EPA-230-12-85-028
September 1985

METHODS DEVELOPMENT FOR ENVIRONMENTAL CONTROL BENEFITS ASSESSMENT

Volume X

EXECUTIVE SUMMARY

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OTHER VOLUMES IN THIS SERIES

Volume 1, Measuring the Benefits of Clean Air and Water, EPA-230-12-85-019.

This volume is a nontechnical report summarizing recent research for EPA on methods development for better estimates of economic benefits from environmental improvement. The report presents the basic economic concepts and research methods underlying benefits estimation as well as a number of case studies, including several from other volumes of this series. Finally, it offers insights regarding the quantitative benefits of environmental improvement.

Volume 2, Six Studies of Health Benefits from Air Pollution Control, EPA-230-12-85-020.

This volume contains six statistical epidemiology studies. They show that large associations between health and current levels of air pollution are not robust with respect to the statistical model specification either for moratality or morbidity. They also find that significant relationships, mostly small, occasionally appear.

Volume 3, Five Studies on Non-Market Valuation Techniques, EPA-230-12-85-021.

This volume presents analytical and empirical comparisons of alternative techniques for the valuation of non-market goods. The methodological base of the survey approach - directly asking individuals to reveal their preference in a structured hypothetical market - is examined for bias, replication, and validation characteristics.

Volume 4, Measuring the Benefits of Air Quality Changes in the San Francisco Bay Area: Property Value and Contingent Valuation Studies, EPA-230-12-85-022.

This volume replicates a property value study conducted in the Los Angeles Basin for the San Francisco Bay area. A taxonomy series of air quality types and socioeconomic typoligies are defined for cities in the area to examine how property values vary with pollution levels. The contingent valuation method surveys individuals, directly asking their willingness to pay for changes in air quality. The survey method yields benefit values that are about half the property value benefits in both the Bay area and Los Angeles.

Volume 5, Measuring Household Soiling Damages from Suspended Particulates: A Methodological Inquiry, EPA-230-12-85-023.

This volume estimates the benefits of reducing particulate matter levels by examining the reduced costs of household cleaning. The analysis considers the reduced frequency of cleaning for households that clean themselves or hire a cleaning service. These estimates were compared with willingness to pay estimates for total elimination of air pollutants in several U.S. cities. The report concludes that the willingness-to-pay approach to estimate particulate-related household soiling damages is not feasible.

Volume 6, The Value of Air Pollution Damages to Agricultural Activities in Southern California, EPA-230-12-85-024.

This volume contains three papers that address the economic implications of air pollution-induced output, input pricing, cropping, and location pattern adjustments for Southern California agriculture. The first paper estimates the economic losses to fourteen highly valued vegetable and field crops due to pollution. The second estimates earnings losses to field workers exposed to oxidants. The last uses an econometric model to measure the reduction of economic surpluses in Southern California due to oxidants.

Volume 7, Methods Development for Assessing Acid Deposition Control Benefits, EPA-230-12-85-025.

This volume suggests types of natural science research that would be most useful to the economist faced with the task of assessing the economic benefits of controlling acid precipitation. Part of the report is devoted to development of a resource allocation process framework for explaining the behavior of ecosystems that can be integrated into a benefit/cost analysis, addressing diversity and stability.

Volume 8, The Benefits of Preserving Visibility in the National Parklands of the Southwest, EPA-230-12-85-026.

This volume examines the willingness-to-pay responses of individuals surveyed in several U.S. cities for visibility improvements or preservation in several National Parks. The respondents were asked to state their willlingness to pay in the form of higher utility bills to prevent visibility deterioration. The sampled responses were extrapolated to the entire U.S. to estimte the national benefits of visibility preservation.

Volume 9, Evaluation of Decision Models for Enviromental Management, EPA-230-12-85-027.

This volume discusses how EPA can use decision models to achieve the proper role of the government in a market economy. The report recommends three models useful for environmental management with a focus on those that allow for a consideration of all tradeoffs.

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ABSTRACT

The studies summarized by this volume represent original efforts to construct both a conceptually coherent and empirically verifiable set of methods for assessing environmental quality improvement benefits. We have found that a conceptually and empirically simpler method than traditional--the survey method--holds great promise for expanding the range of environmental phenomena that benefit-cost analysis can reliably capture. We also demonstrate that some environmental phenomena, particularly those involving the human health and ecosystem effects of pollution, will require the use of more complex models and estimation procedures if consistently reliable measures intended for policy guidance are to be obtained.

