. This is particularly relevant for the estimates of health expenditures. While some studies use the same methods and data sources as the comprehensive studies, others estimate expenditures based on more disaggregated data, such as the observation of actual cases. For a review of the methodology and quality of over 200 studies that estimate the costs of illness, see Hu and Sandifer (1981). Briefly, the studies by the National Heart and Lung Institute (NHLI (1972, 1975)) and the Acton (1975) study follow essentially the same methodology as the Paringer and Berk (1975) and the Hodgson and Kopstein (1984) studies, as reviewed above in Section 2.4.4. The study by Freeman, et al., (1975) represents a slightly different methodology (and it is thus notable the close correspondence of the Freeman estimates and the NHLI (1972) estimates of the cost of emphysema). The Hartunian, et al., (1980) follows a methodology followin, an incidence-based approach to measuring medical expenditures.[4]

It is difficult to make many general statements concerning the range of estimates presented in Table 2-4. It is clear that the estimates from the Paringer and Berk and the Hodgson and Kopstein studies are much higher than comparable estimates from other studies. This seems to be part of a general trend that the more recent estimates are higher than estimates based on an earlier time period and scaled up for inflation. Two influences seem important. First, the use of the medical care component of the CPI and the general CPI in adjusting for inflation may somehow be biasing the earlier estimates downward. Second, the more recent studies may be a more complete accounting of costs, reflecting improvements in methodology and data sources. For instance, more expenditures are allocated by disease in the more recent studies, and more allowance is made for household production in the estimation of foregone earnings. For these reasons, .it is likely that the more recent estimates are more accurate, and whenever possible that most recent study should be used to provide estimates for use in benefit cost analysis.

TABLE 2-4: TOTAL MEDICAL EXPENDITURES AND FOREGONE EARNINGS DUE TO SELECTED ILLNESSES

(in million $, August 1984)

Disease Category	Medical Expenditures	Foregone Earnings
All diseases		
Hodgson and Kopstein (1984)	315,058	
Paringer and Berk (1977)		112,319
Infective and Parisitic Diseases		
Hodgson and Kopstein (1984)	6,459	
Paringer and Berk (1977)		3.024
Neoplasms (cancer)		
Hodgson and Kopstein (1984)	19,563	
Paringer and Berk (1977)		2,144
Hartunian, et al. (1980)	14,522	
Diseases of the Circulatory System		
All		
Hodgson and Kopstein (1984)	47,652	
Paringer and Berk (1977)		16,963
Acton (1975)	14,557	10,557

TABLE 2-4 (continued)

Disease Category	Medical Expenditures	Foregone Earnings
Cerebreovascular Disease (Stroke)		
Hodgson and Kopstein (1984)	7,324	
Paringer and Berk (1977)		685
Hartunian, et al. (1980)	5,364	
Acton (1975)	2,201	1,132
NHLI (1975)	3,789	735
Coronary Heart Disease		
Hartunian, et al. (1980)	5,642	
Acton (1975)	5,871	5,416
NHLI (1975)	7,912	1,157
Respiratory Diseases		
All		
Hodgson and Kopstein (1984)	24,850	
Paringer and Berk (1977)		16,572
NHLI (1972)	6,385	4,284
Emphysema		
NHLI (1972)	652	1,414
Freeman, et al. (1976)	579	3,610

2.4.5.2. Per Case Estimates of Medical Expenditures and Foregone Earnings Due to Morbidity

Table 2-5 reports per case estimates of medical expenditures are foregone earnings due to various illnesses. The estimates are based on the same sources as the totals of Table 2-4. In addition, independent per case estimates by Scitovsky and McCall (1976) and Acton (1975) are presented. All estimates are updated to August 1984 dollars (See Notes to Table 2-6 for details).

In putting the total figures on a per case basis, the basic procedure is simply to divide the total cost figure for ayearby the appropriate number of cases of that illness in that year. The proper measurement of the appropriate number of cases is not simple, however. In defining what constitutes a "case" of an illness, the specific use of the per case estimates in benefit cost analysis must be considered. For instance, it might be known from epidemiologic or health econometric studies that a reduction in pollution will reduce the number of serious cases of a particular disease, i.e. only those cases that involve medical expenditures and foregone earnings. In this situation, in preparing per case estimates it would thus be desirable to define a case as only a case of the disease that does involve medical expenditures and foregone earnings. Instead, it might be known only that the reduction in pollution will reduce the number of cases of a particular disease, without specifying if the cases are serious or not. Under these circumstances, a more general definition of case is desirable, allowing for cases involving varying amounts of medical expenditures and foregone earnings to be included. Essentially, the per case estimates of medical expenditures and foregone earnings represent the average cost of a case of disease, but what population over which to average is somewhat ambiguous. The per case estimates of Table 2-5 are prepared using a broad definition of the number of cases, so the average medical expenditures and foregone earnings due to a case of illness are conservative estimates.

The source of the data for the number of cases of acute and chronic illnesses (except neoplasms) is the National Health Survey, as reported by the National Center for Health.Statistics (NCHS) in various issues of Vital and Health Statistics As described above, the estimates from the survey are subject to possible inaccuracies. Estimates of the number of cases of the different illnesses may understate the actual number of cases, in general. For acute cases, the estimates exclude all conditons involving neither restricted activity nor medical attention. For chronic cases, data is available on the degree of impact the illness had, so the number of cases could be adjusted downward so that only more severe cases are counted. However, the fact that chronic illnesses are generally under-reported in surveys, and the likely use of' the per case estimates in benefit cost analysis of changes in all types of cases of illness argue forthebroader measure of chronic cases to be used.

An additional problem encountered in estimating the number of cases of chronic illnesses is encountered in that the prevalence of chronic conditions is not estimated for every year. The prevalence estimates used in preparing Table 2-5 are estimates from the survey for the closest year to the year used as a base for the different studies that report total medical expenditures and foregone earnings due to morbidity.

Estimating the number of cases of neoplasms (cancer) presents several special problems. Three different measurements are possible candidates. First, the incidence of cancer, that is, the number of new cases of cancer diagnosed in a given year, could be used, Second, the number of individuals under medical care for cancer is a possible measure of the number of cases of cancer existing in a given year. Third, by combining incidence and survival data, it is possible to estimate the number of people alive in a given year with a history of cancer. The incidence measurement is an understatement of the number of cases of cancer, since in any given year there will be individuals with cancer that was incurred and diagnosed in an earlier year. The number of people alive with a history of cancer is an overstatement, because it includes individuals who for all practical purposes have been totally cured of cancer. So the figure used in preparing Table 2-5 is the number of individuals under medical care for cancer, for 1974 (Cancer Facts and Figures, 1974), though the measure is not exactly comparable to the broader definitions of cases used for other illnesses. Added to this figure is an estimate of the prevalence of neoplasms of the skin, from NCHS estimates. It should be pointed out that adding neoplasms of the skin doubles the number of cases of cancer, and biases the per case estimates of the medical expenditures and foregone earnings due to cancer downwards, since neoplasms of the skin are likely to involve lower medical expenditures and foregone earnings than other cancers. This is an example of the inaccuracies involved in using estimates of the costs of broad groups of illness, such as cancer, as opposed to an estimate of the cost due to a more specific illness, such as a particular type of cancer.

The basic procedure for deriving per case estimates described above is not applied to the totals from the study by Hartunian et al.(1981). This study follows an incidence based approach to estimating the costs of illness, while the other studies cited follow a prevalence based approach. A problem of comparability results. On an aggregate basis, incidence based estimates and prevalence based estimates may be approximately the same; in fact, Hartunian et al.(1980) find relatively small differences between the two approaches for some conditions. However, putting the prevalence based estimates on a per case basis yields estimates of the average yearly costs of a case of illness. In contrast, expressing incidence based estimates on this same basis would yield estimates of the average lifetime costs of a case of illness. A second problem is that expressing the total incidence based estimates of costs would entail

dividing total costs by the incidence of the different conditions, and estimates of incidence are limited in scope and accuracy.[4]

The per case estimates due to Hartunian et al. reported in Table 2-5 are estimates of the average first year costs of several conditions. The estimates are derived from the details given of the calculation of the total costs in Hartunian etal. (1981, various chapters). Since detailed descriptions of the calculations were only given for selected conditions to be illustrative of the methodology, the number of conditions for which first year costs can be estimated is limited.

In addition to the per case estimates derived from studies estimating total medical expenditures and foregone earnings, Table 2-5 includes per case estimates from two independent sources. Scitovsky and McCall (1976, as cited in Mushkin (1979)) report average medical expenditures due to several conditions, based on the cost of care in the Palo Alto Medical Clinic in 1971 actually incurred by patients. Estimates of per case medical expenditures and foregone earnings derived from Acton (1975, tables 7 and 9) are also presented. In what is described as an illustrative exercise, Acton puts his total estimates of the costs of various diseases of the circulatory system on a per case basis using a procedure similar to that described above. The important difference is that Acton attempts to estimate the medical expenses and foregone earnings of an average person actively suffering the consequences of a disease. That is, Acton uses a narrower definition of a "case" of a disease than is used in the preparation of the other per case estimates of Table 2-5.

While Table 2-5 may seem to include a very wide range of estimates, considering truly comparable diseases shows some agreement between the studies. The lowest estimates of medical expenditures and foregone earnings per case are for all respiratory diseases ($87 and $56, respectively), and for all infective and parasitic diseases ($123 and $63). However, the per case figures for all respiratory diseases are influenced by the very large number of cases of upper respiratory tract infections that presumably involve relatively low medical expenditures and foregone earnings. The estimates of the medical expenditures and foregone earnings due to a more serious respiratory disease such as emphysema are substantially higher ($497 and $1,078 from NHLI, or $441 and $2,753 from Freeman, et al.). A similar result holds when comparing the cost of cases of diseases of the circulatory system. The per case estimates for all diseases of the circulatory system are much smaller than the per case estimates for specific, more serious diseases, such as cerebreovascular disease (stroke), coronary heart disease, and myocardial infarction. The different estimates for these specific diseases show more agreement between studies, but there is still a fairly wide range. For instance, Acton estimates the medical expenditures due to a stroke as $1,561, while the per case estimate based on Hodgson and Kopstein is $4,210. As noted above, Acton uses a lower estimate of the number of cases in

expressing his results on a per case baiss, which implies that if the Acton and the Hodgson and Kopstein estimates were computed in exactly the same manner, the difference would be even greater. This difference in the medical expenditures due to a case of stroke is the most extreme difference found in Table 2-5 for a specific disease; in general the per case estimates based on different studies' estimates of the medical expenditures and foregone earnings for a specific illness are much closer together.

To sum up, in using the per case estimates of Table 2-5 in benefit cost analysis, two considerations should be kept in mind. First, just as for the estimates of the totals in Table 2-4, the per case estimates in Table 2-5 based on the most recent studies are judged as generally superior in quality. Second, the estimates of the costs of a specific disease should be used rather than the estimates of the costs of a group of diseases, whenever possible.

TABLE 2-5: PER CASE MEDICAL EXPENDITURES AND FOREGONE EARNINGS

(in $, August 1984)

Disease Category	Medical Expenditures Per Case	Foregone Earnings Per Case
Infective and Parasitic Diseases		
Hodgson and Kopstein (1984)	123	
Paringer and Berk (1977)		63
Neoplasms		
All		
Hodgson and Kopstein (1984)	8,780	
Paringer and Berk (1977)		962
Lung Cancer		
Hartunian, et al. (1981)	15,687	13,404
Cancer of the Breast		
Scitovsky and McCall (1976)	7,605	
Diseases of the Circulatory System		
All		
Hodgson and Kopstein (1984)	773	
Paringer and Berk (1977)		275
Cerebreovascular Disease (Stroke)		
Hodgson and Kopstein (1984)	4,210	
Paringer and Berk (1977)		394
NHLI (1975)	3,708	1,318
Acton (1975)	1,561	803

TABLE 2-5 (continued)

Disease Category	Medical Expenditures Per Case	Foregone Earnings Per Case
Coronary Heart Disease		
NHLI (1975)	2,393	350
Acton (1975)	1,406	1,297
Angina Pectoris		
Hartunian, et al. (1980)	246	0
Myocardial Infarction		
Scitovsky and McCall (1976)	11,242	
Respiratory Diseases		
All		
Hodgson and Kopstein (1984)	87	
Paringer and Berk (1977)		56
NHLI (1967)	25	17
Emphysema		
NHLI (1967)	497	1,078
Freeman, et al. (1976)	441	2,753
Pneumonia (non-hospital care)		
Scitovsky and McCall (1976)	253	

TABLE 2-6: PART 1
PER CASE MEDICAL EXPENDITURES
(background for Table 2-5)

Disease Category and Study	Total Costs (in millions)	Number of Cases (in thousands)	Per Case costs (year varies)	Per Case costs (August 1984)
Infective and Parasitic Diseases				
Hodgson and Kopstein (1984)	4,498	52,691	85.37	123
Neoplasms				
Hodgson and Kopstein (1984)	13,623	2,228	6114.5	8,780
Diseases of the Circulatory System				
All				
Hodgson and Kopstein (1984)	33,184	61,652	538	773
Stroke				
Hodgson and Kopstein (1984)	5,100	1,740	2,931	4,210
NHLI (1975)	971	1,534	633	3,708

TABLE 2-6; PART 1 (continued)

Disease Category and Study	Total Costs (in millions)	Number of Cases (in thousands)	Per Case costs (year varies)	Per Case costs (August 1984)
Coronary Heart Disease				
NHLI (1975)	2,072	3,307	627	2,393
Repiratory Diseases				
All				
Hodgson and Kopstein (1984)	17,305	285,323	60.65	87
NHLI (1967)	1,672	258,473	6.47	25
Emphysema				
NHLI (1967)	171	1,313	130.24	497
Freeman, et al. (1976)	183	1,313	139.5	441

TABLE 2-6: PART 2
PER CASE FOREGONE EARNINGS

Disease Category and Study	Total Costs (in millions)	Number of Cases (in thousands)	Per Case costs (year varies)	Per Case costs (August 1984)
Infective and Parasitic Diseases				
Paringer and Berk (1977)	1,559	48,206	32.34	63
Neoplasms				
Paringer and Berk (1977)	1,105	2,228	496	962
Diseases of the Circulatory System				
All				
Paringer and Berk (1977)	8,744	61,652	141.8	275
Stroke				
Paringer and Berk (1977)	353	1,740	203	394
NHLI (1975)	421	1,534	274	1,318
Coronary Heart Disease				
NHLI (1975)	370	3,307	112	350
Respiratory Diseases				
All				
Paringer and Berk (1977)	8,542	285,323	28.75	56
NHLI (1967)	1,370	258,473	5.3	17

Emphysema

NHLI (1967)	452	1,313	344.25	1,078
Freeman, et al. (1976)	1,343	1,313	1,023	2,753

Explanatory Notes For Table 2-6

1. Total costs (in millions) are the original estimates of the various studies of the total medical expenditures and foregone earnings. These estimates are for various years.

2. Number of cases (in thousands) is the sum of the incidence of acute cases and the prevalence of chronic cases, for the year closest to the year the studies estimated that could be found. Source: Vital and Health Statistics, various issues.

3. Per case costs = total costs divided by number of cases. These per case costs are for the years of the original studies.

4. Per case costs (Aug. 1984) are the previous per case costs expressed in current (Aug. 1984) dollars; medical expenditures are adjusted using the medical care component of the CPI; foregone earnings are adjusted using the general CPI.

2.4.5.3. Estimates of the Costs of Illness per Day Spent Ill

The third column of Table 2-7 presents estimates of the costs of various illnesses per day spent ill. These estimates are derived by dividing the per case costs developed above by the average number of days spent ill per case of illness per year. In the first column of Table 2-7 are per case costs of illness (medical expenditures plus foregone earnings) from Table 2-6. Estimates of the average number of Restricted Activity Days (RADs) are available from the Health Interview Survey for most acute conditions and certain chronic conditions. These estimates are presented in column two of Table 2-7.

Costs of different illnesses per day spent ill present a fairly narrow range, from $10 to $81. This reflects the fact that a great deal of the difference between a minor and a serious illness is simply the average number of days spent ill: the number of days per condtion varies from about 4 for an average case of acute infective and parasitic disease or for an acute respiratory disease, to over 40 days spent ill due to heart disease. Another possible difference is the degree of disability on the day spent ill. A Restricted Activity Day is defined as "one on which a person substantially reduces his normal activity for the whole day due to an illness or injury" (Vital and Health Statistics), this can range from reduced activity alone to a day of work loss to a day of bed disability. The RADs for the more serious conditions may reflect a greater restriction of activity than the RADs for the minor conditions.

TABLE 2-7: COSTS OF ILLNESS PER DAY SPENT ILL

(in $, August 1984)

Disease Category	costs Per Case	RADs Per Case Per Year	costs Per RAD
Infective and Parasitic Diseases			
Hodgson and Kopstein (1984)	186	4.06	46
Paringer and Berk (1977)			
Diseases of the Circulatory System			
Coronary Heart Disease			
NHLI (1975)	2743	43.1	64
Acton (1975)	2703	43.1	63
Respiratory Diseases			
All			
Hodgson and Kopstein (1984)	143	4.1	35
Paringer and Berk (1977)			
NHLI (1967)	42	4.1	10
Emphysema			
NHLI (1967)	1575	35.8	44
Freeman, et al. (1976)	3194	35.8	89
Pneumonia (non-hospital care)			
Scitovsky and McCall (1976)	253	18	14

2.4.6. Concluding Remarks on the Cost of Illness Approach

Section 2.4 is concerned with the problems of valuing changes in health risks as reduction in health expenditures and foregone earnings, i.e., the cost of illness approach. A contribution of the present project has been to put aggregate costs of illness on an individual per case and per day spent ill basis. Results indicate that a typical case of acute respiratory disease involves $87 of medical expenditures, and $56 of foregone earnings. A case of emphysema involves $441 of medical expenditures, and $2,753 of foregone earnings. A day spent ill due to a typical case of acute respiratory illness costs $35, while a day spent ill due to emphysema implies costs of $89. Estimates of this kind on an individual basis needed to evaluate environmental policy changes have not been available heretofore.

The cost of illness approach is an important source of estimates for the value of health, because it is commonly accepted by many researchers in the health care fields, and it provides estimates for the value of a wide range of health effects. Therefore, section 2.4 includes a careful evaluation of the approach to assess its usefulness and accuracy.

This evaluation reveals that the approach suffers from conceptual and methodological shortcomings, which limit its usefulness. One set of issues essentially raises the problem that the cost of illness benefit measure is not well-related to the conceptually correct willingness to pay measure. The discussion of this problem (section 2.4.2) suggests that a cost of illness measure may be a lower bound to a willingness to pay measure. It is not necessarily a good approximation to the willingness to pay measure, however. In addition, the distinction between individual and societal willingness to pay has been treated unevenly in the cost of illness approach, and deserves further consideration.

The review of the methodology of the cost of illness approach in section 2.4.4 leads to the conclusion that the estimates of medical expenditures and foregone earnings due to morbidity are not particularly precise or reliable. This is especially significant since it is the presumed practical advantages of calculating medical expenditures and foregone earnings, instead of calculating willingness to pay, that is often the stated reason for preferring the cost of illness approach.

2.2.10. Footnotes

1. The Paringer and Berk (1977) study is cited by Mushkin (1979), and is part of a series of estimates of the cost of illness for the years 1900, 1930, 1975, and projected for the year 2000, prepared at Georgetown University Public Services Laboratory.

All details of the methodology of Hodgson and Kopstein (1984) study are not described in the published article. They state that their "methodology follows closely that originally devised by Cooper and Rice (1976) to allocate expenditures among diagnoses, amended to include several additional sources of data." My discussion and criticism of the quality of the estimation of health care expenditures is based on the Cooper and Rice methodology, so most of it should apply to the Hodgson and Kopstein study. Since Hodgson and Kopstein do use new sources of data, it is expected that their estimates will be superior to earlier estimates, and some of the criticisms below may not apply.

2. As explained earlier, the Paringer and Berk and Hodgson and Kopstein studies are used because they represent the most recent estimates of foregone earnings and medical expenditures due to illness that could be found.

3. The Hartunian et al. study reports foregone earnings due to morbidity and mortality combined, so the foregone earnings due to morbidity alone could not be derived easily. For this reason, only the estimates of medical expenditures from this study are reported in Table 2-4.

4. For a more complete discussion of the difference between prevalence based and incidence based estimates of the cost of illness, a report is available upon request.

2.2.11. References

1. Acton, J.P. Measuring the Social Impact of Heart and Circulatory Disease Programs: Preliminary Framework and Estimates. The Rand Corporation, Santa Monica, California, April 1975. pp. 35-57.

2. Bailey, M.J. Reducing Risks to Life: Measurement of the Benefits, American Enterprise Institute, Washington, DC, 1980.

3. Berk, A., L. Paringer and S.J. Mushkin. The Economic Cost of Illness, Fiscal 1975. Medical Care, 16, 1978, pp. 785-790.

4. Blomquist, G. The Value of Human Life: An Empirical Perspective, Economic Inquiry, 19, January 1981. pp.157-164.

5. Conley, B.C. The Value of Human Life in the Demand for Safety, American Economic Review, 66,1976. pp. 45-55.,

6. Cooper, B. and Rice, D. The Economic Costs of Illness Revisited. Social Security Bulletin, 39, 1976. pp. 21-36.

7. Courant, P. and Porter, R. Averting Expenditures and the Cost of Pollution. Journal of Environmental Economics and Management, 8, 1981. pp. 321-329.

8. Crocker, T.D., Schulze, W., Ben-David, S., and Kneese, A.V. Methods Development for Assessing Air Pollution Control Benefits. Experiments in the Economics of Air Pollution Epidemiology, Volume 1, U.S. EPA Grant #R805059010, U.S. Environmental Protection Agency, Washington, DC 1979.

9. Feldstein, P.J. Health Care Economics. John Wiley and Sons, New York, 1979, 1982 (second edition).

10. Freeman, R.A. et al. Economic Cost of Pulmonary Emphysema: Implications for Policy on Smoking and Health. Inquiry 13, March, 1976. pp. 15-22.

11. Gibson, R.M., Waldo, D.R., and Levit, K.R. National Health Expenditures, 1982. Health Care Financing Review 5, Fall, 1983. pp. l-31.

