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

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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

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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 crosssectional 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.

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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

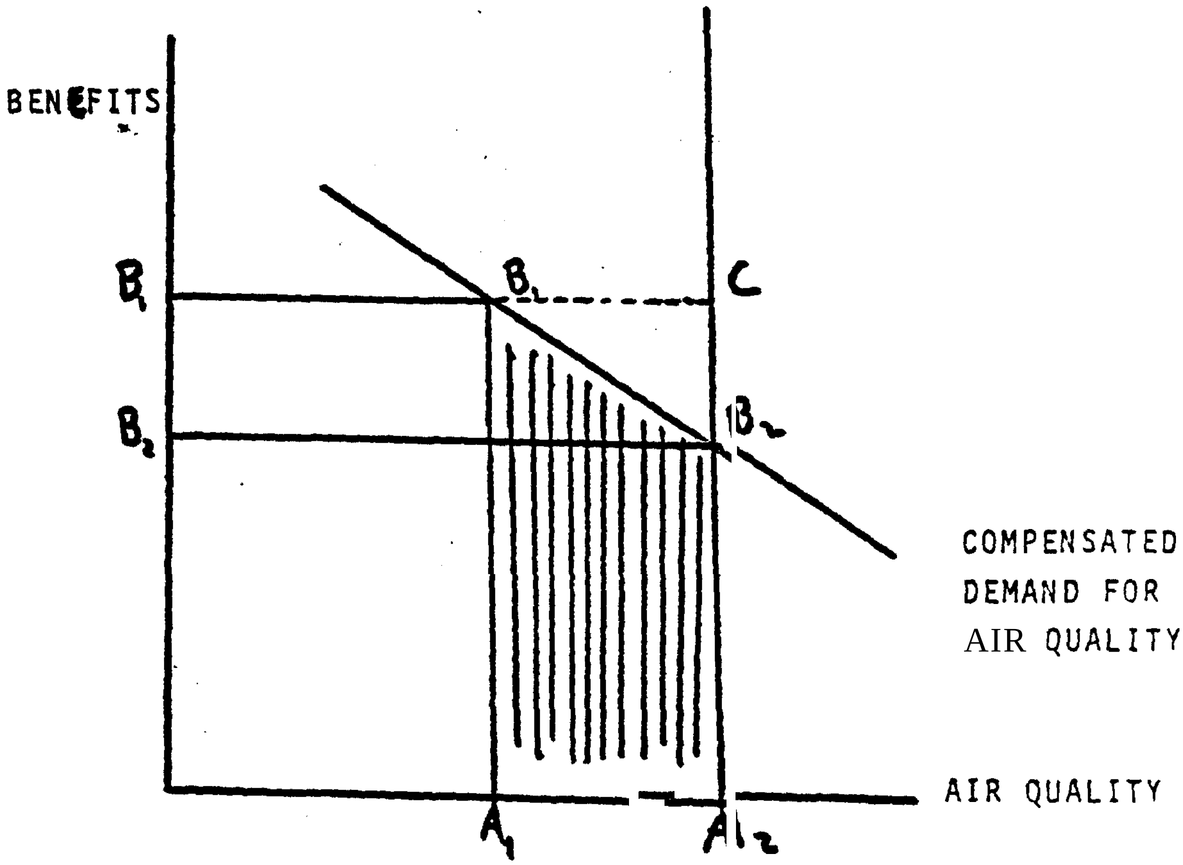

TABLE 2-11 ESTIMATES OF MARGINAL PRICES OF AIR POLLUTION
(Suspended Particulates)

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 Q_i form a set of compensated (inverse) demand functions, and the derivatives of Q_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.

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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	--individuals' health status is already low
--marginal and non-marginal changes in time spent ill	
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: discomfort	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	medi-cal	preven-tion
--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	medi-cal	preven-tion
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	medi-cal	preven-tion
--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	medi-cal	preven-tion
--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 <u>Illness</u>						
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.