A single empirical finding pervades the nine volumes reviewed here: the benefits of air pollution control appear to be sufficiently great to warrant the exercise of great caution in implementing proposals to relax current ambient air quality standards. Contrary however, to the thrust of much existing clean air legislation, air pollution-induced health effects, with the possible exception of chronic morbidity, cannot at this time be identified as the major benefit of air pollution control. The weight of our evidence leads us to conclude that the greater proportion of the benefits of control now resides in aesthetic improvements, maintenance of the life-support and direct pleasure-material provision capacities of ecosystems, and the reduction of damages to artifacts and materials.

Introduction

As we move into the 1980's, the heart of the environmental concerns of the 1960's and 1970's continues to beat, but other major difficulties now burden us. The economy seems weak, inflation is high, and the identification and application of corrective policies has been confused. In this adverse economic atmosphere, there is heightened interest in the question of whether the costly environmental regulations previously put in place are, in fact, worthwhile. To try to shed some light on this question, appeal is often made to an economic evaluation method called benefit-cost analysis.

Benefit-cost analysis was developed initially to provide a useful picture of the costs and gains associated with investments in water development projects. In recent years, the most striking development in benefit-cost analysis has been its applications to the economic and environmental consequences of new technologies and scientific and regulatory programs. These new applications of the analysis bristle with quantification, analytical, and ethical issues of which proponents of continuing expansions in its use do not always seem aware. For the last several years, so as to broaden the domain of benefit- cost applications from which policymakers may obtain consistently dependable policy guidance, researchers located principally at Resources for the Future and the Universities of New Mexico and Wyoming have been grappling with these issues. The series of volumes summarized here reports the advancements in analytical and empirical techniques made by some of them. As in an earlier series of volumes [Crocker-Schulze, et al. (1979); Brookshire, et al. (1979); Adams, et al. (1979); Cropper, et al. (1979)] by many of the same authors, air pollution is the environmental problem of research focus. Although they have made real and substantial progress, the research program they and other economists have undertaken is far from completed. The discriminating policymaker must continue to be knowledgeable about and highly sensitive to the analytical, empirical, and the ethical limits of the state-of-the-art.

A single empirical finding pervades these ten volumes: despite the location and/or time-specific nature of the estimates, the benefits of air pollution control appear to be sufficiently great to warrant the exercise of great caution in implementing proposals to relax current ambient air standards. Contrary to the thrust of much existing clean air legislation, air pollution- induced health effects, with the possible exception of chronic morbidity, cannot at this time be identified as the major economic benefit of air pollution control. The weight of our evidence leads us to conclude that the greater proportion of the benefits of control now resides in aesthetic improvements (e.g., atmospheric visibility), maintenarce of the life-support and direct pleasure-material-provision capacities of ecosystems, and the reduction of damages to human artifacts (e.g., household soiling). Our several bases for the conclusion can be gleaned from the following brief

summaries for each of the separate volumes.

Measuring the Benefits of Clean Air and Water

The first volume in the series presents a detailed overview in lay terms of the entire body of work. This overview is buttressed by an elementary discussion of the foundations of the research in the economic theory of the consumer and the producer, as well as the place this and similar recent research holds in the historical evolution of benefit-cost analysis. The volume is not a collective enterprise; rather it is one eminent economist's perspective of the usefulness and the implications of the research reported in the other volumes.

Six Studies of Health Benefits From Air Pollution Control

The six studies contained in this volume all aim to increase our understanding of the health benefits of air pollution control. The calculation of health benefits requires both an understanding of how people themselves value health affects in dollar terms (correctly measured by the willingness-to-pay concept) and an understanding of air pollution-induced health effects. Much progress has been made with respect to the former problem. However, the link between air pollution and human health remains problematic. Two approaches are available for determining the health affects of air pollution. First, animal experiments or, rarely, human experimentation can provide direct evidence in a controlled situation. However, extrapolation from animal to human populations is difficult and possibly unconvincing given that many human exposures to air pollution occur over periods of decades as opposed to the exposure periods of months possible in the laboratory. The second approach is to analyze data on human health affects taken from the real world, uncontrolled environment, hoping that careful statistical analysis will allow one to account for all of the important factors determining human health.

This latter approach, statistical epidemiology, is the principal focus of this volume.

