METHODS DEVELOPMENT IN MEASURING BENEFITS OF ENVIRONMENTAL IMPROVEMENTS

Volume I

EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

ABSTRACT

Any society directing its efforts towards continual economic growth must learn to deal with the accompanying environmental Impacts. That is, if society values the preservation of its natural environment, a portion of the economic resources generated by growth trust be expended to create a balance between the inevitable pollution of the biosphere and the preservation of a pristine environment. Thus, policies to regulate sources of environmental degradation will bring about economic costs as well as environmental improvements. One method for assessing the merits of particular environmental policies is to compare these economic costs with the dollar benefits that they are expected to yield. However, obtaining the needed dollar benefit estimates is complicated by the 'public good aspects of environmental commodities. Since ccnmodities such as air quality are not traded in easily defined markets, this value can only be determined by indirect methods.

Volume II considers experimental or contingent valuation approaches to valuing air and water quality improvements. Particular attention is drawn to determining the benefits of improving visibility in the national parks, improving national water quality, reducing the risks of exposure to hazardous waste, and reducing ambient ozone concentrations in the South Coast Air Basin. Volume III updates earlier efforts to estimate the benefits of controlling acid deposition. Theoretical advances are presented in addition to a discussion of the role of nonconvexities in evaluating acid deposition impacts. Volume IV deals with methods of valuing the economic impacts of air pollution on ecosystems. A theoretical model is described for the imputation of economic damages and an empirical illustration is presented in which the contingent valuation method is used to value the condition of a forest stock.

Volumes V, VI, and VII address the questions related to air pollution impacts on human health. In Volume V, data on twins obtained from the National Academy of Sciences is employed to examine the effects of elevated levels of sulfur dioxide and total suspended particulates on symptoms including chest pain, cough, and shortness of breath. Volume VI, then, develops a new methodology for estimating the benefits of reduced human morbidity stemming from improved air pollution control and tests that methodology using data drawn from adult residents of St. Louis, Missouri. Volume VII presents a collection of three papers that assess the economic benefits of controlling pollutants, such as lead, that affect the health of children. Finally, Volume VIII contains a non-technical discussion of recent developments estimating benefits of environmental improvements. The work summarized in this volume, which was conducted by investigators at

Resources for the Future, the University of Wyoming, the University of New Mexico, and the University of Chicago, describes research sponsored by the USEPA through a sustained program over several years. The contents of each of these volumes now will be summarized in greater detail.

VOLUME II: EXPERIMENTAL APPROACHES FOR VALUING ENVIROMIENTAL COMMODITIES

Volume II discusses four separate experiments: (1) the National Parks Visibility Experiment (Chapter 2); (2) the National Water Quality Experiment (Chapter 3); (3) the Hazardous Waste Experiment (Chapter 4); and, (4) the Ozone Experiment (Chapter 5). The overall objective was to develop and assess the effectiveness of the contingent valuation method CVM as a technique for the valuation of benefits from different environmental. improvements. Four general issues were explored.

First, the issue of validating CVM as a method of benefit estimation was explored. The approaches taken have included.: (1) comparing CVM results to those obtained from alternative benefit estimation techniques (i.e., the hedonic method), (2) analyzing individual CVM responses obtained under iterative and payment card formats, and (3) utilizing alternative consumption sets. The second issue considered dealt with aggregation over: (1) attributes of a commodity, (2) different commodities, (3) geography, and (4) individuals. Third, a set of issues related to how individuals perceive the commodity to be valued was examined. Specifically, two classes of environmental commodities were reviewed, the first associated with very high risk and uncertainty (Chapter 4), and the second for which risk and uncertainty are not major factors in describing the commodity (Chapter 2). The fourth and final set of issues involves the extent to which CVM measures are truly expenditures for marginal changes in environmental condition. Additionally, the method of soliciting CVM responses is analyzed. That is, a comparison of mail (Chapter 5), door-to-door (Chapters 2, 3, 4), and pre-arranged interviews (Chapter 5) is made. Table 1 illustrates a brief overview of the contribution of each study experiment to these four issues.

In studying results from the different experiments, more questions were raised than answered. Attempts to validate the CVM by comparing it to the hedonic or property value technique revealed two confounding issues (Chapter 5). The first dealt with the appropriateness of assuming additive and separable utility functions over time with respect to an individual's preferences towards ambient levels of ozone pollution. The second related to a severe multicollinearity problem arising from high correlation between the "distance to beach" and "ozone" explanatory regression variables. In two of the experiments (the Parks Visibility and Hazardous Waste experiments) iterative bidding processes yielded contingent values significantly higher than initial starting bids. However, with respect to bids given when individuals must concurrently indicate which expenditure/savings item(s) would be reduced (to make the bid), it was found no statistical difference existed from individual bids made without budget constraints imposed. This result was obtained in all of the experiments except the one for ozone. The effects of altering the

TABLE 1

OVERVIEW OF THE CONTRIBUTION OF STUDY EXPERIMENTS TO STUDY PURPOSES

Experiment	Validation Issues	Aggregation Issues	Perceptions of CV Commodities	Other Experimental Issues
The National Parks Visibility Experiment	x	x	x	
National Water Quality Experiment	x	x		
The Hazardous Waste Experiment	x	x	x	x
Ozone Experiment	x		x	x

consumption set of a primary commodity by adding substitute environmental and private market commodities had the effect of lowering average bids for the primary commodity (Chapters 2, 4).

In regards to the aggregation problem, hypothesis tests were conducted to determine the distinctiveness of the primary (and assumed disaggregated) commodity in question. In the National Parks Visibility Experiment, individual valuations of visibility at the Grand Canyon (the specific commodity) was not affected by valuations for five other regional parks or all other national parks. However, when summing the visibility bids for the five other regional parks, this aggregate value is greater than the corresponding bids for improving national air quality. A similar result was discovered between bids for national water quality relative to national water and air quality improvements. The null hypothesis that air and water quality are disaggregated commodities is rejected. In testing the geographical aggregation issue, the null hypothesis of equal bids for the hazardous waste commodity in each of these regions was not rejected.