12. Grossman, M. On the Concept of Health Capital and the Demand Health. Journal of Political Economy 80, March/April 1972. pp.223-225.

13. Harberger, A.C. Survey of Literature on Cost-Benefit Analysis for Industrial Project Evaluation, in his Project Evaluation, The University of Chicago Press, Chicago, 1972.

14. Harberger, A.C. Three Basic Postulates for Applied Welfare Economics: An Interpretive Essay", in his Taxation and Welfare. The University of Chicago Press, Chicago, 1974.

15. Harrington, W. and Portnoy, P.R. Valuing the Benefits of Improved Human Health". Mimeo, Resources for the Future, Washington, D.C., 1982.

16. Hartunian, N.S., et al. The Incidence and Economic Costs of Cancer, Motor Vehicle Injuries, Coronary Heart Disease and Stroke: A Comparative Analysis. American Journal of Public Health 70, December 1980, pp. 1249-1260; and The Incidence and Economic Costs of Major Health Impairments, Lexington Books, 1981.

17. Hodgson, T. and Kopstein, A. Health Care Expenditures for Major Diseases in 1980. Health Care Financing Reviews 5, 1-12, Summer 1984.

18. Hodgson, T. and Meiners, M. Cost-of-Illness Methodology: A Guide to Current Practices and Procedures. Milbank Memorial Fund Quarterly/Health and Society 60: 2, 1982. pp. 429-462.

19. Hu, T. and Sandifer, F.H. Synthesis of Cost of Illness Methodology. Prepared for the National Center for Health Services Research, Department of Health and Human Services, Washington, DC, 1981.

20. Institute of Medicine. Reliability of Hospital Discharge Abstracts, Reliability of Medicare Hospital Discharge Records, Reliability of National Hospital Discharge Survey Data, National Academy of Sciences, Washington, DC, 1977.

21. Institute of Medicine. Costs of Environment-Related Health Effects: A Plan for Continuing Study, National Academy Press, Washington, DC, January 1981.

22. Landefeld, J.S. and Seskin, E.P. The Economic Value of Life: Linking Theory to Practice. American Journal of Public Health 72, June 1982. pp. 555-566.

23. Lave, L.B. and Seskin, E.P. Air Pollution and Human Health. The Johns Hopkins University Press, Baltimore, 1977.

24. Liu, B. and Yu, E. Physical and Economic Damage Functions for Air Pollutants by Receptor. EPA Publication No. 660/5-76-011, Socioeconomic Environmental Studies Series. NTIS Publication No. PB 262 340. 1976.

25. Linnerooth, J. The Value of Human Life: A Review of the Models, Economic Inquiry 17, January 1979. pp. 52-74

26. Mishan, E.J. Evaluation of Life and Limb: A Theoretical Approach. Journal of Political Economy 79, July/August 1971. pp. 687-705.

27. Mushkin, S.J. Biomedical Research: Costs and Benefits. Ballinger, Cambridge, MA., 1979.

28. Paringer, L. and Berk, A. Costs of Illness and Disease Fiscal Year 1975, Georgetown University Public Services Laboratory, Washington, DC, January 1977.

29. Rice, D.P. Estimating the Cost of Illness. Health Economics Series Number 6, U.S. Department of Health, Education and Welfare, Public Health Service, Washington, DC, 1966.

30. Rice, D.P. and Hodgson, T.A. Social and Economic Implications of Cancer in the United States. National Center for Health Statistics, Washington, DC. Department of Health, Education, and Welfare, 1978.

31. Rosen, Sherwin. Valuing Health Risks. American Economic Review 71:241-245. 1981.

32. Salkever, D.S. Morbidity Costs: National Estimates and Economic Determinants, NCHSR Research Summary Series, DHHS Publication No. (PHS) 86-3393, October 1985.

33. Scitovsky, A. Changes in the Costs of Treatment of Selected Illnesses, 1951-65. American Economic Review, 1967. Vol. 57, PP. 1182-95.

34. Scitovsky, A. Costs of Medical Treatment, Reply, American Economic Review, 1968. Vol. 58, pp. 939-940.

35. Scitovsky, A.A. Estimating the Direct Costs of Illness. Milbank Memorial Fund Quarterly/Health and Society 60:3, 1982, pp. 463-489.

36. Scitovsky, A.A. and N. McCall. Changes in the Costs of Treatment of Selected Illness. 1954-1964-1971 NCHSR, Research Digest Series, DHEW Publication No. (HRH) 77-3161, July 1976.

37. Smith, V.K. and Desvouges, W.H. Averting Behavior: Does it Exist? Vanderbilt University Department of Economics Working Paper, September 1985.

38. U.S. Health Interview Survey. Current Estimates from the Health Interview Survey. Vital and Health Statistics 1975, series 10, no. 115.

39. U.S. Health Interview Survey. Prevalence of Chronic Conditions of the Genitourinary, Nervous, Endocrine, Metabolic, and Blood and Blood-Forming Systems, and of Other Selected Chronic Diseases. Vital and Health Statistics 1973 and 1977, serices 10; no. 109.

40. U.S. Health Interview Survey. Prevalence of Chronic Skin and Musculoskeletal Conditions. Vital and Health Statistics 1976, series 10, no 124.

41. U.S. Health Interview Survey. Prevalence of Seleected Chronic Digestive Conditions. Vital and Health Statistics 1975, series 10, no 123.

42. U.S. Health Interview Survey. Prevalence of Selected Reported Chronic Conditions. Vital and Health Statistics 1979, series 10, no 99.

43. U.S. National Heart and Lung Institute (NHLI) Task Force in Arteriosclerosis. Economic Impact of Arteriosclerosis. Appendix D. Report by NHLI, Vol. 2, G.P.O. Washington, DC, June 1971.

44. U.S. National Heart and Lung Institute (HNLI). Economic Costs of Respiratory Diseases. Respiratory Disease Task Force Report on Problems, Research Approaches, Needs. DHEW Publication No. (NIH) 76-432, pp. 205-243. U.S. National Institute of Health,Washington, DC, October 1972.

45. Usher, D. An Imputation to the Measure of Economic Growth for Changes in Life Expectancy. Conference on Research in Income and Wealth, National Bureau of Economic Research, New York: 1971.

46. Violette, D.M., and Chestnut, L.G. Valuing Reductions in Risks. A Review of the Empirical Estimates. Energy and Resource Consultants, Inc. for U.S. EPA 1983.

47. Weisbrod, B.A. Economics of Public Health. University of Pennsylvania Press, Philadelphia, Pennsylvania, 1961.

48. Weisbrod, B.A. Costs and Benefits of Medical Research: A Case Study of Poliomyelitis. Journal of Political Economy 79, May/June 1971. pp. 527-544.

2.5: CONTINGENT VALUATION OF HEALTH

2.5.1. Introduction

One approach to valuing a non-marketgoodis to conduct a survey and ask people what they would pay for the good, hypothetically assuming (contingent upon) the existence of a market for the good. This approach is termed the contingent valuation method (CVM), and has been applied to a variety of environmental goods, including air quality and health. The purpose of this section is to review the applications of the CVM to the problem of valuing health. Since the goal is to find useful empirical evidence, discussion of both methodological issues and of actual results is required.

Section 2.5.2 is a brief overview and assessment of the contingent valuation method, drawing heavily upon the recent review by Cummings, et.al. Section 2.5.3 concerns the application of contingent valuation to health. It critiques three studies that apply the method to health effects possibly related to air pollution: Loehman, et al. (1979), Rowe and Chestnut (1984) and Tolley et al. (1985, Volume 3 of this report). Section 2.5.4 is a conclusion and summary of the empirical results, with emphasis on explaining the differences between the studies.

2.5.2. Overview and Assessment of Contingent Valuation

Contingent valuation is an established, though still controversial, research method for valuing non-market goods. Since it is a fairly flexible approach providing a conceptually correct and complete measure of willingness to pay, it has been applied to a wide variety of non-market goods, especially in the area of environmental economics. Studies have also compared the results to indirect market methods for valuing such goods. Many methodological issues concerning the CVM have been addressed as well. Reviews of the literature exist elsewhere, notable is the review by Cummings, et al. (forthcoming). In addition, Volume 3 of this report addresses methodological problems from the practical perspective of designing a survey instrument for contingent valuation of health. Therefore, the discussion that follows of some of the important issues in CVM is quite brief. The focus is on the accuracythatcan be expected for values from contingent valuation studies.

2.5.2.1. Biases and Contingent Valuation

The basic reason contingent valuation results may be inaccurate is the possibility that the responses are biased away from the unobservable true maximum willingness to pay (or accept). Types of bias often mentioned include hypothetical

bias, strategic bias, starting point bias, vehicle bias, and information bias, though these categories can overlap.

Hypothetical bias and strategic bias can be understood as a dilemma for contingent valuation. On the one hand, if a respondent be-lieves the questions to be entirely hypothetical, he has little incentive to give accurate information concerning his maximum willingness to pay. On the other hand, if the respondent sees the exercise as playing an important role in future policy-making and not hypothetical, he may have incentives to strategically misrepresent his values.

Other biases stem from the structure of the CV questionnaire. If a bidding process is used that begins by asking whether the respondent is willing to pay a certain amount, respondents may view this figure as appropriate and so bids would be biased- towards the starting point. Another problem is the vehicle by which the contingent payment is made. If it is suggested that the payment will occur through a concrete vehicle such as an increase in taxes, respondents who dislike taxes may under-report their values, or protest the exercise by giving zero bids. Finally, the values reported by respondents in a CV experiment may be sensitive to the information provided them during the questioning, and even the order of questions asked may be important.

Various studies shed light on the importance of the possible biases the CVM may be subject to. The fundamental problem that contingent valuation is hypothetical has been investigated by conducting experiments that include both hypothetical payments and actual cash payments. Bishop and Heberlein conducted surveys of hunters who had received free early season goose hunting permits. For actual cash payments, the mean willingness to sell was $63, while for hypothetical payments the mean willingness to sell was $101. Carson and Mitchell dispute this finding: in a re-analysis of Bishop and Heberlein's data they find no statistically significant difference between the hypothetical and actual values. However, Bishop and Heberlein defend their original methodology, and present preliminary results from a new survey that supports the finding that hypothetical bias exists. For a discussion of this debate, see Bishop and Heberlein in Cummings, et al. (forthcoming), and the Appendix to Cummings et al. by Carson and Mitchell.

Other sources of bias can also be more or less directly tested, by varying the starting point, payment vehicle, or information given, or by changing the incentives for strategic behavior. Results to date are somewhat inconclusive, though Cummings et al. tend to minimize the importance of strategic bias and starting point bias, while noting that payment vehicle and information may be more important sources of bias. No strong consensus seems to have been reached in this area, and in particular a number of researchers believe starting point bias may be quite significant. For a discussion of the various studies' results that relate to these biases, see Cummings et al.

(forthcoming, Chapter III).

In short, existing reviews of the CVM suggest that bias problems are not insurmountable, and that careful design of the survey can minimize them in many cases. This points to the need to carefully consider the design of the survey that produces any contingent valuation results. Of particular concern are the tradeoffs faced in survey design. For instance, it may be possible to reduce hypothetical bias by using more concrete payment and delivery vehicles, but only at the cost of increasing the chances of strategic behavior. The tradeoffs chosen in designing a particular survey need to be explicitly recognized and discussed.

2.5.2.2. Accuracy of Contingent Valuation

Aside from issues of bias, the basic question remains, however: in a properly designed contingent valuation study, how accurate are the values reported? In a sense, the question is unanswerable, since the true values are unobservable. Several types of evidence can suggest a range of accuracy.

First, as Tolley, Randall, et al. (p.63) point. out, studies have found that contingent values are systematically related to income, availability of substitute goods, and other variables that economic theory suggests should be important. This implies that the contingent market is to some extent similar to an actual market and that the values reported are not random but are reasonable subjects for economic analysis.

Second, a number of studies have compared the CVM to alternative indirect market methods of valuing non-market goods. Cummings et al. review these studies and stress that the results can not establish the accuracy of the CVM. But: "Assuming that, within the range of plus or minus 50%, value estimates derived from indirect market methods include 'true' valuations by individuals, these results suggest that CVM values may yield 'accurate' estimates of value in cases where individuals have had some opportunity to make actual previous choices over that commodity in a market framework."

Based on their comprehensive review of the methodology and practice of contingent valuation, Cummings et al. suggest a range of accuracy for carefully designed contingent valuation studies. (These suggestions are linked to a set of Reference Operating Conditions that the study must meet for the accuracy range to apply.) At the least, "the method produces order of magnitude estimates--but we think one can argue that error ranges are much smaller." (p.279) At the best, "one might tentatively conclude that, given the current state of the arts, the CVM is not likely to be more accurate than plus or minus 50 percentofthe measured valued." (p.123) This plus or minus 50 percent range is a suggested reference accuracy, and though it is a somewhat arbitrary figure it does seem reasonable.

2.5.3. Applications of Contingent Valuation to Health

2.5.3.1. Introduction

This section critiques three studies that use the contingent valuation method to value health symptoms related to air pollution. The first study by Loehman et al. (1979) values symptoms linked to air pollution using a mail questionnaire of the general public. The second study reviewed is Rowe and Chestnut (1984). This study values a reduction in asthma symptoms, using personal interviews of a group of individuals suffering asthma. The third study is the contingent valuation experiment described in Volume 3 of this report (Tolley, et al. (1985)). This study includes four separate surveys valuing different types and quantities of air pollution related symptoms, using personal interviews of the general public.

2.5.3.2. Scope of the Review

At the outset, the limited scope of this section should be explained. In line with the overall purpose of Volume 2, the focus is on empirical estimates of the value of health. As a result, no attempt is made to report and review all of the findings of the studies in question. In particular, for our purposes the values of health are best summarized by a simple statistic such as a mean value for the sample. Other statistical analysis, including the estimation of bid functions based on the contingent valuation responses, are not reviewed, though they are important parts of these studies. In addition, questions of methodology and survey design are only addressed in the context of evaluating the usefulness and accuracy of the value estimates produced.

A second limitation in the scope of this review is that several studies that use the contingent valuation method to value changes in air quality, including the health effects, are not considered.[1] These studies do not yield usable values of health for various reasons. In two of them (Brookshire, et al. (1979), and Loehman et al. (1981)), respondents were asked separately about their values for the visibility and health effects of air pollution, but it is not clear if people can meaningfully disentangle these effects. The values of health alone may be overstated, reflecting part of the value of visibility, or understated if part of the value of health is included in the reported value of visibility.

A third study by Schulze et al. (1983) concentrates on

health effects of ozone, so it may not share the above problem. It does share with the two studies previously mentioned another problem of the definition of the product purchased in the contingent market. In all three studies respondents were provided with descriptions of the health effects likely to result from air pollution levels, and then asked for their values for a change in pollution levels. The descriptions are of the general form: for a given level of pollution, some people (or a certain percentage of people) experience these effects. Such a description has multiple interpretations. A respondent could identify the general population risk as his individual risk. So if he is told that 50% of people will experience a symptom, he views this as a 50% chance he will experience the symptom. Another interpretation is that the information provided helps remind the respondent of his experiences with air pollution. In this case, the respondent will bid for a change based on his prior subjective probability estimates of experiencing a symptom given varying levels of pollution. Or, he may adjust his prior beliefs on the basis of the information given. In either case, the commodity the respondent is valuing is a change in risks (probabilities of symptoms) that is unobservable to the researcher.

These different interpretations of the effects of the information provided mean that it is not clear if all respondents were valuing the same good in these studies. More to the point for the purposes of this section, it means that values of health can not be inferred from these studies. To do so would require numerous arbitrary assumptions concerning what we think the respondents were thinking when they answered the questions.

2.5.3.3. Loehman,et al. (1979)

Study Design

The study by Loehman et al. (1979) concerns the benefits of controlling sulfur oxides in Florida. A mail contingent valuation survey was sent to 1,977 residents in that Tampa Bay area, resulting in 432 returns. Willingness to pay questions were asked about the following three groups of symptoms: shortness of breath/chest pains; coughing/sneezing; head congestion/eye/ear/throat irritations. Values were elicited for minor and severe symptom days, which were defined briefly. Respondents were asked to value one day, seven days, and ninety days of relief. No mention was made of any specific underlying disease, nor were causes such as air pollution mentioned. No specific delivery vehicle, such as a pill, was employed, and a simple, abstract payment vehicle--"tell us how much you would pay"--was chosen. The means of payment was a checklist, or payment card, ranging from $0 to $1000 per year in ten increments.

The Loehman et al. study design is similar to our seven

symptom survey described in Volume 3. In both cases a pure health attribute approach was used. The Loehman et al. study carefully avoided the introduction of redundant information in its introductory letter, its symptom narrative and in its delivery and payment vehicles. One difference between the design of the Tolley et al. (1985) survey and the Loehman et al survey is the large number (24) of similar willingness to pay questions on the latter survey. The Tolley et al. surveys employed fewer questions on any survey instrument in order to avoid taxing the respondents' concentration and the extent of their information and preference review. This problem might account for the relatively low return rate (22 per cent) encountered by Loehman et al. It also could imply a reduction in the accuracy of their estimates of the value of health.

The major difference between Loehman et al. and the other two contingent valuation studies reviewed below is that the Loehman et al study used a mail questionnaire. The advantage to using this approach is that the lower cost per survey completed allows a larger sample size. There are several disadvantages. An obvious question is whether the respondents are representative of the general population. Loehman et al. test for this, and find that the sample seems to be more or less representative, at least in terms of standard demographic characteristics.

Another problem with using a mail survey is that in a contingent valuation experiment there will be some protestors, or people who either refuse to participate in the contingent market or do not understand the nature of the exercise. In a personal interview, follow-up questions and interviewer comments can help identify respondents who are protestors. A mail questionnaire gives no indication of the identity of protestors, except for the bids themselves. Loehman et al. note the presence of bids from respondents who gave values of $1000 (the highest amount on the payment card). These bids were statistically outlyers, and the respondents exhibited intransitivity of preferences. It seems reasonable that these respondents were protestors. However, it is also possible that these individuals simply had high values for health. The limited information from a mail questionnaire means this problem is difficult to resolve.

A final disadvantage of using a mail questionnaire is that it requires the use of a payment card. Such a card lists the possible amounts of people might be willing to pay, and the respondents choose among the different amounts. Designing a card that covers a wide range of low to high values and allows small but important differences between values to be reported is difficult. In addition, some have questioned whether such a card elicits maximum willingness to pay responses. Cummings et al. (forthcoming) suggest that if a payment card is used, it should be followed with iterative bidding, but this is not feasible in the context of a mail questionnaire. These problems indicate that the values from the Loehman et al. study may be inaccurate, and in particular they may be under-estimates of the maximum willingness to pay for health.

Results

Table 2-8 lists the median and mean bids found by Loehman, et al. All bids are expressedinterms of 1984 dollars, to insure comparability with other estimates of the value of health discussed in this report. The bids were adjusted using the Consumer Price Index, and were rounded to the nearest dollar.

The bids cover a fairly wide range. For one day of relief, the lowest median bid is $4 for mild coughing/sneezing, and the highest median bid is $18 for severe shortness of breath/chest pains. However, the mean bids for 1 day of symptoms are often an order of magnitude larger, ranging from $42 for mild coughing/sneezing to $127 for severe shortness of breath/chest pains. There is generally a smaller difference between median and mean bids for 7 days of relief and 90 days of relief.

The large difference between median and mean bids results from properties of the distribution of bids. As Loehman et al describe it, the distribution is clearly not normal, but includes a large number of relatively low bids, with a few bids in the upper tail of the distribution. These bids were for $1000, the highest bid possible, and represent the possible protestors discussed above. The mean bids are much more sensitive to these outlyers than are the medians, and so the means are much larger than the medians.

In their analysis, Loehman et al use only the median bids. One justification for this use is normative. They argue that the median is "indicative of majority voting since it indicates the bid which at least 50% of the population would agree to pay..." (Loehman et al, 1979, p.232). Though this majority voting criterion is certainly reasonable, it represents an alternative to the standard methodology of applied welfare economics, where programs are evaluated using the criterion of a potential Pareto improvement. Using this criterion all individuals' values are given equal weight, including the very high values. It is possible that a program that represents a potential Pareto improvement would not be favored by over 50% of the population. Potentially, though, payments by gainers could compensate the losers by enough that all would favor (or at worst be indifferent to) the program. If this standard of applied welfare economics is accepted, the correct summary statistic is the mean, which puts equal weights on all, and not the median.

Loehman et al. also justify their use of median bids by noting that the median is less likely to be biased due to the outlyers. V.K. Smith explains how this problem could justify use of median bids even if the potential Pareto improvement criterion is accepted as relevant. If a distribution of individuals' true

values of health in a population is known, the mean value is the correct summary statistic as explained above. Applying this reasoning to a distribution of values resulting from a contingent valuation experiment is not necessarily correct. To do so requires the assumption that all contingent valuation responses are judged as equally'good estimates of each individual's willingness to pay. Arguments that have been made in the contingent valuation literature for the use of the median implicitly assume that not all responses to contingent valuation questions are equally good estimates of each individual's willingness to pay. In particular, there is a presumption that very large or very small responses are more likely to have large errors associated with them. Since the mean value is more affected than the median, the mean would be a less robust estimate of the "average person's" willingness to pay. In this case, if outlyers are a problem, the median bid may be preferred.

Accepting the criterion of a potential Pareto improvement as the relevant welfare guideline, the choice of using median or mean values from a contingent valuation study depends upon the informational content assumed for different responses. Reporting median bids avoids overstating values due to the effect of very high bids which may be inaccurate in the sense that they are not a true reflection of willingness to pay. At the same time, legitimately high bids are also given little weight. In addition, though the very high bids may be inaccurate, they probably do indicate that these individuals are actually willing to pay an amount higher than average. Finally, the argument is symmetric with respect to low bids. While very low bids probably do indicate that these individuals have lower than average willingness to pay values, the true values may not be as low as the values reported in the contingent valuation experiment.

To rigourously account for all of the considerations discussed above requires a model of how people respond to contingent valuation questions. In section 4.3 there is the beginnings of such a model, but it does not allow any definite conclusions to be made regarding the mean versus median question. In practice, both mean and median values are important pieces of evidence. Inferences of the informational content of very high and very low bids can be drawn from careful consideration of the study design and the distribution of bids found. For 'the Loehman et al. results, the problems inherent in a mail survey and the distribution of bids suggest that the high bids are not accurate reflections ofwillingness to pay. Thus the medianmay be a more robust summary statistic.