The first three studies attempt to determine the association between air pollution and mortality. One study examines evidence from data on aggregate mortality rates in sixty U.S. cities and points out the extraordinary difficulty in obtaining a stable, robust statistical association between current air pollution levels and current mortality rates. The conventional wisdom holds that a large positive relationship exists between particulates in air and mortality. The study demonstrates that this relationship is highly unstable depending on specification of the statistical model used in the analysis. A second mortality study uses a small sample of data on individual ages at death, taken from the Survey on Income Dynamics (1972), to see if, by using disaggregate information on individuals, a more stable and convincing relationship can be obtained. In this small sample of individuals, no significant statistical relationship is obtained between current air pollution levels and longevity. A final mortality study is a very preliminary description of an ongoing research effort using an excellent and highly detailed data set on twins collected by the National Academy of Sciences

[Hrubec and Neel (1978)]. Of the three studies relating to mortality, this one has perhaps the best data and should be capable of detecting even small effects. In fact, a strong but small statistical correlation is shown between air pollution and prior symptoms of cardiovascular disease such as chest pain. An association with coronary heart attack is small and not as strong.

Two of the studies examine morbidity. One focuses on chronic illness while another considers acute illness. Both studies use Survey on Income Dynamics data and data on current air pollution levels. The relationship between chronic illness and air pollution is shown to be potentially large but is again very sensitive to model specification. Since little a priori knowledge is available on appropriate model specification, it is impossible to choose between a specification which yields a large impact and one which yields no significant impact. The study of acute health impacts shows, using a particular specification, a small positive association of marginal statistical significance between sulfur oxide and lost work days.

In summary, the five statistical studies presented in this volume show: (1) large associations between health and current levels of air pollution are not robust with respect to statistical model specification either for mortality or morbidity; and (2) statistically significant relationships, mostly small, do occasionally appear.

The final study considers the type of data which might resolve controversies over the magnitude of air pollution health affects. The principal conclusion is that, before a very expensive primary data collection effort is undertaken, it would be better to continue statistical modeling of human health affects working with existing data sets, some of which are of fairly high quality. However, all work of this sort should henceforth be built upon explicit physiological and economic models that specify the parameter space. The results of these secondary data studies can then be used to guide the specification of future primary data collection efforts.

As a final remark which should not be overlooked in light of the rather ambiguous evidence presented in this health effects volume, all studies to date have only looked for health affects associated with current air pollution exposures, not at any possible association between current health affects ard long term cumulative air pollution exposures. Thus, it is premature to draw any final conclusions from existing epidemiological evidence concerning human health and air pollution exposures.

Five Studies on Non-Market Valuation Techniques

Two approaches are generally considered for estimating the value of nonmarketed goods. The most widely accepted approach has been the use of hedonic prices, where it is assumed, for example, that either wages or housing valued reflect spatial differences in the quality of air resources. Alternatively, using survey techniques, one may directly ask households or individuals to state their willingness-to-pay for alternative levels of air quality. The necessity for an alternative approach to the hedonic lies in the spatial nature of air resources. In a well developed housing market, the hedonic

approach is appropriate. However, consider the case of a remote and unique scenic vista, valuable to recreators, which is threatened by air pollution from a proposed coal fired power plant--a typical situation in the western United States. Although it is possible, in principle, to impute the value of clean air and visibility from the relative decline in local visitation which might follow construction, information prior to construction on the value of visibility at the site is needed for socially optimal decisionmaking. The hedonic approach is unavailable both because the scarcity of local population makes use of wage or property value data impossible and because scenic vistas may themselves be unique.

Because of its hypothetical nature, the empirical implementation of the survey approach raises questions of bias, replicability, validation by other techniques, and appropriateness for benefit-cost analysis. Before incorporation of survey approach results into benefit-cost analyses, these questions require answers. The research reported in this volume tries to provide them.

The first paper of the volume evaluates the results of six recent experiments which have utilized the survey approach for estimating the value of a nonmarketed environmental attribute. Where possible, the issue of replication of results is addressed. The range of environmental attributes valued in the six experiments was quite large, including noise, wildlife, strip mining, and visibility. Four out of six attempted some internal methodological cross check. Biases, within the survey approach, do not appear to have been an overriding problem. However, the studies indicate the need to establish a precise market--hypothetical in nature--for the results of a survey approach to be interpretable. to be interpretable.