In regard to the remaining issues, results from the Hazardous Waste Experiment showed the CVM produced bids for marginal environmental changes. Further, the null hypothesis of equal bids between different solicitation modes (mail, door-to-door, and pre-arranged interviews) was not rejected. Such a result is encouraging in light of the considerable cost differences between modes.

Finally, the four experiments just summarized leave three questions unanswered. First, additional research is warranted on the definition, delineation and understanding of the aggregate commodity (or mental account) issue relevant to a particular environmental improvement. Secondly, additional experiments are required to test the means by which values attributed to the aggregate commodity can be allocated to its disaggregated attributes. A third important problem involves the role of individual perceptions in formulating bids for environmental improvements in a CVM framework.

VOLUME III: AN UPDATING OF EARLIER EFFORTS TO ESTIMATE THE NATIONAL BENEFITS OF CONTROLLING ACID PRECIPITATION

Volume III contains two sections concerned with updating earlier efforts to estimate the national benefits of controlling acid deposition. The first section presents a formal theoretical structure appropriate for assessing the economic benefits of reduced damages caused by acid deposition. Emphasis is placed on the importance of capturing producer and consumer adaptations, existence values, and price effects. Additionally, a discussion of the information economists require from natural scientists and engineers as well as prospects for empirically implementing the theoretical structure is included. The second section is motivated by Daniel Violette's (1984) critiques of a paper by Crocker and Forster (19@1) which deals with nonconvexities in acid deposition impacts.

More specifically, it discusses certain features of Violettes empirical examples and his economic damage functions for biological/physical impacts commonly associated with acid deposition and its precursors. Also demonstrated is Violette's failure to show that nonconvexities in acid deposition impacts are not a significant problem for economic analysis. Moreover, in situations where nonconvexities are relevant to consider, a greater understanding of the physical/biological system is required to support benefit-cost analyses. The contents of each of these two sections is described more fully below.

Research on materials damage caused by air pollution generally focuses on isolated production inputs, such as physical structures. Hence, the conventional procedure to materials damage estimates is to multiply the reduction in that inputs' stock by its prevailing market price. This simple procedure, however, can produce misleading estimates of economic losses since possible input substitutions and input and output price changes are ignored. Consequently, a better theoretical procedure for estimating economic losses from materials damage would be to examine the changes in consumer surpluses and producer quasi-rents over varying levels of pollution.

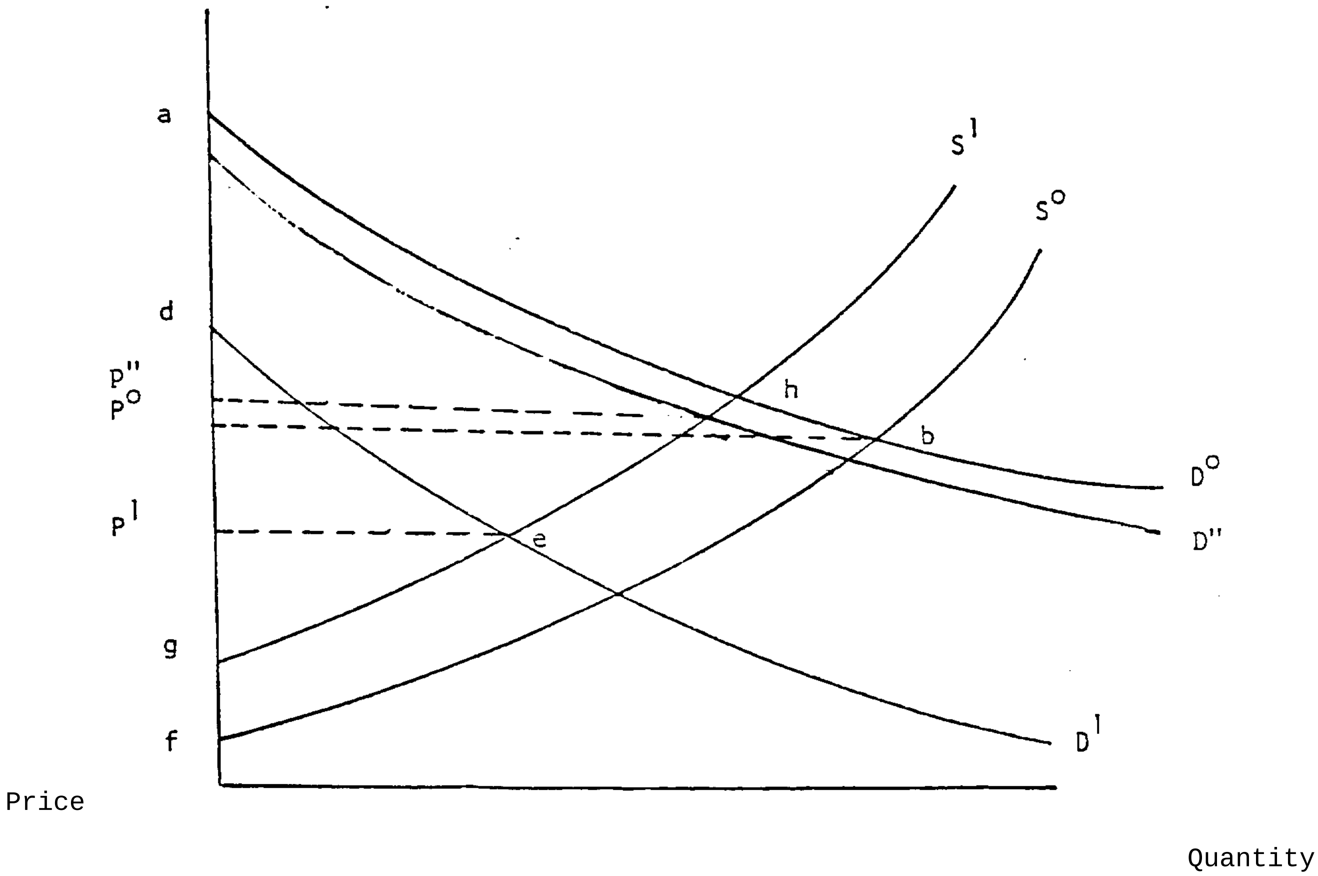
Figure 1 depicts one example of the changes an air pollution increase can have upon consumer's surplus and producer's quasi-rent. The air pollution increase reduces the desirable physical properties of the output, diminishing the consumer's willingness to pay and causing his demand function to shift from Do to D'. Simultaneously, the air pollution increase damages one or more materials in the production process for the output, bringing about increased production costs and an upward shift in the supply function from SO to S'. Market price for the output drops from PO to P’, partly due to the greater relative magnitude of the shift in the demand function, and partly to the lesser relative slopes of the demand functions. Consumer surplus was the area aP 0 b; it is now the area dP'e. Producer quasi-rent was the area fP 0 b; it is now the area gP'e. Total social surplus from the production and use of the output in question is thus reduced by the area fgbh plus the area adeh.