It is interesting to note the relationships between the bids for 1 day, 7 days, and 90 days of relief found by Loehman et al. Using mild coughing/sneezing as an example, bid for 1 day is $4, while the bid for 7 days is $13. roughly three times as large. The bid for 90 days is $37, about nine times as large as the bid for 1 day. Roughly similar results are found for other median bids. For mean bids the ratios are even smaller; the bid for 7 days of relief from mild coughing/sneezing ($71) is less

than twice the bid for 1 day ($42), and the bid for 90 days ($138) is only about three times the 1 day bid.

Two explanations for these relationships are possible. The marginal disutility from sickness (symptoms) could be diminishing rapidly, so that extra days of symptoms do not matter much and the individual is-willing to pay increasingly less for relief from the symptoms. This does not seem very plausible, especially since decreasing marginal disutility from sickness implies increasing marginal utility from health, which is not consistent with the assumptions of economic theory. A second possibility is that the respondents had trouble valuing large changes in health because these changes were outside of their experiences. That bids for unfamiliar commodities may be inaccurate has been suggested by users of the contingent valuation method (see Cummings, et al). This explanation seems to be more powerful in explaining why bids for 90 days of relief (an unfamiliar commodity to most people) are so small compared to the bids for 1 day of relief(amore familiar commoditywithinthe range of most people's experiences). It is less powerful in explaining the ratio of bids for 1 day and 7 days of relief, since both seem to be familiar experiences to most people.

Table 2-8

Contingent Values of Health (1984 $)
Source: Loehman, et al (1979)
Sample Size = 432

Symptom	Median Bid	Mean Bid
1 day of:		
--shortness of breath/ chest pains		
mild	8	78
severe	18	127
--coughing/sneezing		
mild	4	42
severe	11	73
--head congestion, eye, ear, throat irritation		
mild	6	52
severe	13	85
7 days of:		
--shortness of breath/ chest pains		
mild	22	118
severe	57	218
--coughing/sneezing		
mild	13	71
severe	32	116
--head congestion, eye, ear, throat irritation		
mild	15	66
severe'	33	129

(Table 'continued on next page)

Table 2-8 (Continued)

Symptom	Median Bid	Mean Bid
90 days of		
--Shortness of breath/ Chest pains		
mild	56	233
severe	156	403
--Coughing/Sneezing		
mild	37	138
severe	81	236
--Head Congestion, Eye, Ear, Throat Irritation		
mild	40	145
severe	99	288

2.5.3.4. Rowe and Chestnut (1984)

Study Design

The study by Rowe and Chestnut(1984) provides estimates of the value of a reduction in asthma days for people with asthma. The economic research supplemented research underway at the UCLA School of Medicine concerning the effects of air pollution on asthmatics. The UCLA project included over 90 subjects from Glendora, California (in 1983); the general questionnaire that included the contingent valuation questions was completed by 64 adults, and 18 parents of children under 16 years of age. Of this total sample of 82, there was only one refusal. After evaluation of the bids, including checking for protestors and other respondents whose bids were judged to be inaccurate on the bias of consistency checks, 65 bids were retained. This relatively small sample is clearly not representative of the general population since it involves only asthmatics. This is arguably a strength, not a weakness, since people with asthma are a group likely to be affected by pollution who may value the change differently than the general population. Unfortunately, the sample was not chosen so as to be representative of asthmatics in general.

Contingent valuation bids were obtained by asking the respondents: "If federal, state, or local governments set up programs that could reduce pollens, dusts, air pollutants, and other factors throughout this area that might reduce your (and your household's) bad asthma days by half, but would cost you increased tax dollars, what would be the maximum increase in taxes each year that you and your household would be willing to pay and still support such a program?" A number of aspects of this contingent market deserve comment. First, the good or commodity being bid on is a reduction by half of the respondent's and his household's bad asthma days. Given the respondent's experience with asthma and the earlier questions in the questionnaire, it seems reasonable that the respondents understood the commodity and by this point in the experiment had prior valuation and choice experience with respect to consumption levels of it. The major drawback of this definition of the commodity is that it is different for each respondent. What constitutes a "bad asthma day" is subjective, and since the number of bad days varies across respondents, so does the number of bad days removed implied by the 50 percent reduction.

Second, it was made clear that the reduction in asthma days would be the result of a governmental program, and paid for by an increase taxes. That is, relatively concrete vehicles for the delivery of and payment for the good are used. Though this makes the contingent market more realistic, the added realism is purchased at the cost of increasing the possibility of problems such as strategic bias or protestors (either at the idea of increased taxes, or the impossibility of such a program). In addition, experience in focus groups in Chicago showed that

mentioning the environment as a cause of health seemed to distract the respondents from providing reasoned bids. This problem may not have existed for the asthma patients, however, since other results of the project showed that they had a good understanding and accurate perceptions of the effects of pollution on their conditions.

Third, an element of uncertainty is introduced into the market, since it is stated that the program improving air quality "might" reduce bad days by half. This wording raises difficulties in interpreting the bids. Is one respondent bidding a small amount because the reduction in asthma days is not worth much to him, or because his subjective probability that the program will work is relatively low? The extensive analysis of the bids supports the former interpretation, but the issue can not be entirely resolved.

Two more general problems of the structure of the contingent market should be mentioned. First, there is the problem of the bidding format. The Rowe and Chestnut study used a payment card format. It was designed to eliminate some of the problems associated with this format; they note that problems may remain, however.

The second problem is the treatment of protest bids and extreme values (either 0 bids or very large bids). The ideal is to retain all bids that reflect the true value, no matter how extreme, and to remove bids that do not. To be a useful bid, the respondent must be willing to participate in the contingent market, and fully understand the nature of the exercise. Rowe and Chestnut carefully examine the zero bids, and subject bids to a consistency check. This process necessarily involves some rather ad hoc procedures, and is to a certain extent subjective. It would be interesting to know how sensitive the bid results are to the editing process. As mentioned earlier, this process results in 17 of 82 bids being rejected, or roughly 20%.

Results

The results of the Rowe and Chestnut study relevant for this review can be very easily summarized. They found a mean bid for a 50% reduction in bad asthma days (for 65 observations) of $401 per year, with a standard deviation of $85. This is for an average number of bad days reduced equal to 19. Thus, on average a bad asthma day is worth about $21. Of course, this average value can not in general be used to value a marginal change of 1 bad asthma day.

2.5.3.5. Tolley, et al (1985)

Study Design

Volume 3 of this report contains a detailed description of the design of the Tolley et al. contingent valuation experiment, and the considerations involved in this design. To summarize, the experiment consist of four surveys valuing: 1) 1 day of relief from 7 light symptoms such as coughing, etc.; 2) 30 days of relief from these same 7 symptoms; 3) relief from mild and severe angina (chest pain) given that the respondent already suffered from 10 days of this symptoms; and4) relief from mild and severe angina given that the respondent already suffered from 20 days of this symptom. Separate surveys were used to keep the length of the survey at a level where reasoned responses could be reached, but respondents' patience and concentration were not over-taxed.

A total of 199 interviews were completed, roughly equally divided between the four types of surveys. The surveys were personal interviews of a randomly selected sample from Chicago and Denver,

Of the total of 199 completed surveys, 23 surveys were removed from the sample. Several criteria were used to determine which responses to remove. First, protestors who refused to give any bids were removed from the sample. Protestors are distinguished from those who wished to bid zero. Zero bidders were left in the sample on the grounds that the bids were felt to be legitimate. A second group excluded from the sample were those respondents who indicated that they would pay any amount for the improvement in health, or exorbitantly high amounts (two or three times their yearly income). The last group of respondents removed from the sample were random bidders whose bids bore no logical relationship to each other. Interviewer comments were used in all cases to help identify individuals unwilling or unable to participate in the contingent market. For a more complete description of and rationale for the editing process, see section 3.5.2 in Volume 3.

As described in Volume 3, a great deal of care was taken in the creation of the contingent market. The contingent commodities were described to the respondents, and the structure of the survey encouraged respondents to think about the commodities before bidding began. A form of iterative bidding was used. Abstract payment vehicles and delivery vehicles were chosen,. to avoid protests and to avoid distracting respondents from giving reasoned values. Finally, interviewer comments and analysis of the bids were used to identify protestors.

For the two surveys concerning the seven light symptoms, the structure of the survey instrument first helps the respondent to recall his own experience with these common symptoms, and then establishes a standardized hypothetical product (relief from symptoms) to be valued. As a result the respondent should be

familiar with the commodity of the contingent market, an important prerequisite to obtaining accurate value estimates.

The procedure described above could not be exactly followed. for the two surveys concerning angina, since most respondents had little or no-experience with this symptom. Standard questions on health status help the respondent to begin to think about his or her health and its importance. The contingent valuation section begins with a general two paragraph introduction that asks the respondent to imagine having mild or severe angina, and includes a brief statement about the extent of angina in the United States. The actual contingent valuation includes a description by the interviewer of the specific symptoms to be valued, and a card summarizing of this description is then handed to the respondent. The complete survey instruments are reproduced in the Appendix of Volume 3. This approach to survey structure was used to minimize the problems associated with respondents being unfamiliar with angina. While the value estimates resulting may not be as accurate as for the more familiar seven symptoms, it is felt that most respondents did give reasoned bids:

Results

Table 2-9 presents the values for symptoms, from the four surveys conducted by Tolley et al. Part 1 of Table 2-9 presents median and mean bids for relief from one additional day of seven individual light symptomes, and two combinations of symptoms. Part 2 of Table 2-9 presents the same statistics for relief from thirty additional days of the same individual and combined symptoms. Parts 3 and 4 of Table 2-9 present bids for relief from angina. The number of additional days of angina, the severity of the angina, and the endowment that respondents were asked to assume described their situation are varied to provide a range of values.

The median bids for relief from one additional day of the seven light symptoms range from $11 for relief from a day of coughing to $20 for headaches. Mean bids are roughly two to three times larger, ranging from $25.20 for a coughing day to $50.28 for relief from a day of nausea. Relief from combinations of three symptoms is more highly valued than relief from one symptom alone, but is not the simple sum of the values of the individual symptoms. For instance, a day of cough, throat and sinus symptoms combined is valued at $65.60 The sum of the bids for relief from these symptoms indvidually is $89.22.

For the Tolley et al. results the difference between the median bids and the mean bids is substantially less than that found for the Loehman et al. results. As described above, the excessively large bids resulting from respondents who explicitly or implicitly protested the contingent market were removed from the Tolley et al. sample. This shows one advantage of the personal interview structure compared to mail surveys: interviewer comments can help identify protestors. Since all

responses were subject to the editing process, and the distribution of bids shows'a smaller impact of the largest bids, the mean seems to be the most robust summary statistic for this sample. In other words, the assumption seems justified that all responses, even the very large and very small bids, have roughly equivalent informational content.

For relief from 30 days of the seven light symptoms, the median bids range from $95 for 30 days of coughing to $135 for 30 days of sinus problems. Again, mean bids are usually about two or three times larger than the medians, ranging from $166.50 for 30 days of coughing to $488.20 for 30 days of headaches. The same relationship between the bids for combinations of symptoms and the sum of the bids for relief from the individual symptoms is found as in the one day survey. A combination of three symptoms is valued more than any one symptom alone, but not as much as the sum of the bids for the three individual symptoms.

Just as in the Loehman et al results, a somewhat surprising relationship is found between the bids for different days of relief. The mean bids for 30 days of relief from the light symptoms are not 30 times larger than the mean bids for one day of relief. The 30 day bids are closer to ten times the size of the one day bids. Though these bids result from two different samples of individuals, in terms of observable characteristics the samples seemed similar. Another possible explanation is that the results reflect diminishing marginal disutility from sickness, but this explanation implies increasing marginal utility from health which seems implausible. In addition, other results from these surveys reported in Volume 3 support the more standard relationship of increasing marginal disutility from sickness. Finally, it could be argued that 30 days of sickness are a more unfamiliar commodity to most individuals, so they are under-valuing it. This possibility points to the continued need for a formal model of how respondents react to contingent valuation questions, since it is not obvious why bids for an unfamiliar commodity would be systematically biased downwards.

The third survey conducted by Tolley et al. concerns the value of relief from angina (chest pain), given an endowment of up to 10 days of severe angina. Median bids range from $50 for relief from 1 mild day given an endowment of 10 mild days, to $200 for relief from 10 severe days given 10 severe days. The mean bids are fairly close to the median bids, ranging from $66.08 for relief from 1 mild day given 1 mild day, to $261.84 for 10 severe days given 10 severe days. For comparable endowments, median and mean bids for mild days are always less than bids for severe days, as would be expected. Comparing across endowments, it is generally true that relief from a given number of days of angina is valued more highly as the endowment increases. This is consistent with increasing marginal disutility of illness, and is the expected relationship.

The fourth survey also concerns angina, but the endowment ranges up to 20 days of mild and severe angina. Median bids

range from $40 for relief from 1 mild day given 20 mild days, to $200 for relief from 20 severe days given 20 severe days. Mean bids show a larger difference between the value of 1 day and 20 days of angina. The mean bid for relief from 1 mild day given 1 mild day is $90.24, while the mean bid for 20 severe days given 20 severe days is $844.38. Again, as expected relief from severe days of angina are valued more highly than relief from mild days. However, comparing bids across endowments, the results do not always support that increasing the endowment increases the bid for a given number of days of relief. For example, the mean bid for relief fromlsevere day given 1 severe day is $278.88, while the mean bid for relief fromlsevere day given 20 severe days is only 208.78 This difference may not be highly significant. Closer examination of the bids reveals that some respondents bid a large amount to be completely free of angina, while placing a small value on a day at the margin given a large endowment. Though this behavior is not consistent with increasing marginal disutility of illness, it is not necessarily irrational. Whether individuals with actual experience of angina would bid in this way is an interesting and open question.

It is possible to compare the results of the two surveys on angina in a few cases where identical commodities were valued by the different samples of individuals. The mean bid for relief from 1 mild day given 1 mild day is $66.08 for Survey 3 and somewhat larger for Survey 4 at $90.24. A larger difference is found for the only other case in which the surveys are directly comparable. In Survey 3, the mean bid for relief from 1 severe day given 1 severe day is $123.59, while in Survey 4 the mean bid is $278.88. This larger mean bid in Survey 4 reflects the influence of a few very high bidders who bid a large amount to be completely free of angina. In fact, the median bid from Survey 4 for relief from 1 severe day of angina given 1 severe day ($75) is less than the median bid from Survey 3 ($100). These results show the effect a few bids can have on the summary statistics, and suggest that the values reported for relief from angina may not be highly accurate.

Table 2-9: Part 1

Contingent Values of Health
Source: Tolley, et al (1985)

Symptom	Median Bid	Mean Bid
1 day of:		
-- cough	11	25.20
-- sinus	14	35.05
-- throat	13	28.97
-- eyes	12.50	27.73
-- drowsiness	15	31.49
-- headaches	20	40.10
-- nausea	17.50	50.28
-- cough, throat, and sinus	30.50	65.60
-- drowsiness, headaches and nausea	25	95.08

(Table continued on the next page)

Table 2-9: Part 2

Survey 2

Symptom	Median Bid	Mean Bid
30 days of		
-- cough	95	166.50
-- sinus	135	265.62
-- throat	100	206.26
-- eyes	100	235.53
-- drowsiness	100	317.98
-- headaches	132.50	488.20
-- nausea	100	186.02
-- cough, throat, and sinus	200	624.98
-- drowsiness, headaches and nausea	300	868.89

(Table continued on the next page)

Table 2-9: Part 3

Survey 3

Relief from angina, given endowment of angina	Median Bid	Mean Bid
--1 mild day		
given 1 mild day	53	66.08
given 10 mild days	50	83.95
--1 severe day		
given 1 severe day	100	123.59
given 10 severe days	100	144.74
--5 mild days		
given 10 mild days	55	96.18
--5 severe days		
given 10 severe days	150	192.90
--10 mild days		
given 10 mild days	100	154.36
--10 severe days		
given 10 severe days	200	261.84

(Table continued on next page)

Table 2-9: Part 4

Survey 4

Relief from angina, given endowment of angina	Median Bid	Mean Bid
--1 mild day		
given 1 mild day	53	90.24
given 20 mild days	40	99.05
--1 severe day		
given 1 severe day	75	278.88
given 20 severe days	60	208.78
--10 mild days		
given 20 mild days	100	287.63
--10 severe days		
given 20 severe days	125	506.25
--20 mild days		
given 20 mild days	100	486.25
--20 severe days		
given 20 severe days	200	844.38

2.5.4. Conclusions and Summary

An assessment of the contingent valuation method suggests that with careful design the resulting value estimates may be fairly accurate. With this in mind, this section reviewed three studies that applied the CVM to the problem of valuing health effects related to air pollution: Loehman et al. (1979), Rowe and Chestnut (1984), and Tolley et al. (1985). Each of these studies seems to be carefully designed, though certain problems are noted. As a result, the value estimates are probably as accurate as any estimates based on contingent valuation; similar to Cummings et al. (forthcoming), the reference accuracy may be set at plus or minus 50 percent.

While the health effects valued are not exactly the same, certain comparisons can be made between the results of the three studies. For instance, each of the studies implies a value for one day of respiratory symptoms, though not always of the same symptoms. From the Loehman et al. study, one day of of coughing/sneezing has a mean value of $138 (mild day) or $236 (severe day). The Rowe and Chestnut study implies that relief from one day of asthma symptoms is worth on average about $20. The Tolley et al. study finds that relief from one day of coughing, throat, and sinus problems has a mean value of $65.60.

These different values can be reconciled, to some extent. First, the Rowe and Chestnut value is not a value for a marginal day of relief, but an average value for one day, given an average of 19 days of symptoms relieved. Thus, it is not really comparable to the other estimates. The Loehman et al. and Tolley et al. studies are more directly comparable. In general, somewhat different values result. But comparing median bids across the two studies, or comparing mean bids across the two studies, the values do not seem to be necessarily inconsistent.

2.5.6. Notes

1. For a review of these and other contingent valuation studies concerned with the value of morbidity, see Chestnut and Violette (1984).

2.5.7. References

1. Bishop, R.C. and Heberlein, T.A. Does Contingent Valuation Work? in Cummings, et al. Valuing Public Goods: An Assessment of the Contingent Valuation Method, pp. 149-179, forthcoming.

2. Brookshire, D.S., R.C. d'Arge, W.D. Schulze, and M.A. Thayer, Methods Development for Assessing Air Pollution

Control Benefits, Vol. II: Experiments in Valuing Non-Market Goods: A Case Study of Alternative Benefit Measures of Air Pollution Control in the South Coast Air Basin of Southern California. Prepared for U.S. Environmental Protection Agency, Wash. D.C., 1979.

3. 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. Prepared for U.S. Environmental Protection Agency, Wash. D.C.,September, 1984.

4. Cummings, R.G., D.S. Brookshire, and W.D. Schulze, Valuing Environmental Goods: A State of the Arts Assessment of the Contingent Valuation Method. (forthcoming)

5. Loehman, E.T., S.V. Berg, A.A. Arroyo, R.A. Hedinger, J.M. Schwartz, M.E. Shaw, R.W. Fahien, V.H. De, R.P. Fishe, D.E.Río, W.F. Rossley, and A.E.S. Green, "Distribution Analysis of Regional Benefits and Cost of Air Quality Control,'" Journal of Environmental Economics and Management 6 (1979): 222-243.

6. Loehman, E.T., D. Boldt, and K. Chaikin, Measuring the Benefits of Air Qualtity Improvements in the San Francisco Bay Area. Draft Final Report prepared for the U.S. Environmental Protection Agency, Wash. D.C., 1981.

7. Rowe, R.D. and L.G. Chestnut, Valuing Changes in Morbidity: WTP versus COI Measures, Energy and Resources Consultants, Inc., December 1984.

8. Tolley, G.S., A. Randall, et al, Establishing and Valuing the Effects of Improved Visibility in the Eastern United States, Report prepared for the U.S. Environmental Protection Agency, Wash. D.C., 1984.

2.6. COMPARING COST OF ILLNESS AND CONTINGENT VALUATION

2.6.1. Introduction

The cost of illness (COI) approach and contingent valuation (CV) are two important methods that allow a dollar value to be placed on a change in morbidity or sickness. A direct comparison of values based on these methods is undertaken in this section. This comparison is especially interesting because the methods are in some sense complementary. The cost of illness approach, focusing on medical expenditures and foregone earnings, uses widely available data and straight-forward empirical techniques, so it is generally accepted on a practical level. However, there is no strong theoretical basis for using COI values in benefit cost analysis. That is, there are serious questions whether a COI value associated with a given change in morbidity will be close to what an individual would be willing to pay for that change. In contrast, contingent valuation experiments can be designed to directly estimate what an individual would be willing to pay for a certain change in morbidity. So CV values are estimates of the conceptually correct benefit measures for benefit-cost analysis under certainty. Unfortunately, the proper design of CV experiments is difficult and still Controversial, and many economists tend to be skeptical of the actual values given by individuals in a CV experiment. On a practical level, COI values are often judged superior to CV values, while on a theoretical or conceptual level, CV values are preferred.

Due to the perceived practical advantages of the cost of illness approach, recent theoretical work has investigated the relationship between COI values and an individual's true willingness to pay (WTP) for changes in morbidity. Harrington and Portney's (forthcoming) theoretical analysis supports the conclusion that a COI value is a lower boundtothe true WTP, for the certainty case. The more general model presented in section 2.2 also implies that under plausible conditions, COI < WTP under certainty; the model also allows the analysis to be extended to the case of uncertainty.

CV studies of the value of morbidity have considered changes in health status that occur with certainty. This seems justified since the costs of adding uncertainty seem large in light of the problems encountered in surveys that deal with concepts of uncertainty, and the benefits of adding uncertainty in the context of non-serious morbidity may be small. In this section only the relationship between willingness to pay and cost of illness for certain changes can be directly addressed.