A second paper takes up the central issue of validating the survey approach. Although the studies reviewed in the previous paper suggested that the survey approach is internally coherent and consistent with the theory of the consumer, and that its results are replicable, no external validation had been undertaken whereby a comparative analysis using another approach independent of the survey had been conducted. Thus, this second paper reports an experiment designed to validate the survey approach by direct comparison to a hedonic property value study.

The Los Angeles metropolitan area was chosen for the experiment. Twelve census tracts were chosen for sampling wherein 290 household interviews were conducted during March 1978. Respondents were asked to provide their willingness-to-pay for an improvement in air quality at their current location. Air quality was defined as poor, fair, or good based both on maps of the region (the pollution gradient across the Los Angeles Metropolitan Area is both well defined and well understood by local residents) and on photographs of a distant vista representative of the differing air quality levels. Households in poor air quality areas were asked to value an improvement in fair air quality while those in fair areas were asked to value an improvement in good air quality. Households in good air quality areas were asked their willingness-to-pay for a region-wide improvement in air quality.

For comparison to the survey responses, data was obtained on 634 single family homes sales which occurred between January 1977, and March 1978, exclusively in the twelve communities used for the survey analysis. Households, in theory, will choose to locate along a pollution-rent gradient, paying more for homes in clean air areas. However, ceteris paribus, we show that the annualized cost difference between homes in two different air quality areas (the rent differential for pollution) will in theory exceed the annual willingness-to-pay for an equivalent improvement in air quality for a household in the lower air quality area. Thus, the rent differential of an air quality improvement inferred from hedonic analysis of property value data must exceed estimates of household willingness-to-pay obtained from survey responses, if the survey responses are a valid measure of the value of air quality improvements. The theoretical model described predicts that survey responses will he bounded below by zero and above by rent differentials derived from the estimated hedonic rent gradient. The empirical results do not allow the rejection of this hypothesis, thereby providing evidence that survey methods are a valid means of determining the value of nonmarket goods.

In a third paper, the reasons why the survey approach is often a superior means of generating data for valuing non-market goods are advanced. Specifically the advantages of the hypothetical nature of the survey technique are addressed. We argue that the survey technique will often be more consistent with the precepts of economic theory than is the use of observed behavior, that hypothetical responses are properly viewed as conditional rather than as fictional, and that the survey technique is quite often the only technique which can address future events without going through the costly exercise of "learning-by-doing" or "trial-and-error."

The fourth paper presents the main empirical results of the volume: it is an examination of the benefits and costs of the national ambient air quality standards as applied to all residential areas of Los Angeles, Orange, Riverside, and San Bernardino Counties in southern California. The results set forth are based on the qualified arguments presented in the previous three papers which suggest that both the survey approach and the property value approach are valid techniques of benefit-cost analysis. Based upon modeling contained in the region's Air Quality Management Plan, achievement of the ambient standards in 1979 would have required emission reductions of the 974 tons/day, 5963 tons/day and 503 tons/day respectively of reactive hydrocarbons, carbon monoxide, and nitrogen oxides. Only the share of these emission reductions attributable to onroad mobile source control was evaluated.

Benefits were calculated through an examination of the housing value differentials attributed in the second paper to air quality differences. Achieving the ambient air quality standards was consistent with improving the "fair" and "poor" air quality regions to the "good" category. In effect, this constituted an approximate 30 percent improvement in the fair areas and a 45 percent improvement in the poor air quality areas. Corresponding benefits were estimated to fall between 1.6 ard 3.0 billion dollars per year, indenendent of any benefits accruing to protection of agriculture and ecosystems. The share of these benefits associated with onroad mobile source control was

estimated to be 1.36-2.55 billion dollars.

Cost estimates were developed from existing data sources, primarily from manufacturer statements and government publications. Given the variation in control cost options and the uncertain nature of the cost figures, it was found that onroad mobile source controls consistent with a policy sufficient to achieve the 1979 ambient standards would involve a cost of between .61 and 1.32 billion dollars, with a best estimate of 1.02 billion dollars.