Of course, differing relative shifts in demand and supply relations reflecting different relative pollution induced impacts in the production and consumption sectors, will yield results of a modified character. For example, if the demand curve shifts to D" rather than D', market price will rise to P". Qualitative results are unchanged, however, alterations in producer quasi-rents and consumer surplus are obtained from the pollution-caused changes in the two sectors. These two examples serve to illustrate the issues of concern here: consumers and producers can bear very different economic gains or losses depending on the absolute price elasticities of the demand and supply functions. Moreover, the distribution of these economic consequences can differ drastically with the price elasticity of the demand function relative to the supply function.

In order to better appreciate the subtleties lying behind these observations which describe the social costs and benefits from

Figure 1

Changes in Producer's Quasi-Rent and Consumer's Surplus



pollution-induced materials damages, formal analyses are made by considering pollution-related costs on the production, household, and public goods sectors. Specifically, a producer's constrained profit maximization problem is analyzed to examine the least cost method of altering the operation, maintenance, and replacement processes in the overall production activity as the level of pollution induced materials damage changes.

Additionally, standard utility theory is employed to generate the household's constrained utility maximization problem. The analysis assumes certain goods provide a flow of services through time and are subject to depreciation from normal wear, as well as from pollution-related materials damages. Demand functions, as in Figure 1, are analytically derived to address the issue of impacts from pollution changes in the household sector.

These implied demand, or average revenue, relationships are implicitly used in the analysis mentioned above. That is, they are used to derive the marginal revenue expressions, which when combined with the relevant marginal cost functions, the loss in benefits--social costs--attributable to pollution-caused materials damage from higher pollution levels can be determined.

Finally, a simplified analytical model to illustrate damages to the class of public goods is developed. The modeled representative citizen obtains utility from three classes of goods: (1) purchased goods, (2) a stock of historical structures which are valued even if the sites are not visited (existence value), and (3) a stock of goods accruing value from use, including historical structures. Again, demand relationships are defined for the stock historical structures. However, these relationships lack interpretive neatness because of the absence of market prices for the structures. Consequently, even though a conceptual measure for pollution damages to public goods is defined, the issue of how to obtain the measure remains open.

Regarding empirical implementation, discussion focuses on estimating social costs of pollution-related materials damages to public goods as well as in the private household and production sectors. The most tractable method for estimating social costs of pollution damage in the production sector is the direct costs method (i.e., costs of pollution-related incidence, of premature maintenance and/or replacement costs). A similar method is prescribed for the social cost of pollution damages on the household sector. Finally, survey methods are recommended as a means of estimating both the consumption and existence values relative to the social costs of pollution in the public sector.

Recommendations from this section focus mainly on aggregate approaches to estimating materials damages. In short, the offered conclusion is that the acquisition of information on the covariation of pollution and maintenance/replacement policies, defined in terms of their economic categorization rather than physical manifestations, is necessary before performing economically meaningful studies on Pollution-induced materials.

As noted previously, the second section of Volume III is concerned with updating theoretical discussions related to nonconvexities in acid deposition control policies. Contrary to previous work by Violette (1984), it is argued that nonconvexities at the aggregate level are not always a disappearing phenomenon. Moreover, the fact they could be important even in the aggregate establishes their importance, particularly with respect to the acid deposition problem.

Therefore, circumstances in which the nonconvexities of the function relating biological damages to the acidity of aquatic ecosystems (caused by the shape and nature of the biological/physical dose-response function) could be policy relevant, and greater understanding of the biological/physical system and its economic counterparts will be required to improve the accuracy of benefit-cost analyses.

VOLUME IV: VALUING ECOSYSTEM FUNCTIONS: THE EFFECTS OF AIR POLLUTION

Volume IV presents three papers dealing primarily. with the theoretical implications of employing economic assessment techniques to value impacts of air pollution on existing ecosystems. First, a general equilibrium model is described for the imputation of economic damages to ecospecies. Secondly, a specific example applying the contingent valuation method to value the condition of a forest stock is related. Finally, a methodology with illustrations is covered in the concluding section that deals with the value of yield response information functions used by economists to compute pollution impact damages on managed ecosystems.

A. Integrating Ecosystems and Economics

Economic development, as usually envisioned, is often accompanied by dwindling natural environments. In the United States, and worldwide, lost habitat and species extinction are familiar by-products of this development. Yet, the cost of these losses are never adequately weighed against the benefits of development. What is labeled "economic development" may be, in some cases, economic abatement. In order to measure the costs of development, the ability to quantify the value of the species that comprise ecosystems is necessary.

This need is addressed by modelling an ecosystem using techniques familiar to economists. Each ecospecies encountered is assumed to behave as if to maximize stored energy (which is the difference between energy inputs and outputs). Species are then linked together in food chains, with the entire ecosystem operating in a fashion similar to a perfectly competitive economy. Concepts of equilibrium stability have clear interpretations. The ecosystem is self-sustaining in that human intervention is unnecessary for its existence.