The empirical evidence presented in this section is used to test the hypothesis that'the cost of illness values are lower bounds to the true willingness to pay values. Values reported in

CV experiments are used to represent the true WTP values for a change from being certainly sick to being certainly well. On the assumption that the CV values are reasonable proxies for true WTP, the empirical results support the hypothesis that COI < WTP. Alternatively, the fact that this reasonable relationship holds between COI and CV reported WTP can be seen as additional evidence on the usefulness and reliability of contingent valuation methods.

In section 2.6.2, previous work comparing cost of illness and contingent valuation is reviewed. In'section 2.6.3, the results of a new contingent valuation experiment are presented, to test the hypothesized relationship. The analysis is extended to a preliminary discussion of the relationship of COI and WTP values under certainty, and the amount an individual would be willing to pay for a change in health risks. No direct evidence is available on willingness to pay for morbidity risks, but the analysis of Section 2.2 suggests an approximation from the evidence on certainty values is possible. Section 2.6.4 is a conclusion.

2.6.2. Previous Work Comparing COI and CV

Two contingent valuation studies on the value of morbidity contain some evidence on the relationship between cost of illness values and CV values.[1] The first study, reported in Loehman, et al. (1979), estimated median willingness to pay bids for reductions in air pollution-related symptoms. They note that the bids "are probably low compared to out-of-pocket costs of illness." As an example, the income loss per day for a person with an average income would be $65, while the highest median reported for 1 day of relief from severe symptoms (shortness of breath) is $10.92. Including the value of medical expenditures would cause COI to exceed the CV bid by a larger amount. The differnce may be in part due to paid sick leave and medical insurance causing out-of-pocket expenses to be low. Another problem is the use of median CV bids. In order to avoid over-stating WTP because of the influence of a few very large bids on the means, they instead used the much smaller medians. This might have resulted in an under-statement of WTP, however, which might explain why the CV bids are small relative to reasonable COI values. At least, the median CV bids should be compared to median COI values. In any case, Loehman, *et al* do not collect the data that would allow a direct comparison of individual's CV bids and their experienced or expected costs of illness. Thus, their results seem to be only a weak indication that WTP is less than COI; i.e. this is weak evidence against the hypothesis that COI is a lower bound to WTP.

A second CV study, by Rowe and Chestnut (1984) on the value of asthma, is more suitable to a direct comparison of CV bids representing WTP, and the cost of illness. The first body of evidence on WTP compared to COI is the respondents' rankings

of the importance of the benefits they might receive from reduced asthma. Based on statistical analysis of the rankings, Rowe and Chestnut conclude that discomfort and effects on leisure and recreation activities, which are part of WTP but not part of COI, clearly ranked above medical costs and work lost, which are the only components of WTP that a COI value includes. So according to these rankings, COI estimates do not include the most important benefits of reduced morbidity. This indicates that WTP should therefore exceed COI.

The second body of evidence from the Rowe and Chestnut study is a comparison of the total WTP bid and a constructed COI value. This method reported yields a ratio of WTP/COI of 1.6, supporting the hypothesis that WTP is greater than COI. Other approaches to measuring this ratio examined in their larger study suggest a ratio as high as 3.7.

Unfortunately, the data collected do not include foregone earnings, so to construct the COI value Rowe and Chestnut had to assume that the earnings foregone were equal to the medical costs. The assumption is justified on the grounds that the respondents' rankings of the importance of foregone earnings and medical expenditures were nearly identical. The comparison of WTP to COI does not seen sensitive to any inaccuracies inherent in this assumption.

Another problem in the construction of the COI value is that it includes only variable medical expenditures, such as on medicines or doctor visits. The asthmatics interviewed also had significant fixed cost expenses on one-time goods such as Intermittent Positive Pressure Breathing Machines. From Rowe and Chestnut's Table 1, the total (household) fixed cost expenses were $713, compared to total (household) variable expenses per year of $528. Clearly, the entire sum of fixed costs expenditures should not be compared to the willingness to pay for an improvement in morbidity. However, since the improvement would change individuals' marginal decisions on the purchase of a one-time good, ideally some (unknown) portion of the fixed expenses would be included in a COI value. It does not seem likely that doing so would change the result that WTP is greater than COI.

In general, while the Rowe and Chestnut study is not the ideal test of the hypothesis that WTP exceeds COI, it does offer strong support of that relationship. The final caveat is that the study involved only a relatively small sample of individuals with a chronic condition, asthma, and may not be relevant for the general population.

Comparisons of COI and CV values from the Loehman et al. (1979) and Rowe and Chestnut (1984) studies are thus somewhat inconclusive. The first study contains very weak evidence against the hypothesis that WTP exceeds COI. The second study contains much stronger evidence that supports the hypothesis, but problems with the study may limit its applicability.

2.6.3. Comparing COI and CV - New Results

The contingent valuation study described in detail elsewhere in-this report was designed to collect the necessary data for a direct comparison of CV willingness to pay bids for changes in health status with certainty and experienced cost of illness. Only the surveys on seven light symptoms (coughing spells, stuffed up sinuses, throat congestion, itching eyes, drowsiness, headaches and nausea) are used for this comparative analysis. The surveys on angina couldnotbe usedbecause few if any of the respondents had experience with angina and its related cost of illness.

The total sample of the seven light symptom surveys used in the analysis was 131, using door-to-door and mall-intercept interview methods. Out of this sample, 9 observations were unusuable because they were incomplete. Because of the limited scope of the sample, we view this empirical study as illustrative.

Table 2-10 compares the mean WTP and private COI for each of the seven symptoms in the contingent valuation survey. The comparison is made among those who have experienced the symptom in the previous year, i.e., those for whom we have COI data. The private COI is calculated consistent with the prevailing measure in the COI literature. It is the expenditures on medicine and doctor visits less any insurance payments plus any lost earnings. Both the individual WTP and COI measures are expressed on a daily 2 basis.

Out of the entire sample of 122 individuals, the subsamples of those who had experienced the various symptoms in the previous year ranged in size from 6 for drowsiness to 48 for headaches. Within each of these subsamples, the mean WTP always exceeded the mean cost of illness. The last column of Table 2-10 indicates that in 5 of the 7 cases, the differences were significant at the .05 level in a one tailed test.

Another way to test the equality of the private COI and the WTP is through the use of a nonparametric sign test (see Hoel (1971, pp.310-315)). This type of test is less sensitive to extreme WTP or COI values than is the t-test. For the sign test the 192 WTP-CO1 pairs across all seven symptoms are compared. In 174 cases, the WTP exceeds private COI. If the WTP-CO1 pairs had in fact come from the same distribution, we would expect that in only 96 cases would WTP exceed COI. We can then test whether 174 is significantly greater than 96 by using the binomial approximation to the normal distribution.[3] The resulting value of the test statistic is 11.26 which is significantly different from zero at a .001 level of significance, further adding to the empirical evidence that WTP exceeds COI.

TABLE 2-10

Willingness to Pay and Private Cost of Illness Comparisons of Means

Symptom	Sample size (a)	Mean Daily Willingness to pay (b)	Mean Daily Private Costs of Illness (c)	t-value(d)
Coughing Spells	27	$105.34	$11.29	2.12*
Stuff Up Sinuses	43	38.84	6.79	2.22*
Throat Congestion	24	43.93	14.27	1.59
Itching Eyes	16	172.23	14.56	1.24
Heavy Drowsiness	6	173.89	21.50	2.57*
Headaches	48	173.21	3.33	2.07*
Nausea	18	91.24	2.36	2.03*

[a] Only those experiencing the symptom are included

[b] Willingness to pay to avoid one extra day of the symptom.

[c] Calculated as expenditures on doctor visits and medicine net of insurance reimbursements plus lost earnings, expressed on a daily basis.

[d] Test of the null hypothesis that willfngness to pay is less than or equal to private costs of illness. *Indicates hypothesis rejected at 0.05 level of significance in a one-tailed test.

There are two types of additional evidence which support the finding that WTP exceeds COI. First, we asked individuals to rank the reasons for their values for symptom relief. Focus group feedback led to development of a five-item list which covered most reasons. The reasons and the percentage of the 122 respondents who ranked the reason as the most important are: comfort (67%), loss of work at home (6%), loss of work away from home (12%), loss of recreation (2%), reduce medical expenses (11%) and other (2%). So as in the Rowe and Chestnut (1984) study, the components of the value of health included in COI are ranked as less important than the components COI omits.

We also estimated simple ordinary least squares regressions of WTP on the private COI.[4] In each case the intercept is positive, and in most cases is significantly different from zero. The slope term is never significantly different from zero. However, in the cases in which it approaches significance, it is positive. Thus, the regression results are consistent with the above finding that in general WTP exceeds COI, although there does not appear to be any strong tendency for the two to move together. This suggests it is not possible to predict WTP based on COI. So while WTP/COI ratios could be computed based on the means reported in Table 2-22, yielding ratios of about 3 to over 50, the regression results suggest that these ratios are not particularly meaningful.

Implicit in our WTP-CO1 comparison is the assumption that the symptoms which people experienced in the previous year are the same as those which they are bidding on in the contingent valuation experiments. For the light symptoms included in the survey the differences are rather inconsequential. When the samples are limited to those who reported that their symptoms were the same, not worse or less severe than the contingent symptoms, the mean of WTP is still greater than the mean of COI for each symptom and although the dollar differences are greater for four of the seven symptoms only two of the t-values are significant at the .05 level due to the smaller sample sizes. The nonparametric sign test yielded a test statistic of 8.77 and the regression results are similar to those described above.[5]

Our empirical evidence suggests that the private COI, defined excluding time lost from consumption is less than WTP. Is it the exclusion of these time expenditures which is driving the result? In order to investigate this question we use other information available from our contingent valuation survey to construct an expanded COI measure which can then be compared to the WTP values. This measure is the cost of medicine and doctor visits net of insurance reimbursements plus the value of time lost from any activity (e.g. market, work, school, work at home).[6] This increases the measured COI is more compatible with theoretical models of COI. A comparison of the mean COI and WTP for the various symptoms indicates that WTP is greater than COI in six of seven cases (the exception is throat congestion), although the significance levels of the t-statistics are lower than before (they range from -.165 to 2.08). The nonparametric

test produces a test statistics of 5.48, which is again significant at the .001 level, indicating WTP > COI. Regressions explaining WTP again produce positive (although smaller) and mostly significant constant terms and insignificant COI coefficients. So overall, the exclusion of lost consumption time does not appear to be the reason for our earlier result. Our empirical results are consistent with the hypothesis that consumer surplus exceeds the private COI, whether or not the value of lost consumption time is included. It should be noted, though, that our earlier measure, excluding the value of lost consumption time, is more consistent with that used in COI studies.

The next step is to generalize our results to the relationship between willingness to pay for a change in morbidity risks and the expected COI. From the theoretical model of Section 2.2, if an exogenous change which lowers the probability of contracting an illness causes individuals to reduce their preventive expenditures (that is, if dX/dE is negative), then willingness to pay for a change in risks exceed's expected CS. This is true since individuals would also be willing to pay their preventive expenditure savings to avoid increases in health risks. While our survey contains no direct evidence on the sign of dX/dE fortunately it contains some indirect evidence. Individual; are asked whether they have made various defensive expenditures for health reasons: whether they have purchased air conditioners, air purifiers, humidifiers for their home or car or made other preventive expenditures. Nontrivial proportions of the full sample have made some type of preventive expenditure. But more interesting are the differences between those who have and have not experienced at least one of the seven light symptoms.[7] While the percentages of the two groups are almost equal for the purchase of humidifiers, those who have experienced at least one of the seven symptoms are more likely to have made expenditures in the other three categories than those who have not. The difference is most pronounced for air conditioners. No one in the group not experiencing any symptoms purchased an air conditioner for health reasons but 19 of those having at least one of the seven symptoms did so.

What does this pattern of preventive expenditures tell us about the sign of dX/dE? The pattern is consistent with a negative dX/dE in the following way. Assume that those having experienced the symptoms also experience worse exogenous environmental conditions. This results in a higher probability of experiencing the symptom. In looking across the sample, we observe an increase in the quality of the environment(dE > 0) in moving from those who have experienced at last one of the symptoms to those who have not. The resulting change in preventive expenditures then appears to be negative. It should be stressed that the above explanation is only consistent with dX/dE < 0. The data in the survey do not allow for a strict test of hypothesis.

However, if it is true that dX/dE < 0, then our empirical

results are also consistent with willingness to pay for a change in morbidity risks being greater than the expected COI. This allows us to make statements about our theoretical model with uncertainty from our empirical results, which by practical necessity are couched in terms of certainty, and yield only estimates of willingness to pay under certainty, in other words, an estimate of consumer surplus (CS).

One final illustration will help show the usefulness of our empirical consumer surplus estimates. From the theoretical model, it is plausible that the expected change in consumer surplus is a lower bound on willingness to pay for a change in health risks. Since the contingent valuation experiment measures CS, if we assume some value for the change in probabilities of becoming sick, we canestimate a lower bound for the value of the reduction of health risks. For example, in Table 2-10 we report that among those having experienced coughing spells in the previous year, the mean CS for avoiding one extra day of cough with certainty is $105.34. These individuals had on average approximately 48 days of coughing spells in the previous year. If we assume that the probability of having a coughing spell on any given day is constant throughout the year, the mean individual faces approximately a .13 probability of having a coughing spell each day. A lower bound estimate of the willingness to pay for a 10% reduction in the risk of a coughing spell on any given day for the mean individual is simply - CS dH/dE or $105.34 x .013 = $1.37. The willingness to pay for a whole year's worth of 10% reductions is $1.37 x 365 = $500.05. Lower bounds on the values of changes in the risks of the other symptoms can be similarly calculated. It should be stressed, however, that our lower bound estimates, while useful for comparisons among approaches, should be used for policy purposes with caution. Our small sample is probably not representative of the entire U.S. population. In addition, it should be recalled that the contingent valuation experiment contained no direct evidence on the value of morbidity risks, and the lower bound estimates depend upon the theoretical model used in section 2.2.

2.6.4. Conclusions

Our empirical work provides evidence on WTP and COI for seven light symptoms in the certainty case: coughing spells, stuffed up sinuses, throat congestion, itching eyes, heavy drowsiness, headache, and nausea. The WTP values that are obtained are equivalent to consumer surpluses. The results suggest that WTP exceeds COI, but there is no strong indication that WTP and COI move together in any systematic fashion. Assuming that exogenous changes affecting health risks reduce preventive expenditures, our results also imply that the WTP for reduction in health risks which arises from our uncertainty based model exceeds expected COI. We then provide an illustrative lower bound estimate of the value of a change in health risks from our contingent valuation survey.

The results of the new empirical work thus tend to confirm Rowe and Chestnut's (1984) preliminary results that WTP exceeds COI. It should be noted that this relationship is also found in the experimental mail survey completed (see Section 3.7); but the results are for a very small sample. So there is a growing body of evidence that suggests contingent valuation responses on WTP exceed COI, as predicted by several theoretical models. The major limitation is the small sample sizes of the studies.

2.6.5. Footnotes

1. These studies are described in greater detail in section 2.5.

2. The contingent valuation experiments were conducted for both one-day and thirty-day changes in the experience of the various systems. Implicit in the normalization to one-day changes is the assumption of constant marginal costs in the case of cost of illness and constant marginal utility in the case of willingness to pay.

3. The standard deviation for calculating the normal distribution test statistic is constructed under the null hypothesis that the WTP - COI pairs come from the same distribution. In this case the probability that WTP > COI is 1/2 and the standard deviation for the binomial approximation to the normal distribution is 192 x 1/2 x 1/2 = 6.93.

4. These and other results not reported in the paper are available upon request.

5. A final piece of corroborating evidence is contained in the survey. Individuals were asked how much they would be willing to pay to avoid all of the symptoms they had experienced in the previous year, Of the 46 individuals who did not experience symptoms in combinations with one another, 41 had WTP > COI, yielding a nonparametric sign test statistic of 5.3, which is highly significant. The mean WTP greatly exceeded the mean COI and a simple regression yielded results similar to those described previously.

6. The value of time lost from market or nonmarket activity is measured by multiplying the number of days lost by the daily wage (hourly wage x 8). This reduces the sample somewhat since not everyone in the sample worked in the previous year and thus reported a wage rate. We also expanded the definition of cost of illness even further to include days of market and nonmarket activity "hindered." This cost of illness measure is the same as above except that'it also includes the number of days hindered multiplied by one-half the daily wage. The means test, sign

tests and regressions were all recalculated and the results are very similar to those described for the first expanded cost of illness measure.

7. The proportions of the full sample having made various preventive expenditures, and the proportions among those who have and have not experienced at least one of the seven light symptoms are as follows:

Preventive Expenditure	Full Sample	No Symptoms	One or more Symptoms
Air Conditioner	.151	.000	.188
Air Purifier	.110	.044	.126
Humidifier	.311	.318	.309
Other	.074	.056	.078

2.6.6. References

1. Harrington, W. and P.R. Portney, "Valuing the Benefits of Improved Human Health," Journal of Urban Economics, forthcoming.

2 Hoel, Paul G. Introduction to Mathematical Statistics, 4th ed. (New York: John Wiley and Sons, Inc), 1971.

3 Loehman, E.T., S.V. Berg, A.A. Arroyo, R.A. Hedinger, J.M. Schwartz, M.E. Shaw, R.W. Fahien, V.H. De, R.P. Fishe, D.E.Rio, W.F. Rossley, and A.E.S. Green, "Distribution Analysis of Regional Benefits and Cost of Air Quality Control," Journal of Environmental Economics and Management 6 (1979): 222-243.

4 Rowe, R.D. and L.G. Chestnut, Valuing Changes in Morbidity: WTP versus COI Measures, Energy and Resources Consultants, Inc., December 1984.

2.7. HOUSEHOLD PRODUCTION OF HEALTH AND AVERTING BEHAVIOR

2.7.1. Introduction

Following Grossman (1972), economic analyis of health has usually taken place in the context of household production models. In these models, the individual produces the commodity health by combining his own time and effort with purchased goods such as medical care, diet, and so on. So in effect, health is partially under the control of the individual, that is, it is partly endogeneous. It may also be affected by exogeneous factors the individual can not control, including environmental quality.

Some recent theoretical and empirical work has used this framework to derive expressions for what an individual would be willing to pay for an exogeneous improvement in environmental quality. The theoretical studies, such as the model developed in section 2.2 and the references therein, investigate how the conceptually correct willingness to pay measure will be related to observable quantities namely the cost of illness and preventive expenditures (averting behavior).

Two empirical studies have taken the analyis further and attempt to estimate willingness to pay directly. Gerking and Stanley (1984) estimate willingness to pay for health risks related to ozone exposure, and Cropper (1981) estimates willingness to pay for health risks related to an index of air pollutants. In sections 2.7.2 and 2.7.3 below these studies are reviewed to investigate the usefulness and comparability of their empirical estimates of the value of health. Section 2.7.4 is a conclusion.

2.7.2. Gerking and Stanley (1984)

The Gerking and Stanley study formulates a household production model where environmental quality enters as a factor in the production of health - which is in preferences, and which affects the number of days sick. Thus the willingness to pay (WTP) for an environmental quality imporvement can be derived:

$$WTP = dY/dA|(dU=0) = -Ha(S,A,D)/Hs(S,A,D)$$

where H is a multidimensionsl health production function, S is averting activity -- in this case visits to a doctor -- and D represents individual characteristics which parameterize individual productivities of S and A in producing H; for example, D will include the existence and length of a chronic health condition. Given that the assumptions of the implicit function theorem hold, $H=H(S,A,D)$ may be expressed as $F(H,A,D)$, and thus:

$$Sa = -Fa/Fs = -(Fa/Fh)/(Fs/Fh) = -Ha/Hs.$$

Gerking and Stanley measure $dS(A,D)/dA$ using a cross-

sectional survey of 2,594 households in St. Louis, Missouri, over the years 1977-1980, which is combined with air quality data from the Regional Air Pollution Study matched to each data point. Because two of the independent variables in the regression -- the existence and length of the chronic condition -- are determined under the formulations of the model simultaneously with the health decision, a two-stage logit procedure is followed; the health variables are regressed on the other explanatory variables, and from this, predicted values are entered into the final logit regression.

Of the four pollutants considered in the model--ozone, sulfur dioxides, total suspended particulates, and nitrous oxides-- only ozone has a coefficient significantly different from 0, at the 1 percent level of significance. None of the other pollutants are significant at the 10 percent level. By multiplying this coefficient by the mean cost of a medical visit and by a posited change in ozone levels, Gerking and Stanley calculate the change in new first medical visit expenses due to a 30 percent reduction in ambient ozone levels. The reduction in expenditures range from $18.45 to $24.45 per capita, annually.

As a result of the' order of their two stage estimation process Gerking and Stanley do not directly estimate the effects of ozone onhealth, so it is impossible to specifywhatchange in health results from a given ozone reduction. Thus, these values of WTP for an ozone reduction do not unambiguously imply a value for WTP for health. However, Gerking and Stanley do suggest that it might be reasonable to assume that each medical visit is associated with a day of restricted activity due to illness. If this is true, the value of preventing a restricted activity day is equal to the full price of the medical visit, which they estimated at about $40.

Another approach is to use an independent estimate of the effect of ozone on health, and calculate what change in health individuals are purchasing when they purchase a given change in ozone. Portney and Mullahy (forthcoming) present a range of estimated effects of ozone on health. When combined with the Gerking and Stanley values for a 30 percent reduction in ozone, these estimates imply values not inconsistent with the $40 per restricted activity day value above.

Two problems noted by Gerking and Stanley that may affect the robustness of this study are the choice of the dependent variable, and the possible sample selection bias created by the use of a relatively small subset of the entire sample. First, whether or not an individual has ever visited a doctor within a year just does not seem very sensitive to the particular health care needs created by high ozone levles. It does not capture additional medical trips made by those already visiting doctors for other reasons, and similarly, does not reflect the intensity of care related to a particulate ozone-related health problem. Second, because the model is formulated using the full price of medical care - which equals the direct price of medical care plus

the time cost of receiving such care, the need for wage information to value time suggests that only the 824 households who list their primary occupation as employed, and who had reported wage date, be included in the regressions. If employees experience different exposures to air pollution levels than those not employed.- they may live in an air-conditioned office, or if employees face different medical cost structures - they have company-provided insurance, the WTP calculated from an employee regression may not be generalizable to the population at large. Gerking and Stanley do report, however, that regression results run on the full sample do not differ much from the subsample regression.