The benefits from onroad mobile emissions reductions consistent with satisfying the ambient standards are of the same order of magnitude as the cost estimates. This implies that the ambient air quality standards have some economic justification, though the confidence intervals for the benefit and cost calculations prevent one from accepting the controls outright. In any case, onroad mobile controls consistent with the air quality standards cannot be rejected as economically inefficient. Therefore, although the midrange benefit estimate exceeds the midrange cost estimate, the situation is best characterized as uncertain. Further, the static analysis performed does not answer significant questions concerning the behavior of the benefit and cost functions over time. Stronger statements could only be made in the context of a much more detailed analysis of the cost side of control efforts.

The final chapter of the volume reports some exploratory estimates of the effect of changes in air pollution levels on offered wage rates. This approach is appropriate for a national benefits study where it is assumed that higher wages must be paid, everything else held equal, to induce people to live in polluted communities. Estimates using this technique were made for two cities: Denver, Colorado, and Cleveland, Ohio.

For Denver, meeting the national secondary standards for TSP results in a reduction in the offered real wage, from $4.1758/hr. to $3.9626/hr. Multiplying this difference of $.2136/hr. by the number of persons affected times 2000 hours yields an estimated annual benefit for Denver of $92,968,935. A similar calculation for Cleveland reveals that meeting the national secondary air quality standards causes the real wage to fall from $3.8756/hr. to $3.7693/hr. implying a benefit of $81,360,489. Note that benefits per household head in the two cities are $426.35 for Denver and $2l2.60 for Cleveland. This preliminary research suggests the wage hedonic technique is viable for estimating air pollution control benefits for standard metropolitan areas across the nation.

A national benefit estimate for air pollution control based on consumer perceptions as reflected in wages and property values appears possible. Further, the use of the survey approach to assess the value of perceived benefits, such as visibility improvements, not captured by wages and property values appears feasible.

Measuring the Benefits of Air Quality Improvements in the San Francisco Bay Area

This volume reports the results of an attempt to repeat the survey and

property value methods developed and set forth in the second paper of the previous volume. The study locale, however, is San Francisco rather than Los Angeles.

While the intention was to make the two studies as comparable as possible, there were some inevitable differences in both the situations and in the data available that made some adaptation necessary. For example, in southern California, as suggested, the mild, year-round climate encourages a variety of ocean related recreational activities. Beach front activity is highly valued and beach front property has generally been densely developed. In the San Francisco Area, the bay is the body of water most accessible to major population centers; however, the bay does not offer the same recreational experiences found along the coast of the Los Angeles area. In the Bay Area, ocean front property is located over the ridge of the Santa Cruz Mountains and is less accessible to the maijor employment centers. As a result, much of the beach front property maintains a rural atmosphere.

Accordingly, it was not necessary to adopt the paired communities approach of the Los Angeles study to control for access to the beach. This made a more nearly random sampling approach possible which has the advantage of providing a better basis for extrapolating the sample results to the entire area.

Another principal difference between the areas is air quality. Smog is considered to be the major problem in both regions. The city of San Francisco itself has a less severe air pollution problem than Los Angeles. However, some cities included in the region (San Jose and Los Gatos, for example) suffer from severe pollution problems.

Thus while the San Francisco region provides suitable contrast in air quality from place to place, still, air quality degradation is not in general so severe and, one would expect, also possibly not so well defined in people's minds. Accordingly, it was judged to be an excellent place to see whether the Los Angeles techniques would hold up in a different situation.

Data were gathered or constructed for 2500 households in the region. These same households also were subsequently used for interviewing. In addition, data were collected on about 5000 residential property sales in areas where these families live. When these property sales were analyzed in a fashion similar to the Los Angeles study, it was found, despite the differences between the two locales, that similar differences in air quality levels in the two locales resulted in similar differences in housing sales prices and in survey bids per household.

Measuring Household Soiling Damages From Suspended Particulates

This volume employs a survey approach and an observed behavior aporoach to estimate in Philadelphia, Pennsylvania, and Los Angeles, California, the dollar value of reducing household soiling attributable to suspended particulate air pollution. The received technical literature is reviewed in the early part of the volume. On the basis of this review, it is concluded

that: (i) the present state of the technical arts does not allow for quantitative estimates of the relationship between particulate concentration and the accumulation of dust/grime in households; in qualitative terms, however, a particulate-soiling effect is demonstratable; (ii) one cannot quantify, with any precision, the relationship between outdoor particulate concentrations and indoor concentrations; (iii) little can be said in terms of differentiating between soiling effects from "large" (greater than 15 microns) and "small" (less than 15 microns) particulates; and (iv) a dominant relationship can be identified, however, between particulate levels and soiling effects and between gaseous pollutants and materials damages. Therefore, while one cannot quantitatively specify the soiling effects that result from alternative particulate levels, it is at least conceptually possible to look to household soiling damages via observed responses in different pollution (particulate) environments.