Next, the ecosystem is placed within a general equilibrium framework. Humans intervene in the ecosystem through farming, hunting, fishing, polluting, and so on. Each human intervention represents an exogenous shock to the ecosystem; and in turn, the ecosystem seeks a new equilibrium with a greater or lesser abundance of various species. The changes in abundance may or may not be predictable, depending on the information the intervenors possess concerning the interaction of species. Situations that result in unexpected ecosystem changes are termed "ecosystem externalities." Finally, a demonstration of value derivation is made. The model allows any species, including those that are neither culled nor an argument in the social welfare function, to be valued. The value derives from the linkages among all species.

B. On The Value of the Condition of a Forest Stock

A specific example integrating economics and ecosystems is illustrated in section two of Volume IV, in which economic analysis is applied to the valuation of the condition of a forest stock. Basic tenets of economic theory are examined in relation to individual preferences -For the aesthetic features of the forest, valued as an environmental asset. Specific to the test is the notion of transitive preferences and the symmetry of the Slutsky matrix.

Several techniques have been employed in the past to assess preferences for a large set of nonmarket environmental commodities. One basic premise from which these different methods (e.g., the travel cost, hedonic, and contingent valuation) proceed is that individual preferences are transitive. Appropriateness of the transitivity axiom, which these techniques invoke without exception, has never been scrutinized; in fact, the axiom is necessary for the uniqueness of preferences. If preferences are transitive (i.e., Slutsky matrix is symmetric), observations on usage of the good across price and income settings can be utilized to generate demand functions from which unique inferences concerning underlying preferences can be drawn.

In this section of Volume IV, findings in experimental economics and psychology are applied to construct a contingent valuation questionnaire. The survey is employed to gather economic data on environmental damages due to air pollution in a national forest; however, with result which cast doubt on the validity of the axiom. Specifically, the survey conducted in southern California where the problems resulting from air pollution are well recognized by local residents, elicited as truthful responses as possible.

Each respondent was told that air pollution was the source of perceived differences in the health status of described forest environments in the region. Nearly all respondents were engaged in outdoor recreation in the forest at the time of the interview. Each was asked to state his maximum WTP in terms of an additional fee to a daily $6.00-$7.00 access fee already paid on the interview day. Some of the features of the data obtained from interviewing 36 respondents during a June, 1983 weekday and 64 on a July, 1983 weekend are reviewed in the tables below. Interviews were conducted at the same forest location.

Tables 2 and 3 report the mean and median bid (WTP), representing the additional access fees, for three depicted environments. Environment A represents a "very slight injury" to the forest from acid deposition. Environment B represents a "very severe injury" to the forest's condition, Environment C a "moderate injury" to the condition of the forest stock. Note that the willingness to pay for the A environment in each sample was more than twice the willingness to pay for either the C or B environments. Table 4 reports the frequency count of respondent's rank-orderings across the three environments.

Environment A, which has the "very slight injury," obviously rules the preference structure. Yet, the nearly equivalent frequencies of A > B > C and A > C > B, along with ten respondents who expressed A > (BC), imply the individuals were unable to express a clear preference when asked to choose between B and C. This same preference pattern emerges in the previous Tables 2 and 3, when individuals elicit their cardinal evaluations. No respondent exhibited differences between the rank assigned to environment A in the rank-ordering and the cardinal ordering of their bids. However, twelve respondents who indicated B > A, or C > B, stated identical positive bids for C and B.

To explain the source of the patterns displayed in the WTP bids of Tables 2 and 3, the underlying preference structure was analyzed for the three environments. Reduction in oxidant-induced damages was found to have not decreasing, but increasing marginal benefits. Underlying physical and biological relations or adjustments in some endogenous variables (e.g., frequency of visits) could be the source of the nonconvexities. Due to the linearity of the biological damage index, this result is expected from a nonconvex preference ordering, arising either from the inappropriateness of the transitivity or the multidimensional character of the depicted forest environment as sources of the observed increasing marginal benefit function.

In particular, a multiplicative interdependence may be present in utility terms between healthy pine trees and other elements (bushes, terrain, etc.) present in the forest environment. The minimum value of a combination of healthy pine trees and these other elements may be much greater than the sum of their values when treated separately; that is, the health of the pine trees must necessarily be some minimal scale in order for the other elements to be valued. If so, the values obtained here, and perhaps in other contingent valuation studies as well, are relevant only to the entire environmental situation. One could not then repackage particular elements in order to extrapolate their values to other settings.

C. Accurate Yield Response Information and Economic Assessments

Ambient levels of ozone pollution create a pervasive negative effect on not only economically valued environmental commodities, but also on other commodities such as agricultural yields. Hence, national control

TABLE 2

WILLINGNESS-TO-PAY (Weekday Sample, n=36)

	A	B	C
Injury score midpoint	4.5	18	32
Arithmetic mean bid	$2.54	$1.07	$0.69
(Standard Error)	(.604)	(.337)	(.202)
Median bid	$1.00	--	--

TABLE 3

WILLINGNESS-TO-PAY (Weekend Sample, n=64)

	A	B	C
Injury score midpoint	4.5	18	32
Arithmetic mean bid	$1.84	$0.55	$0.65
(Standard Error)	(.257)	(.102)	(.102)
Median bid	$1.00	--	--

TABLE 4

RANK-ORDERING OF ENVIRONMENTS

Rank-Ordering	Incidence	
	Weekday	Weekend
A > B > C	12	20
A > C > B	12	22
A > (BC)	4	6
(ABC)	5	13
B > C > A	2	1
C > A > B	1	--
C > B > A	--	1
B > (AC)	--	1

NOTE:

(BC) is indifference between B and C.
(ABC) is indifference among A, B and C.
(AC) is indifference betwee A and C.

Policies altering the allowable ambient pollution level will most likely translate into improvements in agricultural yields. However, the benefits realized from control-induced improvements are unclear due to a relatively high level of uncertainty surrounding yields (dose-response effects) responding to different levels of control.