2.7.3. Cropper (1981)

Cropper postulates a dynamic health capital model in which pollutants affect health expenditures only through wealth maximization. Pollution increases the rate of health capital decay - changing the margin between the net rate of return on health capital and other investment goods, and increases the number of days ill. But because neither the pollutant nor health is in preferences, the consumer optimization problem can be formulated as a two stage maximum; the individual first chooses a schedule of health to maximize the present value of life-time wealth, and then uses capital markets to shift consumption over time so as to maximize utility. For a small change in the pollutant level in some period t, Cropper defines the WTP as:

$$WTP = (w(dS/dP)p + b(dI/dP)P)e^{-rt}$$

where w is the wage rate, S the number of sick days, P the level of pollution, b the costs of a unit of health investment, I the extent of health investment, and r the discount rate. The first term represents costs of illness(COI), the second the change in health investment expenditures.

In the course of working through the dynamic wealth maximization, Cropper makes three restrictive assumptions which allow the WTP expression to be simplified considerably; the relationships between the pollutant level and the depreciation rate, and between health status and days ill, are assumed to be of constant elasticity, and the health production function is defined as constant returns to scale. Given these assumptions, it can be shown that the change in averting expenditures exactly equals the COI costs; the first order conditions for the wealth maximization insure that the marginal costs of sickness and health investment be equated, but, given the constant returns-to-scale-- which insures constant prices- -and the constant elasticity relationships, the equilibrium margins are constant irrespective of the scale, and hence total costs are also equated. Thus to calculate the WTP one merely needs to calculate COI and multiply by two, or, to calculate the change in averting expenditures, one just needs to measure the COI.

Cropper illustrates her analysis by calculating COI and WTP from Michigan Panel Study of Income Dynamics data. Given the estimated elasticity of sick time with respect to pollution, an average personinthe1976 sample earning $6.00 per hour would be willing to pay $7.20 annually for a 10 percent reduction in the mean of sulfur dioxide.

Since WTP is always twice the foregone earnings in this model, it is also possible to say that this average individual would be willing to pay $96 to avoid the loss of an eight hour work day. Putting this in 1984 dollars implies a value of $176 per work loss day.

2.7.4. Conclusions

In this section, studies by Gerking and Stanley (1984) and Cropper (1981) are reviewed. These studies attempt to estimate what an individual would be willing to pay for an improvement in air quality related to health effects only. The implied values for health are about $40 for a day of restricted activity from the Gerking and Stanley study, and $176 for a work loss day in the Cropper study. Since a work loss day is a more severe effect than a day of restricted activity (as defined in these studies), it is notunexpectedthatthe Cropper estimate is larger than the Gerking and Stanley estimate. The magnitude of the difference does seem large. However, due to the limitations of these studies noted by the authors, these value estimates are probably best described as illustrative of the order of magnitude of the value of health. In this context, the two studies do not produce inconsistent results.

2.7.5. References

1. Cropper, M. Measuring the Benefits from Reduced Morbidity. American Economic Review, 71:235-240, 1981.

2. Gerking, Shelby, and Linda Stanley. "An Economic Analysis of Air Pollution and Health: The Case of St. Louis." (Mimeographed). University of Wyoming, May 1984.

3. Gerking, Shelby, L. Stanley and W. Weirick. An Economic Analysis of Air Pollution and Health: The Case of St. Louis. U.S. Environmental Protection Agency, Office of Policy and Resource Management, Washington, D.C., 1983.

4. Grossman, M. "On the Concept of Health Capital and the Demand for Health", Journal of Political Economy, 80 (March/April 1972): 223-255.

5. Portney, P.R. and J. Mullahy. "Urban Air Quality and Acute Respiratory Illness." Journal of Urban Economics, forthcoming.

2.8. PROPERTY VALUES AND THE VALUE OF HEALTH

2.8.1. Introduction

Hedonic analysis of housing markets frequently has been employed in an effort to estimate the benefits of improved air quality. Presumably, individuals reveal their willingness to pay for environmental quality through their location choices in housing markets and the corresponding housing premiums for various locational attributes, including air quality. The benefit estimates thus obtained, if accurately measured, represent the total benefits to individuals of improvements in air quality, including improvements in health status, reduced property damage (soiling costs), as well as less tangible psychic benefits such as improved visibility. As such, estimates of the aggregate benefits of improved air quality obtained from hedonic analysis of housing markets may be viewed as upper bound estimates of the benefits of improved health status attributable to improved air quality.

This section explores the possibility of deriving meaningful information about the value of health risks from the literature relating property values and air pollution. In section 2.8.2 the hedonic analysis of housing markets is considered in detail. After noting a number of econometric problems that have not been fully resolved in the literature, some estimates of willingness to pay for air quality implied by a number of studies are presented. It should be noted that the review does not attempt to attack or defend the basic methodology of applying hedonic analysis to the problem of property values and environmental quality. Given the existing state of knowledge it seems premature to attempt to make judgements about the appropriateness of housing market hedonic studies, or to attempt the derivation of a consensus or best estimate of the value of air quality as revealed in housing markets. Instead, a number of methodological concerns and a range of empirical values are presented, to explore the robustness of the method.

In section 2.8.3, the estimates of willingness to pay for air quality are combined with estimates of the effects of air quality on health, to imply upper bounds for the value of mortality risks. The extensive literature on the value of mortality risks as revealed in various indirect and contingent markets has been reviewed elsewhere (see Blomquist (1982), Violette and Chestnut (1984) and Jones-Lee (1985)). The upper bound values of mortality risks as revealed in the housing market can be compared to the range other studies have found. The main benefit of examining the housing market results is that this market directly reflects air quality. Other approaches to valuing mortality risks consider other types of risks, such as the risk of accidents while on the job, or traffic accidents. On the other hand, the link between the value of air quality as reflected in housing markets and the value of mortality risks is fairly tenuous and depends crucially upon the validity of various assumptions made.

2.8.2. Hedonic Analysis of Housing Markets

2.8.2.1. Introduction

Ideally, we need estimates of the parameters of the demand function for improved air quality, and an estimate of the initial height of the demand curve. The benefits of a given improvement in air quality can be measured as the integral under the compensated demand curve, from the initial level of air quality to the level of air quality that is attained with the improvement. In Figure 2-2, the initial level of air quality is shown by A_1, and the augmented level A_2. The initial level of marginal benefits as perceived by the consumer are shown as B_1, and the level of marginal benefits corresponding to level A2 are shown as B_2. The value of the improvement to the consumer is shown as the shaded area $B_1B_2A_1A_2$, and corresponds to the equivalent variation of income of the change. This is a measure of the dollar equivalent of the welfare improvement (Hicks, 1968).

The earliest hedonic analysis of housing markets concerns the construction of housing price indices. This literature is motivated by an interest in accurately estimating changes in housing price. Following Gorman (1956) and Adelman and Griliches (1961), the primary emphasis in the housing price index literature is the development of a time-series (or cross-SMSA) housing price index holding housing "quality" constant. In some of these studies, the sales price of a particular house at different points in time is used to estimate a price index (Dobson, 1970; Chinloy, 1977; Palmquist, 1980). In most of the remaining studies, such as Musgrave (1969), Follain (1978), and Palmquist (1980), the sale price is regressed on the characteristics of the house, with the housing price index computed as the change over time (or across areas) in the predicted sales price of a typical housing bundle (that is, a bundle with the sample mean level of each attribute).

Related to the housing price index literature is the early hedonic demand literature. Studies of this type were primarily interested in estimating the "shadow prices" of housing characteristics, that is, the contribution of particular characteristics to total value, rather than an overall housing price. Studies concentrating on the impact of air quality on housing values include Ridker and Henning (1967), Anderson and Crocker (1971), Smith (1978), and Wieand (1973). A summary of the results from these studies and others are provided in Table 2-11. The marginal price estimates vary considerably across studies, ranging from zero to $422.

FIGURE 2-2

BENEFITS OF AIR QUALITY IMPROVEMENT

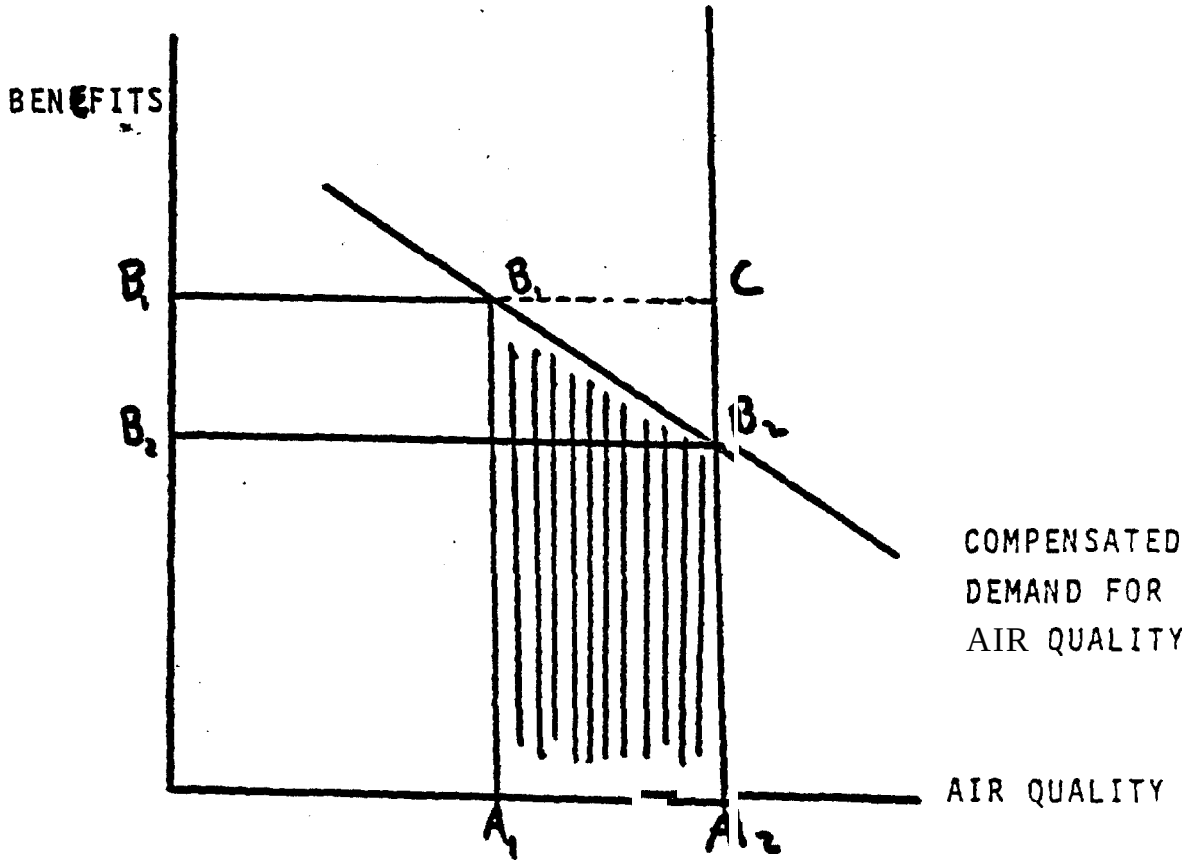


TABLE 2-11 ESTIMATES OF MARGINAL PRICES OF AIR POLLUTION
(Suspended Particulates)

Study	Location	Year	Estimated Marginal Price (1980 Dollars/mm^3)
Diamond (1980)	Chicago	1969-71	$422
Li and Brown (1980)	Boston	1971	2-8[a]
Smith (1978)	Chicago	1971	91-108
Smith and Ohsfeldt (1979)	Houston	1970	4-21
	Houston	1976	14-68
Wieand (1973)	Census	1960	0-9[a]

[a] Not statistically different from zero.

In many of these studies, marginal prices are assumed to reveal the consumer's willingness to pay for various units of a particular characteristic. However, these are not estimates of the consumer's entire willingness to pay schedule, and may not reveal the marginal evaluations of different classes of consumers, except as an overall average. Instead, these estimates are measures of the average market price of a marginal change in a particular locational amenity--clean air. At most, the shadow prices determine only the height of the demand for this characterisitic, but do not throw any light on the shape of the demand function.

An additional problem of using single state hedonic regression concerns the implicit nature of housing characteristics. Consider an ordinary good that is supplied in a competitive market. A consumer faces a constant market-determined price, and adjusts quantity purchased to the point where the person's marginal evaluation of the good (demand) is equal to the market price. If the good is sold in such a way that the price facing the consumer varies with the quantity purchased, the single hedonic estimate of the marginal benefit to the consumer will be a weighted average of marginal evaluations of consumers in different cicumstances. If air quality is a normal good, higher income consumers will have a higher demand for it, and their demand curves will intersect the non-constant price schedule at different points. It is still true that consumers equate marginal evaluation with price, and measures of benefits to improved air quality can be estimated as the area under the compensated demand curve, but these measures will vary with consumers. One may conclude that a proper measure of benefits should segment consumers by different income levels and other characteristics, or alternatively one may accept that the average marginal evaluation, shown by the hedonic estimate, might be used for an overall estimate of benefits to the typical consumer. The single-stage hedonic estimate still will not provide evidence as to the shape of the demand curve, however.

2.8.2.2. Hedonic Prices and the Demand for Characteristics

There have been many attempts to estimate the demand for housing characteristics directly, either as a system of demand equations or with each equation treated separately. Among the earliest studies of this type are Kain and Quigley (1975), Straszheim (1975), and King (1976). Unlike Kain and Quigley, both Straszheim and King include price information in their estimating equations (specifically, the "hedonic" price of the attribute). Since both studies assume a linear housing price structure (that is, a constant marginal price of the attribute), it is necessary to invoke a "segmented markets" assumption to insure variation of the hedonic prices within an urban area at a single point in time. That is, a separate hedonic regression is estimated for each market segment, and the resulting coefficient estimates are used as the price variable in the demand function.

It is important to note that the segmented markets hypothesis arose from the observation that point estimates of marginal price differ across areas within an urban area. If markets were not segmented (or separated), it was (implicitly) assumed that arbitrage between markets would insure price equality across the urban area. Although this argument may be applicable to the literature on racial discrimination in housing, the segmented markets hypothesis, in general, represents a failure to recognize the implicit nature of characteristics markets. The fact that characteristics are purchased jointly in indivisible bundles limits arbitrage possibilities, resulting in a nonlinear price structure. Differences in point estimates of marginal price are to be expected, and do not constitute evidence of segmented markets.

2.8.2.3 Rosen's Model of Implicit Markets

A general model of implicit markets for characteristics was developed by Rosen (1974). In this model, the interaction of supply and demand produces a market clearing price function, $P(Z)$, which relates the price of a heterogeneous good to Z, the characteristics of the good. Rosen defined equilibrium as the state at which the marginal bid price for Z_i, Φ_i, equals the marginal offer price for Z_i, Φ_i, for all i in Z. The bid curve relates the maximum price a consumer is willing to pay for an additional unit of Z_i, holding income (and other exogenous demand variables) and utility constant (U^0). The offer price curve relates the minimum price a producer is willing to accept for an additional unit of Z_i, holding exogenous supply variables and profits constant (Pi^0). Notationally, an implicit market is in equilibrium when

$$\Phi_i(Z, Y_1, U^0) = P_i = \Phi_1(Z, Y_2, Pi^0)$$

for all i, where Y_1 represents income and other exogenous demand variables, Y_2 represents exogenous supply variables, and P_i is the equilibrium implicit marginal price of Z_i.

In Rosen's model, the derivatives of Φ_i form a set of compensated (inverse) demand functions, and the derivatives of Φ_i a set of profit-compensated supply functions. The intersections of the demand and supply functions trace out the price function P_i, which will not in general be linear, and will not imply a constant marginal price. (The usual hedonic technique and the competitive model for an ordinary good both imply constant marginal prices.) If the price function P_i can be determined, then taking its derivative at various levels of Z_i will yield a set of implicit marginal prices, which in turn may be used to estimate the compensated demand function needed in the estimation of benefits to improved air quality. In essence,

since the price function relating the marginal price and the quantity of an attribute is composed of intersections of demand and supply, it is neither demand nor supply itself. What results is an identification problem.

Rosen suggested a two-step estimation procedure, where an hedonic market equation, P(Z), is estimated in the first step using the best fitting functional form, and omitting Y_1 and Y_2. In the second step, the derivatives of the equation estimated in the first step, evaluated at each observation's level of Z, are used in the estimation of a system of supply and demand equations:

$$P_i = \Phi_i(Z, Y_1) \qquad \text{[demand]}$$

$$P_i = \Phi_i(Z, Y_2) \qquad \text{[supply]}$$

where P_i = the partial derivative of P(Z) w.r.t. Z_i, evaluated at each observed Z.

2.8.2.4. Rosen's Model: Applications to Demand for Air Quality

Studies that apply Rosen's technique to the analysis of the demand for air quality are Harrison and Rubinfeld (1978), Nelson (1978), Bender et al. (1980), and Ohsfeldt (1983). Harrison and Rubinfeld are primarily interested in a single characteristic, air quality. They estimate a single demand equation (1) using OLS and (2) with an instrumental variable for air quality. Nelson estimates a supply and demand function for clean air using two-stage least squares. In both cases, the variation in P_i in the system is entirely attributable to the nonlinearity of the price structure and the subsequent differences in point estimates of marginal price. Bender, et al. estimate the demand for air quality giving special attention to the choice of functional form for both the demand function and the hedonic price equation. Ohsfeldt estimates the demand for three housing neighborhood characteristics including quality (of which air quality is a major component) for three cities using the longitudinal Annual Housing Survey for the years 1974 through 1979.

In all of these studies, with the exception of Ohsfeldt (1983), the market price function, P(Z), contains a greater number of characteristics variables than the demand (or supply) equations. One reason why the empirical models have this structure, although it is never explicitly stated as such, is to reduce the severity of a problem that is immediately apparent in Rosen's suggested empirical technique. That is, if Pi is linear in Z and Φ_i is linear in Z, then in the second step of the estimating procedure, Z will explain all of the variance in Pi and the coefficients of Y_1 will be zero. The only way to avoid this result using Rosen's technique is to assume that Pi and Φ_i have different functional forms with respect to Z, of which including linear fewer Zi's in Φ_i is a special case. In other words, with a single market area at a particular point in time,

all of the variation in the estimated marginal price, P_i, can be attributed to the nonlinearity of the price structure, P(Z). In estimating demand (or supply), restrictions on the functional forms must be imposed to avoid duplicating the marginal price function. Even with multiple market data, substantial exogenous price variation is necessary to avoid the effects of spurious correlation (see Ohsfeldt and Smith, 1985). It seems likely that all of these studies suffer, to some degree, from inadequate exogenous price variation. Thus, the benefit estimates obtained from these analyses are not very reliable.

Another basic flaw in most of these studies is that they accept Rosen's view of the identification problem. The object of an implicit market analysis is the individual consumer (or producer). Since the market price structure P(Z), is exogenous to the individual, there is no direct interaction between individual supply and individual demand. The relevant simultaneity problem in an implicit market analysis results from the quantity dependence of marginal prices.

With these limitations in mind a summary of demand elasticity estimates from these empirical studies is provided in Table 2-12.

These estimates, to the extent they are accurate, indicate that the demand for clean air is probably price inelastic, and that clean air is a normal good.

In terms of benefit estimates, Bender et al. suggest a permanent 10 percent reduction in suspended particulates would result in a $700-1800 benefit (present value) per household. A permanent reduction of 20 percent would create $1500-3000 in benefits (present value) per household. Similarly, Harrison and Rubinfeld estimate. that a 2 pphm reduction in nitrogen oxides would create benefit of $800 per middle-income household, while a 9 pphm reduction would result in benefits of $2200 per middle-income household. But, because of the econometric problems outlined earlier, these estimates should be used cautiously.

TABLE 2-12 ESTIMATES OF ELASTICITIES OF DEMAND FOR CLEAN AIR

Study	Location	Date Year	Price Elasticity	Income Elasticity
Bender, et al. (1980)	Chicago	1972	- .516	.609
Harrison and Rubinfeld (1978)	Boston	1970	- .850	.957
Nelson (1970)	D.C.	1970	-1.250	1.000
Ohsfeldt (1983)	Houston	74-79	-1.111	.081
	Chicago	74-79	- .113	.139
	Philadelphia	74-79	- .382	.123

2.8.3. Implied Values of Mortality Risks

In this section, we consider the problem of deriving a value for the risks to human health associated with air pollution, based on the-values implied in property value studies. This exercise follows the proposal made by Portney (1981). A similar exercise has also been carried out by Smith and Gilbert (1984) for values derived from a hedonic wage function that incorporates both job related risks and implicitly the mortality risks associated with air pollution.

As discussed above in section 2.8.2, individuals may reveal their willingness to pay for air quality through their location choices, and so housing prices will relflect this value. From some early studies in this field, estimates of the marginal price of air pollution (suspended particulates) range from zero to $422 per microgram per cubic meter. For the present exercise, we will use this average marginal evaluation as an estimate of the benefits to the typical consumer. For illustrative purposes, assume the true value is somewhere in the middle of this range, say at $100.

Knowing the marginal price of air pollution as revealed in housing markets does not directly lead to estimates of the value of risks to health. What is necessary is additional information linking air pollution to health risks, which can be found from the health econometrics literature (see Section 2.3). Using the same notation as Portney (1981), if the marginal value of risk is V_R, it can be approximated by the ratio of the marginal value of air pollution (dV/dQ) and the marginal effect of air pollution on risks (dR/dQ), i.e.

$$V_R = (dV/dQ)/(dR/dQ).$$

Using the estimates from housing hedonics leads to a value of (dV/dQ); using estimates from a health econometrics study allows the estimation of (dR/dQ). In particular, a "typical" health econometrics estimate (see Section 2.3) suggests that a marginal change in the mean level of suspended particulates results in a change in the average mortality rate of 0.45 (deaths per 100,000).

To actually complete the calculation of the value of health risks, the basic pieces of information must be adjusted to take into account exactly what is revealed in the housing market. First, the marginal prices of 'air pollution, reflecting the difference air pollution makes in housing prices, must be put on an annual cost basis. Using a typical discount rate of 10 percent (again, see Portney (1981)), our assumed value of $100 implies a $10 annual cost. Second, it should be recognized that the choice of location improves health for all members of the household. So if a typical household is made up of 3 individuals, the risk reduction the household "buys" when it buys a house with a marginal reduction of air pollution is a reduction

in mortality risks for 3 individuals, or 3 times .45 = 1.35 deaths per 100,000. With these figures, then, the implied value of a risk reduction is

$$V_R = (dV/dQ)/(dR/dQ) = (\$10)/(1.35 \times 10^{-5}) = \$7.4 \times 10^5.$$

That is, the value of a marginal change in risks, or the value of life in a statistical sense, is $740,000.