As measured by an observed behavior (frequency of cleaning) approach to estimating household cleaning costs, annual household soiling damages in the Pennsylvania-New Jersey-Delaware area range from $762 per household (1980 dollars) to $1,386 per household in "do-it-yourself" households as air particulate concentrations range from 40 microns per cubic meter (u/m3) to 123 u/m3; such damages for households that hire others to perform household cleaning tasks range from $1,531/household to $2,683/household in the same range for particulate concentrations. Marginal household soiling damages attributable to air particulates are estimated at $6.63/household per u/m3 per year.

A survey technique similar in conception and rationale to the Los Angeles and San Francisco surveys reported in previous volumes was found to be an infeasible approach to estimating particulate related household soiling control benefits unless particulates are totally eliminated. Average annual valuations related to the total elimination of air particulates were some $7.32/household in the Los Angeles area and $2.68/household in the Philadelphia area. in the Los Angeles area and $2.68/household in the Philadelphia area.

The results of the survey indicated that individuals in the Los Angeles and Philadelphia areas were willing to pay a maximum of $32.83/month and $12.59/month, respectively, for the elimination of all air pollutants. These total "bids" were allocated to pollution effects as follows: 66 - 76% health; 13 - 18% visibility; and 9 - 16% household soiling. Although independently performed from the Los Angeles study reported in an earlier volume, this estimate is of the same order of magnitude as the earlier estimate.

The volume concludes that only an observed behavior (frequency of cleaning) approach to estimating suspended particulate-induced household soiling damages is likely to be effective in terms of providing logically consistent and replicable estimates it is suggested that an approach of this sort must define cleaning frequency in terms of multi-task household cleaning operations -- such as "light" cleaing and "deep" cleaning -- rather than in terms of specific cleaning tasks. Second, refined estimates for time spent per operation must be obtained. Third, stratified (over income) samples must be used. Finally, data relevant for the value of household labor must be

obtained for various posited changes in household cleaning time.

The Value of Air Pollution Damages to Agricultural Activities in Southern California

In spite of an enormous literature on the phytotoxic effects of air pollution, few research efforts have been directed at the implications of these effects for agricultural markets. Of those few studies that do exist, nearly all do no more than multiply the results of field surveys or experimental studies of yield reduction by an invariant current price in order to estimate the value of air pollution-induced losses, e.g., Thompson and Taylor (1969), Benedict, et al. (1973), Millecan (1976). The adjustments in output and input prices and cropping and location patterns that agricultural markets and growers make in response to altered levels of air pollution have been neglected. The three essays in this volume weigh some of the economic implications of these air pollution-induced adjustments for southern California agriculture.

The initial essay uses a mathematical programming technique to assess air pollution-induced losses to fourteen of southern California's most highly valued annual vegetable and field crops. This technique allows the estimation of the losses in consumer surpluses and grower quasi-rents occurring after growers have been permitted to alter cropping patterns and locations in response to changes in ambient concentrations of photochemical oxidants. As we have used it, however, the technique falls somewhat short of capturing all economically relevant features of the impacts of air pollution upon agricultural markets. Among other things, such as the impact of air pollution on intertemporal agricultural investment patterns, it forces us to disregard losses that inputs employed but not owned by the grower may suffer. In addition, as we have used it, the technique embodies an assumption that air pollution has no influence upon the uncertainties that growers and the inputs they employ face.

The second essay provides estimates of the losses in earnings that workers in citrus groves bear from the oxidant air pollution to which they are exposed in their work environments. Although citrus is not among the fourteen crops to which the mathematical programming technique is applied, the greater than two percent earnings losses that air pollution imposes upon citrus grove workers gives cause to wonder whether labor for other agricultural crops might suffer similarly. If so, these losses would be in addition to those weighing upon consumers and growers.

The final essay is the only one of the three which does not present pecuniary equivalents of some facet of the losses that the air pollution originating from southern California urban and industrial activities forces upon the area's agriculture. Instead, after a brief discussion of why uncertainty is costly to the agricultural sector, we provide empirical evidence of a moderately strong positive association between, a frequently employed measure of the risks faced by agriculturists and increases across space and time in southern California oxidant air pollution.