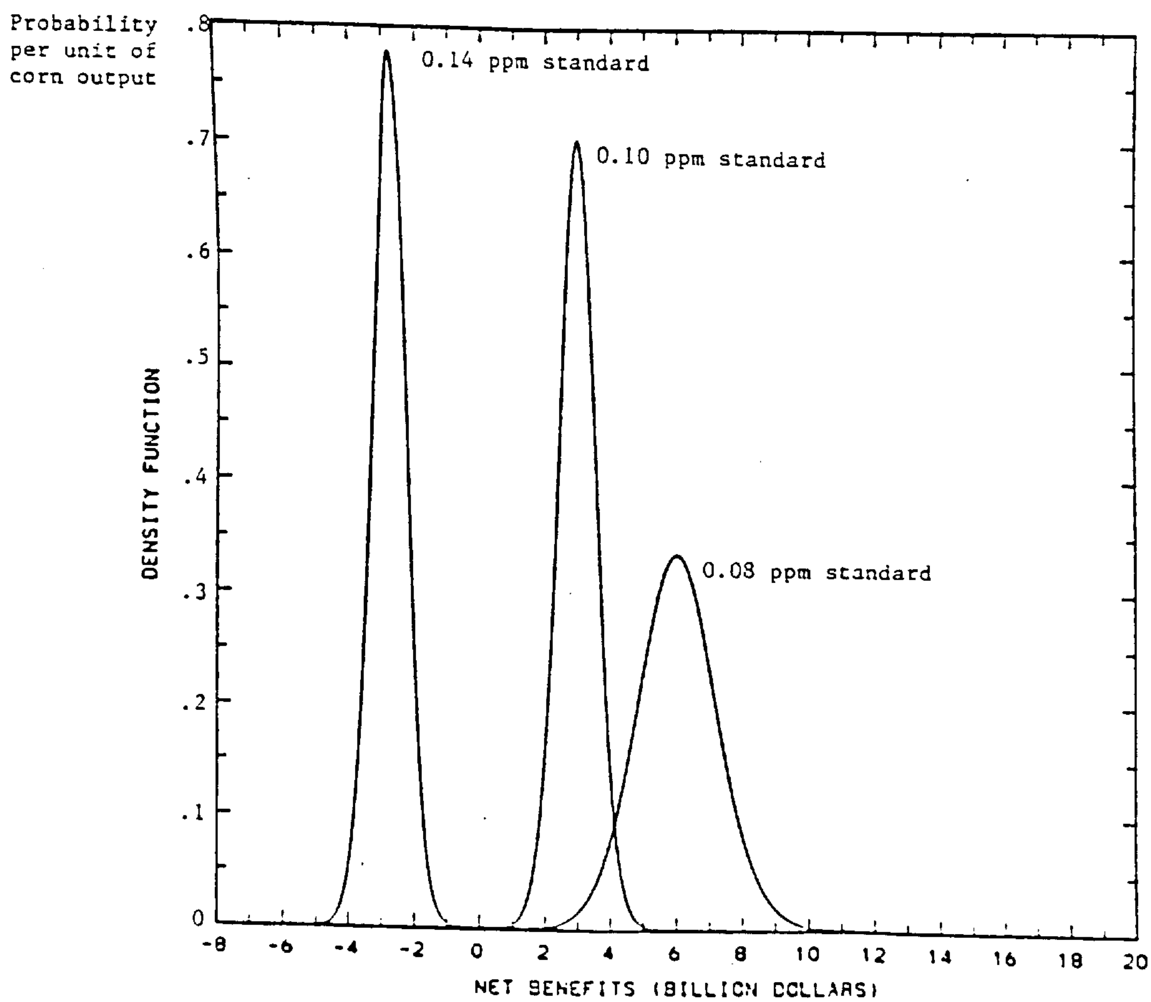
This report attempts to provide a methodological approach for predicting the extent to which improved yield response information will affect net benefit estimation, thereby influencing policy choices. A Bayesian approach is taken to address statistical uncertainty in the precision of biological estimates of yield responses. The basic question asked is then what are the economic consequences of varying control policies on benefits given varying degrees of statistical imprecision of yield response estimates.

Actual measures are derived to demonstrate the value of more precise dose-response information for benefit cost analysis. The worth of this information is described in terms of the different estimates of benefits that result; given varying levels of precision in the information available. Biological dose response information was generated from the United States' Environmental Protection Agency's National Crop Loss Assessment Network (NCLAN). An empirical example is provided which considers estimates of the economic value of controlling ozone impacts in the U.S. for four specific crops: corn, cotton, soybeans, wheat.

As shown in this empirical example, when a particular ozone standard is to be enforced, it is desirable to know the entire probability distribution of the economic surplus. Thus, rather than assume the estimated yield response parameters are the "true" ones, any statistical uncertainty can be explicitly included in the estimated model to obtain insight as to what may be gained by additional observations. That is, additional observations on yield responses of the selected crops to ozone levels will provide reductions in the variance of the yield response parameter, ultimately causing it to converge to some stable yet unknown magnitude.

Figure 2 illustrates the uncertainties in economic surpluses caused by the estimated parameters of the yield responses for the case of corn. (The report also considers three additional crops; cotton, soybeans, and wheat.) This figure depicts the density function of the difference in economic surplus between the current ambient standard of 0.12 ppm and alternative standards (reading from left to right in each figure) of 0.14 ppm, 0.10 ppm, and 0.08 ppm. The scales on the vertical axes are probabilities per unit of output. The mass of the surplus estimates in the immediate area of the mean is very great for each crop-ambient ozone combination. Only the distributions for the 0.08 ppm standard found on the far right of each figure exhibits much variability. Secondly, there is no overlap between distributions, with the exception of the 0.10 and 0.08 ppm surplus distributions for corn and wheat. This lack of overlap implies that the tradeoff between Type I and II statistical error need not be considered in discriminating between these alternative ambient ozone standards. Similar results are obtained for the three other crops

Figure 2: Distribution of Net Benefits, Corn



considered. In summary, the value of more precise yield response information is ultimately dependent upon the extent to which the variability of economic surplus estimates affect the probabilities of either overestimating ultimately realized economic surplus and thereby failing to plan for a more lax ambient standard, or underestimating the realized surplus and thereby failing to plan for a stricter ambient standard.