There are numerous caveats concerning this value of risk. First, for the calculation to be approximately correct, two assumptions must be approximately met: 1) the only reason households value cleaner air (as revealed in the housing market) is for the change in health risks; and 2) households "correctly" perceive the change in health risks associated with changing air pollution.

Since households probably value cleaner air for reasons unassociated with health, the estimate of the marginal value of risk, V_R, will be upwardly biased, or an upper bound to the correct measure. Smith and Gilbert (1984) attempt to at least partially correct for this problem by reducing the implied values of mortality risks by 30 percent. This correction used the results of a contingent valuation study by Brookshire et al. (1979) that asked respondents to allocate their total willingness to pay for air pollution reductions between aesthetic and health motivations. This study indicated that 30 percent of the total willingness to pay was due to aesthetic motives. To use this adjustment, Gilbert and Smith have to maintain the assumption that the same proportion can be applied to willingness to pay estimates from the wage model. Making the same assumption for willingness to pay estimates from property value studies, the value of mortality risks derived above could be similarly adjusted. However, depending upon the individual's exposure to pollution at work and at home, the relative importance of health versus aesthetic motives may differ. Maureen Cropper suggests, for instance, that most of the observed housing price premiums may be due to aesthetic and not health motives. Since working persons spend a large portion of their time away from their homes, willingness to pay for cleaner air at home cannot capture the total willingness to pay for cleaner air for health reasons. This implies that the derived value of mortality risks overstates the true value because of the inclusion of aesthetic and other benefits, but understates the true value because it excludes the value of clean air on the job.

If households underestimate the effect of air pollution on health (i.e. households' estimates are smaller than the health econometric studies' estimates of dR/dQ), then the estimate of VR will be biased downwards. The converse is of course true if households overestimate the effect of air pollution on health. The effect of air pollution on health as perceived by households is the required, but unkown, value. Smith and Gilbert (1984)

point out that given the range of estimates existing in the technical literature, it is plausible that the relationship as perceived by individuals' could fall anywhere within this range.

Finally, even if the formula for calculating the value of risk is approximately correct, the values plugged into the formula are only possible candidates from a wide range of estimates for both the value of air pollution and the effect of air pollution on human health. Using different estimates could change the value of risk by at least an order of magnitude. In particular, since some property value studies show no premiums for air quality, the lower bound for the value estimated is zero. This could imply that there is no relationship between air quality and health, or that individuals do not perceive any relationship, or that the relationship simply is not discovered by hedonic analysis of housing markets.

With the above caveats in mind, whatcanbe said about the value of risk of $740,000 that was found? In very broad terms, this value does not seem inconsistent with the values derived from the hedonic analysis of labor markets, or from the analysis of risk-related consumption activity. Blomquist (1982) reports a range of implicit values from labor market studies from $378,000 to $2,820,000; and a range of implicit values from consumption activity from $180,000 to $466,000. Further mention should be made of the comparison of Portney's (1981) results to ours, since by following almost exactly the same procedure as used above, he arrives at a value of $180,000. The difference can be explained mainly by the marginal value of air pollution Portney uses. He begins with a value of $335 for 18 micrograms/cubic meter of suspended particulates, which implies a value of (roughly) $18.60 for 1 microgram/cubic meter. This compares to the value of $100 used in the above calculations, and thus accounts for most of the difference in the final value of risk. The estimate Portney used is well within the range of estimates reported in section 2.8.2. Also note that Portney's estimated relationship between air pollution and mortality risks (.5 per 100,000) is very close to that used above (.45 per 100,000).

So the various implicit market values for health risks, where the markets are labor, housing, and certain consumption goods, seem to result in what again is best termed not inconsistent results. The $740,000 estimate can also be compared to the cost of illness approach estimates of the value of mortality risks, which are given by the present value of future foregone earnings. Landefeld and Seskin (1982) report a standard estimate for a male 40-44 years old of $180,352, or their adjusted estimate (to more closely approximate willingness to pay) of $660,193. Again, no large inconsistencies are seen in the estimates. In addition, due to the existence of averting behavior, it has been suggested that the cost of illness approach underestimates willingness to pay (see Section 2.2). This can help explain in particular the relatively low estimate of the standard cost of illness approach.

2.8.4. Bibliography

PROPERTY VALUE STUDIES

A. Theory and Methodology

First Stage Hedonics

1. Freeman, A.M. Air Pollution and Property Values: A Methodological Comment. Review of Economics and Statistics, 53:414-415, 1979.

2. Lancaster, K. A New Approach to Consumer Theory. Journal of Political Economy, 74:133-155, 1966.

3. Lucas, R.E.B. Hedonic Wage Equations and Psychic Wages in the Return to Schooling. American Economic Review, 67:549-588, 1977.

4. McDougall, G. S. and C. Wright. A Proposal for Improving Measurement of the Benefits from Pollution Abatement. Journal of Environmental Economics and Management, 7:20-29, 1980.

5. Murray, M. P. Prices and Composite Commodities. Journal of Urban Economics, 5:188-197,1978.

Second Stage Hedonics

6. Brown, J. N. and H. Rosen . On the Estimation of Structural Hedonic Price Models. Econometrica, 50:765 - 768, 1982.

7. Diamond, D. and B. Smith. Simultaneity in the Market for Housing Characteristics. Journal of Urban Economics, forthcoming.

8. Epple, D. Hedonic Prices and Implicit Markets: Estimating Demand and Supply Functions for Differentiated Products, unpublished paper. Carnegie - Mellon University, April, 1984.

9. Freeman, A. M. The Hedonic Price Approach to Measuring Demand for Neighborhood Characteristics. In: D. Segal (ed.), The Economics of Neighborhood. Academic Press, New York, 1979a.

10. Freeman, A. M. The Hedonic Prices, Property Values, and Measuring Environmental Benefits: A Survey of the Issues, Scandinavian Journal of Economics, 81:154-173, 1979b.

11. Murray, M. P. Mythical Demand and Mythical Supplies

for the Proper Estimation of Rosen's Hedonic Price Model, Journal of Urban Economics, 14:327-33, 1983.

12. Ohsfeldt, R. L. and B. Smith. Estimating the Demand for Heterogeneous Goods. Review of Economics and Statistics, forthcoming.

13. Polinsky, A. M. and S. Shavell. Amenities and Property Values in a Model of an Urban Area. Journal of Public Economics, 5:119-129, 1976.

14. Rosen, S. Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition. Journal of Political Economy, 82:34-55, 1974.

15. Van Lierop, J. House Price Structure and Market Equilibrium. Journal of Urban Economics, 11:272-289, 1982.

B. Application to Value of Air Quality

First Stage Hedonics

16. Anderson, R. and T. Crocker. Air Pollution and Residential Property Values. Urban Studies, 8:171-180, 1971.

17. Diamond, D. B. The Relationship Between Amenities and Urban Land Prices. Land Economics, 56:21-32, 1980.

18. Li, M. M. and H. Brown. Micro-Neighborhood Externalities and Hedonic Housing Prices. Land Economics, 56:125-41,1980.

19. Polinsky, A. M. and D. Rubinfeld. Property Values and the Benefits of Environmental Improvement. In: L. Wingo and A. Evans (eds.), Public Economics and the Quality of Life. Johns Hopkins University Press, Baltimore, 1977.

20 Ridker, R. G. and J. Henning. The Determinants of Residential Property Values with Special Reference to Air Pollution. Review of Economics and Statistics, 44:246-255, 1967.

21 Smith, B. A. Measuring the Value of Urban Amenities. Journal of Urban Economics, 5:370-387, 1978.

22 Smith, B. A. and R. Ohsfeldt. Housing Prices Inflation in Houston: 1970-1976. Policy Studies Journal, 8:257-276, 1979.

23 Wieand, K. F. Air Pollution and Property Values: A Study of the St. Louis Area. Journal of Regional

Science, 13:91-95, 1973.

Second Stage Hedonics

24. Bender, B. T, Gronberg, and H. S. Hwang. Choice of Functional Form and the Demand for Air Quality. Review of Economics and Statistics, 62:638-643, 1980.

25. Freeman, A. M. The Benefits of Environmental Improvements: Theory and Evidence. Johns Hopkins University Press, Baltimore, 1979.

26. Harrison, D. and D. L. Rubinfeld. Hedonic Housing Prices and the Demand for Clean Air. Journal of Environmental Economics and Management, 5:81-102, 1978.

27. McMillan, M. L. Estimates of Households' Preferences for Environmental Quality and Other Housing Characteristics from a System of Demand Equations. Scandinavian Journal of Economics, 81: 174-187, 1979.

28. Nelson, J. P. Residential Choice, Hedonic Prices and the Demand for Urban Air Quality. Journal of Urban Economics, 5:357-369, 1978.

29. Ohsfeldt, R. L. Implicit Markets and the Demand for Housing Characteristics, unpublished dissertation. Department of Economics, University of Houston, 1983.

30. Palmquist, R. B. Estimating the Demand for the Characteristics of Housing. Review of Economics and Statistics, 46:394-404, 1984.

HEDONIC WAGE STUDIES

A. Theory and Methodology

31. Eberts, R. W. An Empirical Investigation of Intraurban Wage Gradients. Journal of Urban Economics, 10:50-60, 1981.

32. Eberts, R. W. and T. Granbert. Wage Gradients, Rent Gradients, and the Demand for Housing: An Empirical Investigation. Journal of Urban Economics, 12:168-176, 1982.

33. Muth, R. F. Cities and Housing. University of Chicago Press, Chicago, 1969.

B. Applications to Value of Air Quality

34. Bayless, M. Measuring the Benefits of Air Quality Improvements: A Hedonic Salary Approach. Journal of Environmental Economics and Management, 9:81-99, 1982.

35. Cropper, M. L. and A. S. Arriage-Salinas. Intercity Wage Differentials and the Value of Air Quality. Journal of Urban Economics, 8:236-254, 1980.

36. Roback, J. Wages, Rents, and the Quality of Life. Journal of Political Economy, 90:1257-1278, 1982.

References (for Section 2.8.3)

1. Blomquist, Glenn. Estimating the Value of Life and Safety: Recent Developments. In: The Value of Life and Safety, Michael Jones-Lee, ed. North-Holland Publishing Company, Amsterdam, 1982.

2. Cropper, M.L. Measuring the Benefits from Reduced Morbidity. American Economic Review, 71:235-240, 1981.

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

4. Portney, P. Housing Prices, Health Effects, and Valuing Reductions in Risk of Death. Journal of Environmental Economics and Management, 8:72-78, 1981.

2.9. CONCLUSIONS: INTERIM VALUES FOR THE HEALTH EFFECTS OF AIR POLLUTION

2.9.1. Introduction

The strengths, weaknesses and major results of the various approaches to solving the problem of valuing health effects likely to result from an air quality change are discussed in the earlier parts of Volume 2. A synthesis of these results is the goal of this concluding section. The task seems formidable, since the studies reviewed often value different aspects of health, using different methodologies. As a result of the methodology used, the studies' results will vary in quality, in terms of accuracy and in how complete a value estimate can be reached.

To organize the issues involved, in section 2.9.2 a framework for value estimates is discussed. This section describes *what* health effects it would be desirable to have values for, and what a complete value estimate would include. Rather than being an ideal, the goal is to develop a framework that can be implemented with data already available or likely to be available in the near future.

In section 2.9.3 the available evidence on the value of health effects is reviewed. The available evidence is compared to the framework, in terms of which health effects are valued, and how complete these values will be. In light of this discussion, reasonable ranges and interim values are developed. To illustrate the usefulness of these values, the section concludes with an illustrative calculation of the benefits of an hypothetical change in air quality.

2.9.2. A Framework for Valuing the Health Effects Of Air Pollution

There are two questions involved in forming a set of values for the health effects related to air pollution. First, what types and ranges of health effects would we like to have values for? Second, for the health effects we would like to value, what would constitute a complete and conceptually correct value estimate? Answers to these questions are discussed below, and this discussion is summarized in Table 2-13.

Other sections of this report contain a more complete discussion of the issues involved in answering these questions. The types and ranges of health effects related to air pollution are discussed in section 2.3 on health econometrics, and in section 3.2 of Volume 3 on dose response relationships. What is involved in a complete value estimate is developed on a rigorous theoretical basis in section 2.2. A preliminary investigation of valuing serious or life-threatening illness is the focus of Volume 4, though the framework developed has yet to be implemented.

TABLE 2-13

FRAMEWORK FOR HEALTH VALUES

Health Effects Valued	Value reflects
Acute or Short-term Morbidity	
--light symptoms	--physical and mental discomfort
--marginal change in time spent ill	--work time lost
	--other time lost
	--medical expenditures
	--costs of averting behavior or preventive measures
Aggravation of Previously Existing Chronic Morbidity	
--chronic lung conditions	--a larger degree of all of the above
--chronic heart conditions	
--marginal and non-marginal changes in time spent ill	--individuals' health status is already low
Increased Incidence" of Non-fatal Chronic Morbidity	
--chronic lung conditions	--all of the above
--chronic heart conditions	--lifestyle and work changes due to the existence of chronic illness
--cancer	
Mortality	
--unforseen instant death	--mortality risks
--chronic lung conditions	--morbidity preceding mortality valued as above
--chronic heart conditions	
--cancer	--psychic costs of imminent death

2.9.2.1. Health Effects to be Valued

Based on the health econometrics literature and what is known about dose-response relationships, the health effects relevant to a change in air quality levels fall into three groups: 1) acute morbidity; 2) chronic morbidity; and 3) mortality. This classification is necessarily somewhat arbitrary. Particularly troublesome is the separation of morbidity and mortality. Almost all morbidity involves some risk of mortality, and conversely almost all mortality is preceded by a period of morbidity. In what follows, morbidity is treated as not involving any risk of death; that morbidity related to death is termed "morbidity preceding mortality."

Most individuals affected by air pollution at all probably experience only acute effects. These include symptoms such as eye irritation, cough and headache stemming directly from the pollutants, and the possibility of increased sucesptibility to acute illnesses such as upper respiratory infections. Reasonable changes in air quality could change the experience of these individuals marginally--a fraction of a day to a few days of this type of health effects more or less. So value estimates should value marginal changes for a range of light symptoms.

Health changes related to chronic morbidity will affect a smaller number of people, but each will suffer more serious effects. Most evidence supports the relationship between air pollution and the aggravation of existing chronic lung conditions. There is also some evidence that those individuals with existing heart conditions may be affected. In general, the dose-response literature seems to suggest that a reasonable change in air pollution levels may provide a significant change in health status for those with chronic conditions, both in the severity of the symptoms and in the change in the number of days the symptoms are experienced. However, at levels of air pollution relevant to the U.S., from the health econometrics literature little evidence has been found of a link between air pollution and any large changes in time spent ill. To value the possible effects of air pollution on the chronically ill, it is thus necessary to address the symptoms the chronically ill experience, and be applicable to both marginal changes in time spent ill, and possibly non-marginal changes as well.

The possibility that air pollution causes (or is one possible cause of) new cases of chronic lung conditions or heart conditions also can not be ruled out. To date, evidence on this possibility is virtually non-existent. There is some evidence linking increases in mortality rates for chronic and serious illnesses to air pollution. If air pollution is increasing the incidence of eventually fatal condtions, it seems reasonable that it increases the incidence of non-fatal conditions as well. On the other hand, air pollution may not be causing new cases at all, but instead aggravate existing cases to the extreme of increasing death rates. While this is an unresolved issue, it is

still useful to value a change in the incidence of non-fatal chronic morbidity. Aside from valuing an important possible effect of air pollution, valuing non-fatal conditions is a first step towards valuing the morbidity preceding mortality.

The most serious health effect related to air pollution is of course mortality. Evidence supports a link between general mortality rates and air pollution levels, possibly stemming from increased mortality due to chronic lung conditions, heart conditions, and cancer. The ideal measure of the value of mortality would include a value of the change in mortality risks, plus a value for the change in morbidity preceding mortality.

2.9.2.2. Components of a Complete Value Estimate

The development of a conceptually correct and complete estimate of the value of animprovementinhealth due to a change in environmental quality can be thought of involving several steps. First, for morbidity, an estimate of what an individual would be willing to pay for a certain change in his health status could be prepared. This estimate will reflect the different reasons an individual values his health. Second, it is necessary to estimate what an individual would be willing to pay for a change in the risks of mortality he faces. This estimate will reflect the value of the morbidity preceding mortality, as well as the value of the mortality risks alone. Each of these steps is discussed briefly below. Following this discussion is a brief discussion of the limitations of the framework that are necessitated by the limitations of the available data. It should also be noted at the outset that the value estimates are being prepared for use in an ex ante evaluation of whether a project is a potential Pareto improvement. This criterion relfects normative judgements, but it is not the purpose of this Report to discuss and defend the general methodology of applied welfare economics.

To analyze why and how much an individual values his health, first consider why an individual would value a reduction in acute morbidity. First, there is the value of discomfort: the direct disutility of illness or symptoms, which in more severe cases might be termed pain and suffering. Second, there is the value of work time lost due to illness or symptoms. This can be measured directly as the value of the foregone earnings the individual actually incurs (allowing for the possibility of paid sick leave). Third, there is the value of other time lost. This includes the value of time devoted to housework, leisure time, and so on. Fourth, there are the direct costs of medical expenditures incurred because of the illness or symptoms. Finally, there are the costs of averting behavior, or preventive actions taken to offset the impact of bad health or the environment.

For the value of chronic morbidity, all of the above

components of the value of acute morbidity remain relevant. Of course, the discomfort may be more severe, and the foregone earnings, lost time, medical expenditures, and averting behavior may be more significant. In addition, there seem to be special considerations required for chronic conditions. Since the condition may restrict activity and cause discomfort for a much longer period of time, the individual may be forced to make large changes in his lifestyle and occupation. For instance, certain strenuous leisure activities or occupations may not be possible. So evenifthe individual has not lostworktime or leisure time, he also may not earn as much or enjoy his leisure as much as he would if the chronic condition were not present. (The influence of chronic conditions on earnings has been explored by Crocker, et al (1979).)

Valuing mortality risks due to air pollution involves valuing the morbidity that precedes death, and finding the amount individuals are willing to pay to avoid increased mortality risks. Valuing morbidity preceding mortality involves the same considerations discussed in valuing chronic morbidity. Valuing mortality risks results in what has been termed the value of a statistical life.

The framework discussed above for developing a complete estimate of the value of health is feasible to implement (though not necessarily perfectly) given existing data, but still falls short of being ideal. Several further steps would need to be taken before the value of health would be ideally estimated.

First, since health and the effects of environmental quality on health are goods involving a high degree of uncertainty, the analysis must take this into account. Graham (1981) addresses the general problem of benefit cost analysis under uncertainty, and investigates how what an individual would pay for a change in risk may be related to what an individual would pay for a certain change. An expression for what an individual would be willing to pay for a change in health risks is derivedin section 2.2. However, in the discussion above of the value of morbidity, health is treated as a certain good, and the complete value measure developed corresponds to a standard consumers surplus measure under certainty. This simplification is necessary because most of the existing empirical work values certain changes. In general, for small changes in the incidence of common illnesses or symptoms (e.g. coughing), treating uncertain changes as if they occur with certainty does not seem very misleading. At the other extreme, valuing mortality risks by the amount an individual would be willing to pay to avoid certain death is clearly inappropriate, and so the value of mortality risks, or the so-called value of a statistical life, is used. In between these extremes, the change involved if an individual develops a new chronic condition is probably large enough that recognition of the inherent uncertainty is necessary. What would be ideal is the value of a change in risks of incurring a chronic condition, but since the only data available apply to certain changes, value estimates must reflect this.

Another conceptual shortcoming of the framework developed above is that it applies mainly to the values individuals place on their own health. That is, individual willingness to pay is the focus, while for benefit cost analysis these measures must be adjusted to reflect societal willingness to pay. This problem is discussed in section 2.4.3, and a preliminary attempt to value some of the differences between individual and willingness to pay is made in the contingent valuation experiment discussed in Volume 3. It is not entirely clear in which direction and to what extent individual willingness to pay is biased away from societal willingness to pay, but it seems likely that in general individual willingness to pay will understate societal.

2.9.3. Interim Values for the Health Effects of Air Pollution

2.9.3.1. Introduction

Based on the framework developed above (summarized in Table 2-13), and the studies reviewed in Volume 2, this section develops a set of interim values for the morbidity and mortality effects due to air pollution. Given that there exists a-good deal of controversy regarding the proper estimation of the value of health, this exercise might seem premature. There are two reasons the development of the interim values is justified at this time. First, a reasonably large body of work already exists on the value of health. Since the studies often use different methodologies and do not always yield easily comparable values, this body of work is not accessible to many policy-makers. So one advantage of developing the set of interim values is that it makes the results of this body of work available for applied benefit-cost analysis. The second reason that the development of interim values is a useful exercise is that it helps indicate where further work is needed.

In section 2.9.3.2, the evidence from which the interim values are developed is briefly discussed. The main criteria used in judging the usefulness of this evidence are presented. sections 2.9.3.3, 2.9.3.4, and 2.9.3.5 detail the actual development of the interim values. Since so many objective and subjective judgements are involved, these sections attempt to spell out in as much detail as possible the considerations involved. It is hoped that the details will show the values presented are reasonable, but providing the details will also show where different judgements could be made, and how these differences would affect the conclusions. To allow for some differences, low, medium, and high estimates are presented. This range is not determined by the range of estimates from the separate studies, but instead is fntended to include all plausible values, given the existing data. Thus, it may narrower or wider than the range of individual estimates. Finally, in section 2.9.3.6 an example of using the interim values in practice is given.

2.9.3.2. Available Evidence on the Value of Health

The available evidence on the value of morbidity and mortality is summarized in Table 2-14 (acute or short-term morbidity),. and Table 2-15 (chronic morbidity). The value of mortality risks has been reviewed elsewhere, most recently by Jones-Lee (1985). The estimates presented are limited to the health effects likely to be related to air pollution, as discussed above and summarized in Table 2-13. All values are expressed in terms of 1984 prices. For details of the derivation of the values, see earlier sections of Volume 2.