The research efforts displayed in these three essays neither embrace all oxidant air pollution-impacted crops grown in southern California nor do they capture all plausible facets of the impacts of oxidants upon the input and output markets for these crops. For example, losses in consumer surpluses and producer rents from reductions in citrus yields are not included, and economic losses generated by any yield uncertainties that oxidants cause are absent. Despite these blanks, and assuming that the crops and inputs we have studied have a reasonably representative distribution of air pollution sensitivities, our informed yet conservative judgment is that the levels of ambient oxidants prevailing in southern California in the mid 1970's were responsible for at least a four percent reduction in the total economic surpluses generated by the area's agricultural activities.

Methods Development for Assessing Acid Precipitation Control Benefits

There has recently been increasing awareness that some environmental pollutants, because of the broad geographical scope of their effects, impose not only the direct affronts to human life and property of the traditional urban pollutants, but also attack the pleasures and the life support services that the earth's ecosystem scaffolding can provide. Acid precipitation might be one of these pollutants. The basic purpose of this volume is to suggest those types of natural science research that would be most helpful to the economist faced with the task of assessing the economic benefits of controlling acid precipitation. However, while trying to formulate these suggestions, inadequacies in the supporting material the ecologist could offer the economist and in what the economist could do with whatever the ecologist offered him became apparent. Therefore part of the research effort was devoted to initial development of a resource allocation process framework for explaining the behavior of ecosystems that can be integrated into a broadened benefit-cost analysis which captures traditional ecological concerns about ecosystem diversity. Our intent has been to make a start at providing a basis for the ecological and the economic disciplines to ask better-defined questions of each other.

Some reasonably well-defined questions have nevertheless been asked and tentative answers have been provided for a few of them. In particular, most of the existing techniques for assessing the benefits of pollution control require knowledge of the magnitude of the response of the entity of interest to variations in the quantity of pollution to which it is exposed. The entity that is the oblect of interest in these estimates of response surfaces or functions must itself have value to humans or it must contribute in some known fashion to another entity having value to humans. Otherwise, the economist is unable to perform his tasks. Additional properties that response surface research must have to be most valuable for the empirical implementation of the techniques of benefit-cost analysis are outlined in the text.

The simplest of these available techniques is applied in a first exercise at using known response surfaces to assess the benefits of controlling acid precipitation in Minnesota and the states east of the Mississippi River. Current annual benefits of control are estimated to be no more than $5 billion in 1978 dollars, with reductions in materials damages constituting the largest

portion of these benefits and reductions in damages to forest ecosystems the next largest. The reader must not treat this estimate as definitive, although the ordering of current annual control benefits by sector is highly plausible.

The known response surfaces used to construct the above estimate sometimes displayed two properties that could impart "all-or-nothing" and “now-or-never” features to the acid precipitation control decision problem. These two features arise because the marginal benefits of reducing acid precipitation appear to be increasing over a substantial interval of increasing pH values, and because the effects of acid precipitation upon ecosystem buffering capacities are less than fully reversible, both technically and economically.

Visibility in the National Parks

This study was designed to improve the state-of-the-art measuring the value of atmospheric visibility and to provide some actual estimates of that value for the Grand Canyon and the surrounding region. A survey technique similar in concept to, but different in detail from, the Los Angeles and San Francisco studies was employed to acquire the requisite data. During the summer of 1980, over six hundred people in Denver, Los Angeles, Albuquerque and Chicago where shown sets of photographs depicting both clear conditions and regional haze. The photographs were taken in Mesa Verde, Zion and Grand Canyon National Parks and represented "poor," below average,” “average,” “above average," and "excellent" visibility. Our calculations suggest that complete decontrol of SO_2 emissions by projected power plants in the region in 1990 would result in a decrease in typical summer visibility from that which was represented in the photographs as "average" visibility to that which was represented as "below average" visibility. Two-thirds of the survey participants were asked how much they would be willing to pay in higher electric utility bills to preserve the current average condition--middle picture--rather than allow visibility to deteriorate, on the average, to the next worse condition as represented in the photographs of the Grand Canyon or of the region (an estimate of total preservation value). They were also asked about their willingness to pay in the form of higher monthly electric power bills to prevent a plume from being seen in a pristine area. To represent plume blight, two photographs were taken from Grand Canyon National Park, one with a visible plume. One-third of the participants were asked how much they would pay for better visibility on the day of a visit to the Grand Canyon (an estimate of user value). The surveying had a very high response rate (few refusals) in part because of the nature of the interviews. Typically, interviews were conducted in the late afternoon or early evening hours in residential neighborhoods. Due to the size of the display boards used, most interviews were conducted on the front lawn of the respondent's home. Often, both husband and wife participated jointly in answering the questions. Individual bids ranged from an average of $3.72 per month in Denver to S9.00 per month in Chicago for preserving visibility at the Grand Canyon. These average bids were increased by $2.89 to $7.10 per month per household in the four cities if visibility preservation was to be extended to the Grand Canyon Region as a whole a represented by the photographs taken from Mesa Verde and Zion. Prevention of a visible plume at the Grand Canyon was worth on the