VOLUME V: AIR POLLUTION AND DISEASE: AN EVALUATION OF THE NAS TWINS

Human disease is caused by a multitude of events including aging, genetic background, and the environment in which the individual resides. Air pollution is but one of the many factors potentially influencing morbidity and mortality rates of the population. In Volume V, the central questions which arises in this volume is whether or not the net effect of air pollution can be assessed and measured such that a scientifically defensible estimate can be made of the change in health resulting from a change in ambient outdoor concentration of air pollutants.

In recent years, a number of studies have been undertaken to estimate this net effect. Lave and Seskin (1977) conclude that air pollution, when other factors are taken into account, contributes substantially to increased mortality across cities in the U.S. More recently, Graves and Krumm (1982) have demonstrated a nonlinear association between hospital admission rates and concentrations of carbon monoxide and sulfur oxides. Also, Ostro (1982) has demonstrated a relationship, between work loss days and particulate concentrations.

In this study, an attempt is made to evaluate the impact of higher ambient concentrations of air pollutants on certain symptoms and reported diseases of a sample of approximately 14,000 twins who served in the Armed Forces during World War II. More specifically, this study attempts to determine the extent to which exposure to higher concentrations of air pollutants leads to a higher level of reported symptoms and incidence of certain diseases. However, problems arise from several sources while using this approach. For example, a symptom such as cough or shortness of breath can be related to the presence of many conditions including asthma, emphysema, chronic bronchitis, or ischemic heart disease. Secondly, the presence of a disease may not be detected because of a lack of one or more symptoms, or not seeking treatment. In addition, symptoms may be related to the presence of more than one type of disease. Therefore, identifying the role of air pollution in producing symptoms is not a trivial undertaking.

Results from examining data on twins obtained from the National Academy of Sciences indicated that sulphur dioxide contributes to the incidence of chest pain and levels of total suspended particulates contribute to severe chest pain, coronary heart attack, cough, and shortness of breath. Statistical measures used in this analysis were probit analysis and ordinary least squares. Total estimates of the savings in health care costs due to a 30 percent reduction in ambient

TABLE 5

TOTAL COST SAVINGS, BY SYMPTOM, FOR A 30 PERCENT IMPROVEMENT IN U.S. AIR QUALITY IN 1981 DOLLARS[a]

Symptom	Total for males between 55-64 years of age	Total U.S. Population[b]
Cough	$1,546,000	$34,416,000
Shortness of Breath	1,218,000	27,110,000
Chest Pain[c]	1,050,000	23,357,000
Severe Chest Pain	210,000	4,665,000
Cardiac Failure	344,000	7,658,000
TOTAL	$4,368,000	$97,206,000

[a]mean values for SO_2 and TSP were used as initial values.

[b]1980 census of population data.

[c]SO_2 is the air pollution variable used here and TSP is used for all other symptoms

concentrations of TSP and SO2 are derived and found to have substantial magnitudes. The actual figures are shown in Table 5. Total cost savings are presented, by symptom, for males between the ages of 55 and 64 and the total population in the United States. Male members of the U.S. population between 55 and 64 years of age most closely represent the twins sample as characterized by 1980 census data. Summation over the five symptoms yields an overall measure of the health benefits of air quality improvement. Note that for the age group nearest to the twins sample, total cost savings from disease is over $4 million. If these results are extrapolated to the entire U.S. population, a savings of nearly $100 million is obtained.

VOLUME VI: AN ECONOMIC ANALYSIS OF AIR POLLUTION AND HEALTH: THE CASE OF ST. LOUIS

Volume VI develops a new methodology for estimating the economic benefits of reduced human morbidity stemming from improved air pollution control. The main goal is to formulate and empirically test a theoretical health model which builds upon the earlier efforts of Grossman (1972), Cropper (1981), Rosenzwieg and Schultz (1982a, 1982b), and Harrington and Portney (1983). The model is empirically tested using survey data on adult workers drawn from households in St. Louis, MO and air pollution data obtained from the Regional Air Pollution Study (RAPS). The empirical results support the hypothesis that reduced ambient ozone levels will reduce human morbidity. On this basis, marginal compensating variation type benefit estimates for various percentage reductions in ozone concentrations are computed based on these empirical results.

In the model applied, individuals derive satisfaction (utility) from the consumption of two classes of goods: their own stock of health capital, H; and X, goods which yield direct utility but do not affect health. The health stock, H, is treated as an endogenous variable determined by a production relationship in which M, medical care, and a, a set of exogenous variables (e.g., air quality) affect the efficiency of the individual to produce H. Utility is then maximized subject to this household production function, as well as income and time constraints.

The comparative static properties of the model shed light on the appropriate method for estimating the WTP for better air quality. The entire equation set describing the model is utilized to generate the expression:

$$\frac{dB}{da} = \frac{H_a q_M}{H_M} > 0$$

where: B = the WTP, or bid for improved air quality.

H_a = the change in the health stock given changes in air quality; $H_a > 0$.

H_M = the change in the health stock given changes in medical care; $H_M > 0$.

and q_M = the "full" price, including pecuniary prices of the medical care commodity and time required to consume one unit of the commodity times the wage.

This expression suggests the individual would be willing to pay more for air quality improvements the greater the associated improvement in health (Ha). Also, that bid would be higher, the lower the productivity of medical services and the higher their cost. As a consequence, if medical services are an expensive and ineffective means of producing good health, then quite naturally the individual would be willing to pay more for air quality improvements. In that situation, air quality improvements simply became a more attractive mechanism through which to augment the health stock. This WTP expression does not include any utility terms indicating that empirical estimation is relatively straight forward. Such estimates are reported in the final chapter of the report.

The empirical results can be summarized by noting that two approaches are available to estimate the marginal WTP. In the first approach, separate estimates of H a and H M are generated from the health production function, whereas in the second, an estimate of the ratio of these two terms, H a /H M, is obtained. The second approach is adopted in this study. A simultaneous equation logit model was developed to estimate the entire model due to the discrete nature of the dependent variable (medical care) and because H was also included as a covariate in the objective function.