In judging the usefulness of the evidence presented in Tables 2-14 and 2-15, the most important criterion is how complete the value estimates are, in relation to the framework developed above. An incomplete value, no matter how precisely estimated, yields limited information on the true value of the health effect. The completeness of the different estimates is summarized in Tables 2-14 and 2-15. In general, the most complete estimates come from the contingent valuation studies. The health production studies may or may not be complete, depending upon the specifics of the derivation. The cost of illness studies are always only partial measures of the value of health. Since the relationship between these partial values of health and the complete value is unclear, the partial values provide only corroborative evidence. A detailed discussion of the estimates and the differences between them is presented below as a partofthe developmentofthe interim values.

Two important criteria concerning the validity of the contingent valuation studies are survey design and sample size. Other factors held constant, an improved survey design or a larger sample size should improve the accuracy of the contingent valuation estimates. The existing studies represent a tradeoff between survey design and sample size. The study by Loehman et al. reflects the largest sample of respondents, but at the cost of using a mail survey. This design may decrease the validity of the results for various reasons as discussed in section 2.5, the most important problem being the inability to identify unrealistic values or protest bids. The other contingent valuation studies are based on personal interviews and may be more accurate as a result, but also represent smaller sample sizes. This tradeoff between survey design and sample size means that no simple rule favoring the largest sample or the best design can be applied in judging the validity of the different estimates.

Finally, some mention should be made of the criteria used in judging the results of the health production function approach. As discussed in section 2.7, shortcomings in the methodology and data are seen as limiting these results to being accurate only within an order of magnitude.

TABLE 2-14

VALUES OF ACUTE MORBIDITY

Approach, study, and health effect	Value ($/day)	Value Components Included				
		dis-comfort	work lost	time lost	medical	prevention
Cost of Illness						
Hodson & Kopstein (1984), Paringer & Berk (1977)			X		X	
--respiratory illness	35					
Contingent Valuation						
Tolley, et al.(1985)						
--cough	25	X	X	X	X	X
--sinus	35	X	X	X	X	X
--throat	29	X	X	X	X	X
--eyes	28	X	X	X	X	X
--drowsiness	31	X	X	X	X	X
--headaches	40	X	X	X	X	X
--nausea	50	X	X	X	X	X
--cough, throat and sinus	66	X	X	X	X	X
--drowsiness, headaches and nausea	95	X	X	X	X	X
Loehman, et al.(1979)						
--shortness of breath/ chest pains:						
mild	8	X	X	X	X	X
severe	18	X	X	X	X	X

TABLE 2-14

VALUES OF ACUTE MORBIDITY
(continued)

Approach, study, and health effect	Value ($/day)	Value Components Included				
		dis-comfort	work lost	time lost	medical	prevention
--coughing/sneezing:						
mild	4	X	X	X	X	X
severe	11	X	X	X	X	X
--head congestion, eye,ear,throat irritation:						
mild	6	X	X	X	X	X
severe	13	X	X	X	X	X
Health Production						
Cropper (1981)						
--acute illness	176		x			X
Gerking,et al. (1984)						
--acute illness	40	X	X	x	x	X

TABLE 2-15

VALUES OF CHRONIC MORBIDITY

Approach, study, and health effect	Value ($)	Value Components Included				
		dis-comfort	work lost	time lost	medical	prevention
CHRONIC LUNG CONDITIONS						
Cost of Illness						
Freeman, et al. (1976)						
--average case of: emphysema	3194				X	
Scitovsky & McCall(1976)						
--average case of pneumonia (non-hospital care)	253				X	
Contingent Valuation						
Tolley, et al.(1985)						
predicted value of 1 day of relief for person usually sick (experienced 36 days of symptom) for:						
--cough	107	X	X	X	X	X
--sinus	82	X	X	X	X	X
--throat	163	X	X	X	X	X
--eyes	334	X	X	X	X	X
--cough, throat and sinus	297	X	X	X	X	X
30 days of: (given normal health)						
--cough	167	X	X	X	X	X
--sinus	266	X	X	X	X	X
--throat	206	X	X	X	X	X

TABLE 2-15

VALUES OF CHRONIC MORBIDITY (continued)

Approach, study, and health effect	Value ($)	Value Components Included				
		dis-comfort	work lost	time lost	medi-cal	preven-tion
--eyes	236	X	X	X	X	X
--cough, throat and sinus	625	X	X	X	X	X
Rowe and Chestnut(1984)						
--average of 38 bad asthma days	401	X	x	x	X	X
Loehman, et al.(1979)						
one week of:						
--shortness of breath/ chest pains:						
mild	22	X	X	X	X	X
severe	57	X	X	X	X	X
--coughing/sneezing:						
mild	13	X	X	X	X	X
severe	32	X	X	X	X	X
--head congestion, eye,ear,throat irritation:						
mild	15	X	X	X	X	X
severe	33	X	X	X	X	X
90 days of:						
--shortness of breath/ chest pains:						
mild	56	X	X	X	X	X
severe	156	X	X	X	X	X

TABLE 2-15

VALUES OF CHRONIC MORBIDITY (continued)

Approach, study, and health effect	Value ($)	Value Components Included				
		dis-comfort	work lost	time lost	medical	prevention
--coughing/sneezing:						
mild	37	X	X	X	X	X
severe	81	X	X	X	X	X
--head congestion, eye,ear,throat irritation:						
mild	40	X	X	X	X	X
severe	99	X	X	X	X	X
CHRONIC HEART CONDITIONS						
Cost of Illness						
Acton(1975)						
--average case of coronary heart disease	2703		X		X	
Hartunian, et al.(1981)						
--average case of angina	604		X		X	
Sctivosky & McCall(1976)						
--myocardial infarction	11,254		X		X	
Contingent Valuation						
Tolley, et al.(1985)						
angina, various endowments:						
--1 mild day	66-99	X	X	X	X	X
--1 severe day	124-279	X	X	X	X	X

TABLE 2-15

VALUES OF CHRONIC MORBIDITY (continued)

Approach, study, and health effect	Value ($)	Value Components Included				
		dis-comfort	work lost	time lost	medical	prevention
--5 mild days	96	X	X	X	X	X
--5 severe days	192	X	X	X	X	X
--10 mild days	154-288	X	X	X	X	X
--10 severe days	262-506	X	X	X	X	X
--20 mild days	486	X	X	X	X	X
--20 severe days	844	X	X	X	X	X
CANCER						
Cost of Illness						
Hodson & Kopstein (1984), Paringer & Berk (1977)						
--average case of cancer	9742		X		X	
Hartunian, et al.(1981)						
--average first year of lung cancer	29,924		X		X	

2.9.3.3. Value of Acute or Short-term Morbidity

Severity of Symptoms Valued

The least serious health effects possibly associated with air pollution are various acute or short-term symptoms. Five separate sources of estimates for the value of a day of acute morbidity are reported in Table 2-14. A brief description of the estimates follows, with emphasis on how the severity of the day of morbidity valued differs. 1) The combination of the Hodgson and Kopstein (1984) and Paringer and Berk (1977) studies provides a cost of illness value for an average respiratory illness. The value is expressed in terms of an average or Restricted Activity Day (RAD). (See Section 2.4 for details). 2) The Tolley, et al. (1985) contingent valuation study provides values for a day of a range of light symptoms, alone and in certain combinations. Based on the descriptions of a "symptom day" given as part of the contingent valuation experiment, it seems reasonable to interpret these days as average RADS. 3) The Loehman, et al. (1979) contingent valuation study provides values for mild and severe days of several combinations of light symptoms. Since only a short description of what is meant by mild and severe was given as part of this experiment, it is somewhat difficult to interpret these values. A mild day probably corresponds to a day of discomfort, without any major restriction of activity. A severe day can either be interpreted as an average RAD, or a more serious day involving work loss and/or confinement to bed. 4) The Cropper (1981) health production study can be used to derive a value for a severe or work loss day (WLD), in theory due to the actual experienced acute illness or symptoms caused by air pollution. 5) The study by Gerking and Stanley (1984) also implies a value for a day of experienced acute illness due to air pollution. In this case, it is not clear what severity of a day is relevant, though Gerking and Stanley (p.24) suggest that interpreting it as an average RAD may be appropriate.

The severity of day valued in the above studies can be broken down into three classes: a severe work loss day, an average restricted activity day, and a mild day of discomfort alone. Interim values for each level of severity are presented in Table 2-17. A consideration in reporting this range of values is the information available or likely to be available linking air pollution to acute morbidity. For example, the study by Ostro (1981) relates air pollution to WLDs, so a value of a WLD is required to use this study in benefit cost analysis. On the other hand, the study by Portney and Mullahy (forthcoming) relates air pollution to RADs, so a different set of values is needed. Future work, such as that by the Rand Corporation using data from the National Health Insurance Experiment, may link air pollution to still different severity of days, such as a mild day involving discomfort, or allow the linking of air pollution to a specific symptom. The range of days valued is limited, however, by the existing data.

It is useful to make a preliminary judgement as to how the values of different severities of days may compare. This comparison allows a more efficient use of the available evidence: if we know how the value of a WLD is related to a value of a RAD, we can use an estimate of the value a WLD as corroborative evidence on the value of a RAD, and vice versa. While the relationship cannot be specified exactly, useful evidence comparing different severities of symptom days comes from Loehman, et al.(1979). Respondents placed values on one day, seven days, and ninety days of mild and severe symptoms; the median value for severe is always between two and three times the median value for mild. Unfortunately, as noted above, it is not clear if a severe day should be interpreted as a an average RAD or a WLD. As a compromise, it can be assumed that a severe day as defined by Loehman et al. is intermediate in severity between an average RAD and a WLD.

In the preparation of interim values, the rule of thumb roughly applied is that relief from an average day (a RAD) should be valued about twice as much as a mild day (discomfort); and relief from a severe day (a WLD) is twice as valuable as relief from an average day. This allows for a slightly larger variation in values from mild to severe than found by Loehman et al. It should be re-emphasized that this rule of thumb is not used to derive the values for different severities, but used to allow some sort of meaningful comparisons between the different studies, for corroborative purposes.

Independent Symptoms-Average Severity

In the interim values presented in Table 2-17, six different sets of estimates are provided for the values of an average day (RAD) of acute morbidity due to air pollution. The first five sets are for fairly specific symptoms. These estimates are derived principally from the Tolley, et al. (1985) contingent valuation experiment, with corroboration from Loehman et al. (1979) when possible. As can be seen in Table 2-14, these estimates from contingent valuation are complete measures of the value of health.

The values from Tolley, et al. are used as follows. The mean values based on the sample including all plausible non-protest bids are presented in Table 2-14: $35 for a day of sinus problems, $29 for throat, $25 for a day of coughing or respiratory problems, $28 for a day of eye irritation, and $40 for a day of headaches. These means are seen as medium estimates. Examination of the median values, the range of values, and other aspects of the distribution of values from the Tolley et al. study is also taken into consideration in the general process of forming the range of values. These considerations suggest that for the Tolley et al. results the mean value is the most robust estimate of an average individual's willingness to pay.

Estimates from the Loehman et al. (1979) contingent valuation study can be used as corrobarative evidence. They are not exactly comparable, however, for several reasons. First, the average day valued in Tolley et al. may be somewhere between the mild days and the severe days valued in Loehman et al., in terms of severity. Also, the Loehman et al. values are for combinations of symptoms, none of which are exactly the same as what is valued in Tolley et al., though several are similar. For instance, a mild day of coughing/sneezing is valued at $4, a severe day at $11; and a day of shortness of breath is valued at $8 for mild, and $18 for severe.

These values can be compared to the Tolley et al. values for a day of coughing, at $25 from above. The difference in the values stems from Loehman et al. 's use of median values. Using median values is generally not appropriate, given the methodology of benefit cost analysis. It should be recognized that in a random sample or the entire population, it is reasonable that some individuals will place very high values on their health. In standard benefit cost analysis, justified by the potential Pareto improvement criterion, all individuals' values should be given equal weight, even if the values are far above the average. If median values are used, however, the values of people with high values are implicitly given very little weight. So though reporting median bids avoids overstating values due to the effect of very high bids which may be inaccurate (i.e., not a true reflection of willingness to pay), legitimately high bids are also given little weight.

If it seems likely that high bids have less informational content than lower bids, as seems to be the case for the Loehman et al. study, the median may be a more robust measure of an average person's willingness to pay than the mean. However, since legitimately high bids may also exist, medians are judged as likely to be underestimates of the values desirable for benefit cost analysis.

The median bids from Loehman et al. are used principally in the development of the low range of estimates, though some small weight is placed on these values in the (subjective) calculation of medium estimates. Some weight is also placed on the mean values from Loehman etal., which are much closer in magnitude to the Tolley et al. estimates. The outlier problem Loehman et al. describes indicates these means are overestimates, so only a small weight is placed on them as well.

The interim values, based on the above considerations, for average days of specific symptoms are as follows: sinus at $20(low), $35(medium), or $60 (high); throat at $10, $25 or $40; respiratory symptoms at $15, $30, or $50; eye irritation at $20, $40, or $100; and headache at $30. $50, or $110. The low, medium, and high estimates reflect the considerations described above, as well as some feedback from the development of additional values that follow.

Symptom Combinations-Average Severity

In addition to valuing a day of specific symptoms, the evidence in Table 2-14 supports estimates for an average RAD due a likely combination of symptoms that could result from air pollution. In this case, relevant estimates come from the cost of illness approach, health production studies, as well as contingent valuation studies. For a RAD due to an average case of acute respiratory illness, the cost of illness approach suggests a value of $35. This may be an overestimate of the medical expenditures and foregone earnings due to an air pollution related illness, since this average includes the influence of severe acute respiratory illnesses (e.g., pneumonia). However, the average is dominated by a large number of upper respiratory infections, which are presumably similar to air pollution related symptoms.

In addition, the cost of illness estimate is not a complete measure of the value of morbidity, since it fails to value discomfort, time lost from non-paid activities, and preventive or averting expenditures. The $35 estimate is used as a lower bound, or low value estimate. It has been suggested that a cost of illness (COI) value can be multiplied by a rough adjustment factor to approximate a conceptually complete willingness to pay (WTP) value. Rowe and Chestnut (1984) find WTP/COI ratios of 1.6 to 3.7, for asthma symptoms; Tolley et al. find much larger ratios from about 3 up to 50, depending on the symptom (some ratios based on very small sample sizes). Using a fairly conservative ratio of 2 suggests that a true value would be $70 per average day of respiratory illness. This value is used as one input in the development of the medium estimate.

Willingness to pay estimates from health production models in principle value the health effects actually due to existing levels of air pollution. Theoretically, the Gerking and Stanley (1984) estimate of $40 includes all aspects of the value of health, but due to data limitations this figure is probably more illustrative of the order of magnitude than of the exact value. The Cropper (1981) estimate of $176 is derived from a theoretical model that assumes discomfort and medical expenses were negligible, and in addition relied on the use of specific functional forms. Thus it also is probably more indicative of the order of magnitude. It applies to a severe work loss day, but if it is scaled down by one-half to none-third, it yields a value of $50 to $80 per restricted activity day. These values serve a's additional inputs in the development of the medium estimates.

The final estimates relevant to the value of an average day of a likely combination of symptoms come from the contingent valuation studies. In using these values, it is necessary to make a judgem'ent as to which symptoms are most likely. Based mainly on the dose-response literature, sinus, throat, and

respiratory symptoms seem likely, with some possibility of headache and eye irritation. Since it seems relatively unlikely that all five symptoms would occur in combination is a single day, the value of sinus, throat, and cough combined from the Tolley et al. study is used as proxy for any two or three likely symptoms. The mean bid is $66, which is used as an input in forming the medium value. Medians and other information on the distribution of values are taken into consideration. The values from Loehman et al. serve as inputs in forming the low estimates. The interim values for an average RAD due to a likely combination of acute symptoms are $35 (low), $50 (medium), and $100 (high).

Severe Symptoms

There is relatively little information from which to develop interim values for a severe or work loss day of acute symptoms. As a definite lower bound, such a day should be valued at the earnings foregone, which on average would be roughly $80 a day. The health production model developed by Cropper (1981) indicates that this figure should be doubled to include the value of preventive or averting expenditures, implying a value of $176 for the typical wage rate she uses in her illustrative example (in 1984 $). The rough rule of thumb that a severe WLD should be valued at twice the value of an average RAD supports this range. So the interim values of a severe WLD due to a likely combination of symptoms are $80 (low), $125 (medium), and $175 (high).

Mild Symptoms

To form interim values for a mild day of a likely combination of symptoms is also difficult. The only direct evidence is from the contingent valuation study by Loehman et al (1979). The value estimates should be relatively complete, but are of somewhat questionable reliability. For combinations of mild symptoms, the median values reported by Loehman et al range from $4 to $8. The mean values for these combinations range from about $40 to about $80. As mentioned above, it is felt that the medians are probably underestimates, but the means may be overestimates, so the medium value for a mild day of a likely combination of symptoms should fall in the middle of this range. Applying the rough rule of thumb that a mild day should be valued at about one-half an average RAD indicates this range is reasonable. So the interim values for a mild day of discomfort due to a likely combination of symptoms are $10 (low), $25 (medium), and $50 (high).

2.9.3.4. Aggravation of Previously Existing Chronic Morbidity

To move on from acute or short-term health effects, the second major class of health effects to be valued is the aggravation of previously existing chronic morbidity. Air

pollution may have its most significant impacts on those already with certain chronic conditions, so a change in air pollution could cause either a marginal change in time spent ill (e.g., one day), or possibly a non-marginal change (e.g., a week or more). However, due to fact that very little support has been found for a link between air pollution and a large change in time spent ill, and due to the limited information on the value of such time, interim values are only developed for an additional day of morbidity for those with previously existing chronic conditions. Two types of chronic conditions are considered: lung and heart.

Lung Conditions

Chronic lung conditions likely to be aggravated by air pollution include the very serious illness emphysema (or chronic obstructive pulmonary disease), and the less serious asthma/bronchitis. To value an additional day of symptoms due to these conditions, the evidence on the value of acute respiratory illness is clearly relevant. The per day values for the chronic lung conditions should be higher than the per day values for acute respiratory symptoms, for two reasons. First, a symptom day is likely to be more severe for a person with a chonic illness. Thus, only the values of an average RAD and the values of a severe WLD from the acute values are likely to relevant for valuing chronic illness. Second, economic theory suggests that the marginal utility of health should be diminishing, so the marginal disutility of sickness should be increasing. The implication is that an individual who already experiences many sick days should value a change at the margin higher than an individual who experiences few. Support for this relationship is found in Tolley et al.(1985) and other contingent valuation studies. So even the values for a severe day of symptoms for a healthy individual may be too low compared to how an individual with a chronic condition would value the same change.

The available evidence on the value of chronic morbidity is presented in Table 2-15, and will be referred to in the ensuing discussion.

Emphysema

For the value of an additional day of emphysema, there are several pieces of evidence. From the results of the Tolley et al. (1985) contingent valuation study, regressions were estimated that relate the bids (values for a day of relief) to various explanatory variables, including overall health status and the individual's experience with the symptom. Though these results are based on a sample of people with normal health, predicted values for a chronically ill individual can be calculated by evaluating the regression equation to correspond to someone with a chronic condition. Thus the dummy variables were set to indicate that the overall health status is low, and the experience with the symptom is set at 36 days, the average number

of RADs for an individual with emphysema, according to the Health Interview Survey. This exercise results in predicted values from $80 to $330 for single symptoms, and about $300 for a combination of symptoms. That the predicted value for the combination of symptoms is lower than the predicted value for relief from eye irritation is not expected, and is indicative of the degree of confidence that can be attached to these results. Nevertheless, they do give some indication of the value a chronically ill person might place on relief from an additional day of illness, and help to quantify the degree to which the values a day of acute illness understate the values of an additional day of emphysema.

Another piece of evidence on the value of an additional day of emphysem symptoms comes from the Freeman et al.(1975) cost of illness study. This study implies that an average case of emphysema involves $3194 of medical expenditures and foregone earnings, or an average of about $88 per restricted activity day due to emphysema. It is impossible to determine how this average cost of illness compares to marginal cost of illness, or what is actually relevant, willingness to pay for a marginal change in days spent ill. Assuming average and marginal cost of illness are similar, this average figure should be an underestimate of the willingness to pay, and applying the adjustment factor of two suggests that relief from a day of emphysema may be worth about $180.

The values for an additional day of emphysema available produce a rather wide range. On the low side, the value should be bounded by the value of an average or severe day of acute respiratory symptoms (medium interim values for these are $60 and $125, respectively). On the high side, the predicted values from Tolley et al. exceed $300. The interim values for the aggravation of emphysema (per day) are $50 (low), $100 (medium), and $300 (high).

Asthma/Bronchitis

To value an additional day of asthma/bronchitis, it is again possible to use the values of a day of acute respiratory illness. In this case, since asthma/bronchitis are less serious chronic conditions than emphysema in general, the values for acute illness may be more useful. For the same reason, however, it was not possible to use the Tolley et al. (1985) estimated bid function to predict values for a day of asthma/bronchitis symptoms different than the values for acute symptoms.

Direct evidence on the value of relief from asthma is available from the Rowe and Chestnut (1984) contingent valuation study. In this study, about 80 asthmatics were asked their maximum willingness to pay to have the number of "bad" days they actually experienced reduced by 50 percent. The average bid is $401, for an average reduction of about 19 days. On average, then, a bad day of asthma is valued at about $20. How this

average value compares to the willingness to pay to avoid a marginal change can not be determined. Based on the results for the value of a day of acute respiratory symptoms, this $20 amount seems low, perhaps because it is an average for 19 days rather than a bid by a person with chronic asthma/bronchitis for a day of relief at the margin.

The interim values for an additional day of asthma/bronchitis symptoms are set at $35 (low), $60 (medium), and $100 (high).

Heart Conditions

Some evidence suggests that air pollution may aggravate existing chronic heart conditions, perhaps causing an individual with heart disease to experience angina pectoris (chest pains). The main evidence on the value of this type of symptom is found in the Tolley et al.(1985) contingent valuation study on angina. In this experiment, individuals who on the whole had little experience with heart conditions were asked to value relief from additional days of angina, given that they already experienced (were endowed with) various numbers of days of the condition. For a day of mild angina, the means ranged from $66 to $99, depending upon the endowment. For a day of severe angina., the means ranged from $124 to $279. It is not clear if air pollution would cause mild or severe angina. It is also notclearwhatthe average experience of angina would be for the individuals affected by air pollution, so it is not possible to narrow the range of values much.

Potentially useful additional evidence is found in the Hartunian et al.(1981) cost of illness study. Their calculations suggest that an average case of uncomplicated angina pectoris involves about $600 of medical expenditures and foregone earnings. It is not possible to discover how many symptom days this average case involves, though, so this figure can not be directly compared to the per day values from Tolley, et al.

With relatively little evidence available, a fairly wide range of interim values for an additional day of angina are developed: $75 (low), $150 (medium), and $400 (high).

Likely Combination of Lung and Heart Conditions

Depending on the data linking air pollution to health, it may be known only that air pollution has aggravated chronic illness, without specifying which illnesses. Thus, values for the aggravation of a likely combination of chronic lung and heart conditions are also needed. To form these values, the basic inputs are the interim values for the separate conditions. These are combined with the judgement that the majority of chronic conditions aggravated will be asthma/bronchitis, with emphysema being the next most likely chronic condition affected, and only a small number of heart conditions relevant. Thus the interim

values for an additional day of a likely combination of symptoms due to chronic lung and heart conditions are $45 (low), $80 (medium) and $190 (high).

2.9.3.5. Increased Incidence of Non-fatal Chronic Morbidity

In addition to the aggravation of previously existing chronic conditions, it is possible that air pollution will cause new cases of chronic conditions. This is an explanation as to why air pollution is linked with higher mortality rates, and if air pollution is causing fatalities associated with chronic illness, it presumably accounts for an increased incidence of non-fatal chronic conditions. Of course, ex ante it is impossible to distinguish conditions that will eventually be fatal from those that will not, but it is useful analytically to first consider the value of the morbidity alone, and then consider the morbidity that precedes mortality. So this section focuses on valuing one year of a case of non-fatal chronic or serious illness. First respiratory conditions are discussed, and then heart conditions.

Lung Conditions

Emphysema

The main piece of evidence on the value of a case of emphysema is the estimate from Freeman et al. (1975) that on average a case involves $3194 of medical expenditures and foregone earnings a year. Using the adjustment that a complete willingness to pay measure is at least twice the cost of illness measure of medical expenditures and foregone earnings suggests that a a case of emphysema may be valued at around $6500 a year.

Evidence to corroborate the cost of illness value is slim. Since a case of emphysema will involve on average at least 30 days of restricted activity (see NCHS estimates), the values for 30 days of symptoms from the Tolley et al (1985) contingent valuation study may be relevant. This study found mean values of $166 to almost $500 for 30 days of a single symptom, and a mean value for 30 days of coughing, throat, and sinus symptoms combined is $625. That these values are considerably below even the pure cost of illness estimate for a case of emphysema probably stems from two factors. First, 30 days of symptoms were beyond the experience of most of the respondents in the Tolley et al. study, and a general result found in contingent valuation experiments is that the values for unfamiliar goods may be inaccurately reported. Second, the symptoms in the Tolley et al. experiment are probably much less serious symptoms than those experienced by an individual with emphysema, particularly one at an advanced stage of the disease. Not much weight can be attached to the Tolley et al. results, then, in forming a value of a case of emphysema. The same problems apply to the Loehman et al. (1979) contingent valuation results on the value of ninety

days of symptoms.

The interim values for one year of a case of emphysema thus mainly come from the cost of illness estimate, with the range developed considering what reasonable adjustment factors might be: $3200 (low), $7000 (medium), and $10,000 (high).

Asthma/Bronchitis

Direct evidence on the yearly value of a case of asthma/bronchitis is found in the Rowe and Chestnut (1984) contingent valuation study. As described above, the mean bid for a 50 percent reduction in the number of "bad" days a group of asthmatics actually experienced is about $400. As a very rough approximation, then, elimination of a case of asthma for a year could be valued at $800 or above, since elimination would involve a 100 percent reduction in the number of bad days as well as reducing the number of days the individuals suffered from less serious asthma symptoms. Clearly, this extrapolation can not be rigourously justified. In addition, the Rowe and Chestnut study may not be typical for asthma in general. In this study, the participants evidently suffered from fairly severe cases of asthma; for instance, the average number of bad days of asthma is 76. The NCHS estimates on the basis of the Health Interview Survey that asthma involves only 15 restricted activity days per conditon per year, and only 0.8 work-loss days per condition per year. So the estimate of $800 a year for a case of asthma based on the sample of individuals in the Rowe and Chestnut study may overstate the value of an average case of asthma.

Additional evidence on the value of a case of asthma/bronchitis is available from a comparison with the value of a day of acute illness. Since asthma/bronchitis are relatively less serious chronic conditions (compared to emphysem, for example), these values may be fairly appropriate. As above, the NCHS estimates that an average case of asthma involves 15 RADs, it also estimates that an average case of chronic bronchitis' involves 7.5 RADs. Using the medium interim value for a day of a likely combination of respiratory symptoms ($60), and multiplying by 7.5 to 15 yields a range of $450 to $900. This range may be low since a chronic illness is generally more severe and relief valued more highly than an acute illness. The results from the contingent valuation studies of Loehman et al. and Tolley et al. are also of interest. The median values reported by Loehman et al. for a week of symptoms are all well under $100 dollars, and even doubling these values to approximate the value of 15 days of symptoms yields at most a value of $114. Judging that these median values are too low, the mean values from this study can also be examined, yielding much higher values. The Tolley et al. study values 30 days of symptoms alone and in combination from $167 to over $800. This implies that 15 days (to correspond to asthma) might be valued at $80 to $400, or 7.5 days (to correspond to bronchitis) at $40 to $200. Again, since these values correspond to acute illness, they may in general be

too low.

Based on consideration of the above evidence, the interim yearly values for a case of asthma are $200 (low), $900 (medium), and $1200 (high).

Lung Cancer

In addition to increasing the incidence of chronic lung conditions such as emphysema and asthma/bronchitis, it is possible that air pollution may increase the incidence of lung cancer. Valuing the small percentage of these cases that will be non-fatal rests largely on cost of illness estimates. Hartunian et al. (1981) estimate that the first year of lung cancer involves almost $30,000 of medical expenditures and foregone earnings. From separate cost of illness studies (Hodgson and Kopstein (1984) and Paringer and Berk (1977)) an average case of any cancer implies costs of almost $10,000. Since lung cancer is more serious and thus more costly than an average of all cancers (including a large number of relatively non-serious neoplasms of the skin), the $30,000 seems quite reasonable. Doubling this estimate to $60,000 may approximate a complete willingness to pay avoid a case of lung cancer.

Additional evidence that relief from cancer is highly valued is found in Jones-Lee (1985). As shown in Table 2-16, given a choice of preventing 100 deaths from either cancer, heart disease, or motor vehicle accidents, most respondents preferred to prevent the cancer deaths, and were willing to pay correspondingly higher amounts to do so on the average. As Jones-Lee (p.68) concludes, the results suggest that people "would be willing to pay very substantial sums to avoid the protracted period of physical and psychological pain prior to cancer death." Similarly, the results seem to also imply that relief from the morbidity associated with even non-fatal cancer is valued highly. So doubling or even tripling the cost of illness estimate may be conservative.

The interim values for a case of non-fatal lung cancer are $30,000 (low), $60,000 (medium), and $100,000 (high).

Heart Conditions

The incidence of non-fatal chronic heart disease may also be related to air pollution. The least serious condition considered is "angina pectoris uncomplicated," defined as a case of angina that does not include more serious aspects of heart disease. On average, Hartunian et al. estimate that such a condition involves about $600 of medical expenditures and foregone earnings, which doubled implies a $1200 willingness to pay estimate of the complete value of angina.

Additional evidence comes from the Tolley et al. contingent valuation study. Mean values range from under $100 for relief from one day of mild angina, to over $800 for relief from 20 days of severe angina. The values also depend on the initial endowment the respondents were asked to imagine they experienced. For instance, the meanbidto relieve 10 mild days whentheywere endowed with 10 mild days is about $154. Since the respondents to this question are "buying" relief from their entire endowment, this value is in effect the value of a case of angina that involves 10 mild days. Similarly, this study also implies that a case of angina involving 10 severe days is worth $262; a case involving 20 mild days is worth almost $500; and a case involving 20 severe days is worth $844. Without knowing the number and severity of days a case of air pollution-induced angina involves, this range can not be narrowed. It should be noted that these contingent valuation estimates are complete measures of value, but they may be inaccurate since respondents were relatively unfamiliar with angina before the experiment.

The interim values for a case of angina pectoris uncomplicated are $500 (low), $800 (medium), and $2000 (high).

More serious heart disease, involving angina as well as other complications, may also be caused by air pollution. Again, evidence on the value of a case of such an illness comes from cost of illness and contingent valuation estimates. Acton (1975) estimates that a case of heart disease on average implies $2700 of medical expenditures and foregone earnings. Scitovsky and McCall (1976) estimate the medical expenditures alone for a myocardial infarction (a "heart attack") at over $11,000, but clearly this is one of the most serious outcomes of heart disease. Acton's estimate is judged to be more representative for the costs of an average condition. This incomplete value may be doubled to approximate a complete value measure at around $5500. Alternatively, Acton's estimate can be combined wtih the Tolley et al. results on the value of angina. Since angina will often be one aspect of a serious heart condition, the values reported above are again relevant, ranging from under $100 to over $800. These values mainly reflect the value of comfort, and are little influenced by the costs of illness. So it may be appropriate to simply add the estimates of the value of angina to the cost of illness value, suggesting a total value of over $3000 for an average case of heart disease. Prevention of more serious cases may have amuchhigher value.

Thus the estimates suggest a range of interim values of $2500 (low), $4000 (medium), and $10,000 (high).

Likely Combination of Lung and Heart Condtions

In case it is known that air pollution increases the incidence of chronic conditions, but the conditions involved can not be specified (possibly because of data limitations), interim

values for an increased incidence of a likely combination of chronic lung and heart conditions are useful. To develop this range, the interim values for the specific chronic conditions are combined with judgements as to which chronic conditions are most likely to result from air pollution. It seems that the likelihood of non-fatal conditions is probably inversely related to the seriousness of the condition: asthma/bronchitis being least serious and most likely to be caused by air pollution; emphysema being next most likely; heart disease is judged as relatively unlikely, with most conditions only involving angina pectoris uncomplicated; and finally non-fatal lung cancer is judged as being extremely unlikely. These judgements and the interim values developed above imply interim values for a likely combination of lung and heart conditions of $1700 (low), $3800 (medium), and $5900 (high).

2.9.3.6. Increased Mortality Risks

A good deal of evidence suggests that air pollution is associated with increased mortality rates. Valuing these risks involves two steps. First, the value of what might be termed "pure" mortality risks is estimated. This value corresponds to the value of an unforseen instant death often estimated in the "value of life" literature, with no significant morbidity preceding the death. However, air pollution at the levels found in the U.S. could not cause such instant death, but instead must influence mortality rates by increasing the incidence or aggravating the severity of chronic conditions. So the second step in valuing the increased mortality risks due to air pollution is to value different causes of death differently, to reflect the differences in the morbidity preceding mortality.

A large number of studies, based on revealed preference as discovered through the hedonic analysis of labor markets or analysis of consumption activities, and contingent valuation methods estimate the value of more or less pure mortality risks or the value of an unforseen instant death (in a statistical sense). These estimates are reviewed by Blomquist (1982), Violette and Chestnut (1983), and Jones-Lee (forthcoming). Updated to 1983 or 1984 prices, all reviews suggest a range from several hundred thousand dollars per statistical life, to estimates of over five million dollars per statistical life. Jones-Lee finds an overall mean of the revealed preference studies of $2.06 million, and an overall mean of the contingent valuation studies of $2.35 million. Support for a value of around $2 million also is found in the Gegax, et al study that incorporates both wage hedonic analyis and contingent valuation. So the interim values for an unforseen instant death are $0.5 million (low), $2 million (medium), and $5 million (high).

The low interim values for mortality from specific illnesses are developed using calculations similar to the "prevalence-based

approach" to estimating costs of illness. The calculations are based on the fact that every current death due to a condition is associated with a much larger prevalence of cases that eventually will be fatal. For instance, if the average life expectancy with a certain condition is 10 years, in a given year there will be one death and 10 person-years of morbidity preceding mortality. To develop the low interim value for such a death, the value of 10 person-years of morbidity is added to the low value for an unforseen instant death ($0.5 million). The yearly morbidity values used are the medium estimates developed for valuing non-fatal chronic conditions. These are conservative values for the value of morbidity preceding mortality, since eventually fatal conditions are obviously more serious and thus more costly than non-fatal conditions. In addition, no allowance ismade for the psychic costs of imminent death. With these caveats in mind, the low interim values are $0.64 million for emphysema, $0.53 million for asthma/bronchitis, $0.58 million for lung cancer, and $0.54 million for heart disease.

In developing the medium and high interim values, the procedure used to estimate the low values is considered as one input. However, a major attempt is made to more completely value the morbidity preceding mortality, Significant evidence are responses to a questionarre given by Jones-Lee et al (1985), reported in Table 2-16. One question related to the seriousness of different types of injury, from losing an eye to being confined to a wheelchair for life or being permanently bedridden. Since the study focused on motor vehicle safety, most of the injuries described are not relevant to the value of chronic lung and heart conditions. However, as these conditions get progressively worse (ending in death), they will generally involve prolonged periods of severe limitations of activity, possibly to the point of confinement to bed. This type of outcome is probably most likely with lung cancer and emphysema, and to a lesser extent heart disease. How people rate being confined to a wheelchair for life or being permanently bedridden in the Jones-Lee et al survey is therefore relevant to the morbidity preceding mortality associated with lung cancer, emphysema, and heart disease. Jones-Lee et al found that about one-half of the sample of about 1000 individuals felt that being confined to a wheelchair was as bad or worse than death. Over one-half felt that being permanently bed-ridden was as bad or worse than death, with almost one-third (30%) ranking it worse than death. If these outcomes are viewed as at least as bad as death, it seems reasonable that an individual would be willing to pay to change the risks of these outcomes approximately the same amount .he would be willing to pay to change mortality risks. This implies that the total value of a death from lung cancer of emphysema may be twice the value of an unforseen instant death. The value of a death from heart disease, possibly involving a smaller but still significant degree of restriction of activity, should also be valued a great deal higher than an instant death. A death from asthma/bronchitis may involve much less restricition of activity, so its value may be much lower than that of the other conditions.

TABLE 2-16

VALUES OF DIFFERENT KINDS OF MORTALITY

Comparing Causes of Mortality
(Source: Jones-Lee (1985)

Cause of Death	Prefer to have Reduced (%)	Mean WTP For reduction in (British pounds)*
Motor Accidents	11	7.35 million
Heart Disease	13	13.23 million
Cancer	76	23.12 million

*Value is a single payment to reduce the number of deaths from these causes by 100 next year. Value is not a value of statistical life.

TABLE 2-16
(Continued)

SERIOUSNESS OF DIFFERENT TYPES OF INJURY

(source: Jones-Lee (1985))

Type	Not as bad as death (%)	As bad as death	Worse than death
Lose an eye	92.1	5.0	2.8
Badly scarred for life, and in a hospital for a year	87.5	7.7	4.7
Confined to a wheelchair for the rest of your life	48.6	27.7	23.8
Permanently bedridden	36.7	33.4	30.0

More evidence from Jones-Lee et al is available on the relative values of deaths from cancer, heart disease, and unforseen instant death (specifically, death from motor vehicle accidents, which are assumed to be instant). As described above, when asked to choose between preventing 100 deaths from these causes, a large majority (76%) chose to prevent the deaths from cancer, indicating that relief from the morbidity associated with cancer is valued highly. The differences can be quantified to some extent by examining the amounts people were willing to pay to prevent the 100 deaths from the different causes. While the question is not worded so as to elicit the value of a statistical life, the amounts should indicate the relative values for the three causes. The means of the responses indicate that preventing 100 deaths from heart disease may be worth almost twice what preventing 100 instant deaths is. Preventing 100 cancer deaths is valued at about three times the value of 100 instant deaths. This is additional evidence that doubling or even tripling the value of an instant death may approximate the value of a death from cancer or heart disease.

The medium and high interim values for a death from emphysema, asthma/bronchitis, lung cancer, and heart disease are based on considering the value of a similar non-fatal condition, and the evidence from Jones-Lee et al suggesting how the value of an instant death may relate to the value of a deathprecededby a prolonged period of morbidity. The low interim values are prepared as described above, using a "prevalence-based" approach. The interim values are: a death from emphysema at $0.64 million (low), $3.5 million (medium), and $9 million (high); a death from asthma/bronchitis at $0.53 million, $2.5 million, and $5.5 million; a death from lung cancer at $0.58 million, $4 million, and $10 million; and a death from heart disease at $0.54 million, $3 million, and $7 million.

It is particularly important to have a value for an "average" death due to air pollution, since most studies linking air pollution and mortality rates do not specify the diseases responsible for the increased mortality. Thus we derive a value that is a weighted average of the value of all causes of death likely to be related to air pollution. In this case, the weights attached are directly related to the seriousness of the condition. Lung cancer is judged as causing the majority of the increase in mortality, with heart disease and emphysema also being signficant. A low weight is attached to asthma/bronchitis, since fatalities from these conditions seem unlikely, and no weight is placed on the value of an unforseeninstantdeath. The interim values for a weighted average of all causes of death are $0.58 million (low), $3.8 million (medium), and $9.4 million (high).

TABLE 2-17
INTERIM 'VALUES FOR MORBIDITY AND MORTALITY EFFECTS OF AIR POLLUTION

Category	Value Estimate Low	Medium	High
Acute or short-term morbidity			
average day (restricted activity day):			
--sinus	$20	$35	$60
--throat	10	25	40
--respiratory symptoms	15	30	50
--eye irritation	20	40	100
--headache	30	50	110
--likely combination	35	60	100
severe day (work loss day):			
--likely combination	80	125	175
mild day (discomfort):			
--likely combination	10	25	50
Aggravation of previously existing chronic morbidity (per day)			
lung conditions:			
--emphysema	50	100	300
--asthma/bronchitis	35	60	100
heart conditions:			
--angina, possibly with other heart disease	75	150	400
--likely combination of lung and heart	45	80	190

TABLE 2-17
INTERIM VALUES FOR MORBIDITY AND MORTALITY EFFECTS OF AIR POLLUTION
(continued)

Category	Value Estimate Low	Medium	High
Increased Incidence of Non-fatal Chronic Morbidity (per case per year)			
lung conditions:			
--emphysema	$3,200	$7,000	$10,000
--asthma/bronchitis	200	900	1,200
--lung cancer	30,000	60,000	100,000
heart conditions:			
--angina uncomplicated	500	800	2,000
--other heart disease	2,500	4,000	10,000
--likely combination of lung and heart	1,700	3,800	5,900
Mortality (per statistical life)			
--unforseen instant death	.5 mill.	2 mill.	5 mill.
--emphysema	.64 m	3.5 m	9 m
--asthma/bronchitis	.53 m	2.5 m	5.5 m
--lung cancer	.58 m	4 m	10 m
--heart disease	.54 m	3 m	7 m
--weighted average of all causes	.58 m	3.8 m	9.4 m

2.9.3.7. Using the Interim Values in Practice

To illustrate the usefulness of the interim values, this section calculates the benefits of a hypothetical program improving air quality in some certain area. To focus on the problem of valuation, suppose the health effects of the program are know (either from health econometrics estimates or dose-response relationships), and the question that remains is how the value the effects. A medium or best estimate of the value of the effects uses the medium interim values from Table 2-17 for the relevant categories. For acute or short-term illness, it is estimated that the program will reduce the number of restricted activity days experienced by the general population by 1000 person-days. Using the medium interim value for a likely combination of symptoms, each of these days is worth $60, so the total value of the change in acute illness is $60,000. The program will also improve the health of sensitive populations by reducing the extent to which air pollution aggravates existing chronic lung and heart conditions. Some of those with emphysema will experience fewer symptom days, for a total of 200 person days of relief. Each of these days is given a medium value of $100. For those with asthma/bronchitis, 300 person days of relief result from the program, and each of these days are valued at $60. Finally, those with existing heart conditions experience a total of 100 fewer days of angina, valued at $80 each. Thus the total value of the reduced aggravation of existing chronic conditions is: (200 x $100) + (300 x $60) + (100 x $80) = $46.000. In addition, the incidence of chronic lung conditions is reduced as a result of the program. In one year, with the program, there are 10 fewer new non-fatal cases of emphysema than there would have been without the program. Valuing each case at the medium value from Table 2-17 gives that this change is worth 10 times $7000, or $70,000. The program also results in a reduction of 20 non-fatal cases of asthma/bronchitis, valued at $900 each for a total of $18,000. Finally, in a given year the mortality due to lung cancer is reduced by two deaths, each valued at $4 million.

The value of the health effects from this hypothetical program can be summarized as follows. The reduction in acute morbidity that results from the program is valued at $60,000. The reduction in aggravated chronic morbidity is valued at $46,000. The reduction in the incidence of non-fatal chronic conditions is valued at $88,000. The two statistical lives saved are valued at a total of $8 million. So the total value of the program, using the medium interim values, is $8.134 million.

In a benefit cost analysis of the hypothetical program, then the health effects resulting imply benefits of over $8 million. Any other benefits should be added to this value, and then the costs can be compared to the benefits to see if the program is justified. To check the sensitivity of the decision to the health benefits estimate, alternative estimates of the health effects could be computed using the low and high interim values

from Table 2-17. In practice the health effects would not be known with certainty so a range of health effects possible could be given a range of values for the sensitivity analysis.

Though the above exercise is entirely hypothetical, it does illustrate the use of the interim values. In addition, it is interesting that the change in mortality risk dominates the total of the value of health effects, even though only two deaths were prevented. This is likely to be a fairly general result, because the value of mortality risks is so many orders of magnitude above the values of morbidity. This suggests that the emphasis that has been placed on linking air pollution to mortality may not be inappropriate, because of the importance of mortality, in both dollars amounts and in human terms.