Table 6 enumerates the variables, with definitions, used to estimate the willingness to pay for improved air quality. The table also provides the arithmetic mean of each variable in each of the two samples. The marginal effects at the mean of each independent variable are reported in Tables 7 and 8. In parenthesis are the X2 statistics (distributed with one degree of freedom) for each variable. Table 7 provides estimates of the health production function based on the 820 cases for which wage data was available. Note the OZONEM air pollution variable is significant at either the 5 or 10 percent level in all six equations.

Table 8 parallels these results for the 2197 observation sample in which the missing observations on the wage were replaced with the mean of that variable. The air pollution variable OZONEM performs better than in the 820 observation sample; i.e., it always is significant at the 1 percent level. Since the ozone variables, including interaction measures between ozone and other pollutants, were the only air quality measures to perform significantly, the willingness to pay measures reported in Table 9 pertain only to that pollutant. As shown there, these WTP estimates, interpreted as annual per employed person benefit to St. Louis residents, were between $2.42 and $2.69 for a 10 percent reduction in mean ozone levels, and between $7.27 and $8.08 for a 30 percent reduction in mean ozone levels.

TABLE 6

VARIABLE DEFINITIONS

VARIABLE	DEFINITION	SAMPLE SIZE 820 MEAN	SAMPLE SIZE 2197 MEAN
MED	1: Denotes respondent sees a doctor at least once annually	.747	.755
PMED	Price of medical care	40.744	45.38
HWAGE	Hourly wage	5.078	5.078
RACE	1: Indicates person is black	.277	.241
AGE	Age in years	39.28	40.33
EDUC	Years of schooling completed	12.65	12.79
SEX	1: Indicates respondents is male	.539	.583
OZONEM	Mean ozone level (ppm)	.019	.019
SULDIOM	Mean sulfur dioxide level (ppm)	.024	.024
TSPSMLM	Total suspended particulates, small size, mean levels, (micrograms/m^3)	22.81	23.77
LEADSMLM	Lead, small size, mean (micrograms/m^3)	706.084	705.42
OZSULM	OZONEM x SULDIOM	<.000	<.000
OZNITM	OZONEM x OXNITM	<.000	<.001
CHRO	1: Denotes respondent reports presence of a chronic illness	.105	.108
LENGTH	Number of years respondent has had chronic illness	1.374	1.327

TABLE 7

ESTIMATES OF THE HEALTH PRODUCTION FUNCTION
(DERIVATIVES EVALUATED AT THE MEAN)
820 CASES

	1	2	3	4	5	6
CONSTANT	-.064 (.046)	-.307 (.269)	-.040 (.018)	-.010 (.001)	-.290 (.231)	.226 (.392)
OZONEM	30.52** (5.04)	33.14** (5.15)	31.25** (5.40)	29.74** (4.86)	33.06** (4.86)	25.72* (3.31)
SULDIOM		-.416 (.055)	.390 (.042)			
TSPSMLM		-.009 (.322)			.008 (.266)	
LEADSMLM						-.0003 (2.07)
OZSULM					-8.82 (.009)	95.94 (.785)
OZNITM			91.90 (.424)	78.12 (.370)		
AGE	-.003 (1.34)	-.003 (1.66)	-.004 (1.96)	-.003 (1.56)	-.003 (1.61)	-.003 (1.16)
EDUC	-.012 (1.29)	-.011 (1.37)	-.009 (.949)	-.010 (.975)	-.012 (1.50)	-.013 (1.84)
SEX	-.198*** (29.62)	-.200*** (30.46)	-.202*** (30.73)	-.I99*** (29.84)	-.1999*** (30.29)	-.196*** (29.14)
RACE	.064 (2.12)	.065 (2.19)	.079* (3.01)	.077* (3.00)	.065 (2.60)	.069 (2.44)
CHRO	-.100 (.008)	-.036 (.001)	.203 (.036)	.044 (.002)	-.078 (.006)	-.248 (.055)
LENGTH	.049 (1.11)	.050 (1.20)	.041 (.823)	.042 (.808)	.052 (1.32)	.057 (1.68)
NC	820	820	820	820	820	820
X^2(df)	51.1(7)***	51.7(9)***	51.7(9)***	51.3(8)***	51.7(8)***	53.3(9)***
FCP	618	618	618	618	618	618

***denotes significance at 1% level.
**denotes significance at 5% level.
*denotes significance at 10% level.

TABLE 8

ESTIMATES OF THE HEALTH PRODUCTION FUNCTION
(DERIVATIVES EVALUATED AT THE MEAN)
2197 CASES

	1	2	3	4	5	6	
CONSTANT	-.793***	-1.38***	-.936***	-.949***	-1.32***	-1.08***	
	(26.58)	(23.73)	(20.92)	(24.18)	(22.40)	(23.24)	
OZONEM	53.85***	56.64***	54.28***	55.86***	53.64***	55.13***	
	(52.53)	(52.86)	(44.66)	(49.02)	(52.46)	(50.58)	
SULDIOM		2.97**	2.73**				
		(6.04)	(5.03)				
TSPSMLM		.020**			.020**		
		(6.60)			(6.59)		
LEADSMLM						.0003**	
						(5.48)	
OZSULM					151.71**	91.04	
					(6.04)	(1.79)	
OZNITM			121.65	197.94***			
			(2.10)	(7.14)			
AGE	-.012***	-.011***	-.011***	-.011***	-.011***	-.011***	
	(41.51)	(39.85)	(35.41)	(39.76)	(40.4)	(39.84)	
EDUC	.005	.005	.004	.004	.005	.004	
	(1.26)	(1.44)	(.957)	(.975)	(1.44)	(.899)	
SEX	-.274***	-.307***	-.300***	-.313***	-.311***	-.306***	
	(119.94)	(119.40)	(113.29)	(117.2)	(119.6)	(118.9)	
RACE	.101***	.105***	.094***	.088***	.106***	.104***	
	(15.51)	(16.16)	(12.89)	(11.82)	(16.52)	(15.87)	
CHRO	5.71***	5.19***	4.85***	4.88***	5.20***	5.12***	
	(41.08)	(42.46)	(36.84)	(40.69)	(42.96)	(41.98)	
LENGTH	-.035	-.033	-.027	-.030	-.033	-.028	
	(1.52)	(1.49)	(.979)	(1.16)	(1.51)	(1.16)	
NC	2197	2197	2197	2197	2197	2197	2197
X^2(df)	149.5(7)	152.8(9)	146.4(9)	149.59(8)	153.1(9)	151.1(9)	114.5(10
FCP	1669	1676	1668	1667	1678	1668	

***denotes significance at 1% level.
**denotes significance at 5% level.
*denotes significance at 10% level.

TABLE 9

WILLINGNESS TO PAY FOR REDUCTIONS IN OZONE LEVELS

	PERCENT REDUCTION IN MEAN OZONE LEVELS			
EQUATION	10%	15%	20%	30%
3(Table 3)	$2.42	$3.63	$4.84	$7.27
3(Table 4)	$2.69	$4.04	$5.39	$8.08

VOLUME VII: ECONOMIC BENEFITS OF CONTROLLING THE EFFECTS OF ENVIRONWMNTAL POLLUTION ON CHILDREN'S HEALTH

In Volume VII three additional reports are presented to assess the economic benefits related to the control of pollutants that may affect the health of children. The first section describes the economic consequences of elevated body lead burdens in children. The second section reports on a unique statistical method which scrutinizes the hypothesis that prior expectations regarding aggregate air pollution epidemiology may dictate or bias the statistical estimates of dose-response functions. Finally, the third section reports on the adequacy of natural science information to reliably evaluate environmental regulations pertaining to lead exposures.

A. Economic Losses and Elevated Body Lead Burdens in Children

Efforts by economists to value environmental health effects have focused almost entirely upon adult population losses in productivity and their willingness to pay to avoid health risks, given their current occupations. The economic value of health impacts upon children have been thus far neglected in such studies. Of all people, children and the elderly are generally considered to be the most susceptible to health damages from environmental pollutants. Children are thought to be particularly susceptible to neurological, neuromotor, and behavioral impacts from ambient lead concentrations.

Thus, in this report, an outline of an analytical framework suitable for estimating the economic losses that parent/guardians suffer from declines in their children's health is proposed. Additionally, given the effects of lead-induced changes in the health status of children on the length of schooling and schooling-success, it is shown how such health status changes can influence subsequent occupational choices and life-cycle incomes.

B. Expectational Effects of Air Pollution Epidemiology

In this section, the role of priors in aggregate air pollution epidemiology is analyzed. The possibility of a significant relationship between urban air pollution and human morbidity is not disputed, yet, the purpose of the analysis is to demonstrate the crucial role that priors play in attempts to infer this relationship from aggregate epidemiological data. The reasoning here rests on the idea that the lack of strong priors leads to difficulty in choosing among the candidate explanatory regression variables (see Chappie and Lave, 1982). A conclusion of this section is that previous study results are most likely dominated by their choice of variables to consider and particular regressions to report.

This specification uncertainty causes their (Chappie and Lave) estimates to be fragile. Only if their sample information is very precise relative to the prior information, can a significant positive association between air pollution and mortality be supported. As the precision of the prior information increases relative to that of the sample information, the precision of the air pollution-mortality association declines and even includes negative values.

In spite of the results, the painstaking and original work of Lave and his colleagues which focused a great deal of academic and regulatory interest on the existence and the size of an air pollution-human mortality relationship must be recognized. Nevertheless, there is a pressing need for additional research into reducing the specification uncertainty associated with this relationship. To accomplish this goal, the suggestion that further air pollution epidemiology research employ data on individuals is made. The effect will be to allow the use of a limited set of stronger Bayesian priors.

C. The Adequacy of Natural Science Information

In the third and concluding section of Volume VII, an alternative Bayesian framework is presented with the purpose of assessing the adequacy of natural science information to effectively evaluate environmental regulations. In effect, the framework explicitly captures the statistical and the model uncertainty associated with yield response estimates. Moreover, by penalizing alternative ambient standards which -are possibly too conservative or too optimistic, the framework allows for uncertainty to be incorporated directly into the decision process.

The framework is applied to four major field crops having dissimilar growing requirements and diverse market levels differing by as little as 10 percent and by no more than 25 percent from levels associated with the current Federal ambient standard of 12 ppm. Results indicate that for all four crops, individually and in the aggregate, 40 or fewer dose-response observations from typical plant science experiments appear adequate to discriminate among the differences in economic surplus that the aforementioned ambient ozone levels generate.

VOLUME VIII: MEASURING THE BENEFITS OF CLEAN AIR AND WATER

Volume VIII of this report contains a nontechnical discussion of the work of a number of investigators at Resources for the Future, the University of Wyoming, the University of New Mexico, and the University of Chicago. The focus of these efforts was to develop improved methods for the economic evaluation of environmental improvements. The work, sponsored by the U.S. Environmental Protection Agency in a sustained program in this area of research, is centered on analyses of actual behavior with respect to environmental goods, including travel to recreational opportunities of varying quality, prices paid for houses in environments of different quality, decisions about farm crops depending upon how they are affected by air pollution.

While a certain confidence adheres to methods based on actual decisions due to their nonhypothetical nature, these methods are not applicable to all environmental benefits. For example, they are not suitable for evaluating visibility effects of air pollution in large landscapes or to a category of benefits termed nonuser or intrinsic. The latter are benefits of people who have a preference for environmental quality in situations in which they do not actually participate. In these situations contingent valuation methods come into play. These methods rely on questioning respondents about their willingness to pay for various hypothetical changes in environmental quality. While doubts about the accuracy of these methods necessarily arise because of their hypothetical nature, the research reported in this volume that the identified sources of possible bias can be controlled for by careful questionnaire design. There remain, however, some questions for future research. In particular, the matter of how to get respondents to evaluate their replies in terms of their overall budgetary situations invites further inquiry. While the central focus of the research reported in this volume was methods development, some broad insights concerning the quantitative benefits from environmental maintenance or improvement also emerged.

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