average between $2.84 and $4.32 per month for the four cities surveyed.

Extrapolating these bids to the nation implies that preserving visibility in the Grand Canyon Region is worth almost 10 billion. dollars per year. These are the benefits of power plant SO_2 controls which are projected to be in place in the region by 1990. Projected emissions with existing and currently planned levels of SO_2 control would not produce a perceived decline in visibility in 1990 according to our calculations. Additionally, prevention of a visible plume at the Grand Canyon is worth almost four billion dollars to the nation. Surprisingly user values alone were about two orders of magnitude smaller than total preservation values. This suggests that existence values derived from knowledge that a unique natural wonder remains preserved may be very large for the Grand Canyon Region. The accuracy of these estimates, given the difficulty of quantifying environmental values in dollar terms, is probably on the order of plus or minus 50 percent. However, the methodology used must still be considered experimental since this is the first study, to our knowledge, to include an estimate of existence values.

As in the acid precipitation study, the incremental values people attached to improved visibility displayed a property that could impart an “all-or-nothing" feature to the visibility protection decision problem: the incremental benefits of improving visibility appear to be increasing over a substantial range of visibility improvements. Although unremarked upon by their authors at the time, at least two earlier and independent studies of the value of visibility [Randall, et al. (1974); Rowe, et al. (1980)] have estimated incremental benefits functions displaying the same prcperty.

Evaluation of Decision Models for Environmental Management

The theme of the final volume of the series diverges from the control benefits estimation emphasis of the previous eight volumes. Its concern is with the contributions alternative classes of decision models can make to the environmental policy problem of: (a) finding the mix and levels of these activities that are consistent with "homeostatic" ecological functioning and society's preferences; (b) achieving this mix and these levels; and (c) deciding the appropriate role of government in a market economy. One section of the volume contains an abstract discussion of models and a survey of candidate models for environmental policy. A fuller treatment of those models thought to be particularly relevant for environmental management problems is presented in a subsequent section. The theoretical foundations and operational linkages of these models are described in detail. A final section considers the informational requirements of each type of model, the extent to which each satisfies earlier - stated model criteria, and promising areas for future research with respect to the application of formal decision models to environmental management issues.

Methodological Conclusions

Benefit-cost analysis is a means of ascertaining the quantity of some numeraire (e.g., current dollars) that the gainers and losers from some public action will consider equivalent in value to their respective gains and losses.

The benefit-cost analyst tries to ascertain what individuals are willing-to-pay and/or would have to be paid for the public action in a world where markets are pervasive. His goal is to provide the public decisionmaker with consistently reliable policy guidance. These ten volumes have demonstrated that this goal is both simpler and more complex to achieve than has perhaps previously been recognized.

The goal is simpler in that survey and differential property value techniques are relatively easy and inexpensive to implement and can readily be designed to provide estimates of national and regional, as well as local, control benefits for a large number of classes of pollution effects. Moreover, the survey technique, though the soiling study in Volume V seems a counterexample, allows one to capture a variety of classes of effects traditionally viewed as intangible (e.g., atmospheric visibility) or outside the realm of historical experience (e.g., a prospective power plant in a national parks region). The potential valuable applications of this analytically and empirically simple yet powerful technique have probably not yet been stretched to anywhere near their limit. Exactly where this limit lies should nevertheless be carefully explored before embarking on a campaign to apply the technique with much greater frequency to broader classes of environmental problems.

Whatever the ultimate potential of the survey technique, it seems that many simple "old reliable" techniques using data on observed rather than contingent behavior are, in fact, substantially less than reliable. The techniques have been idly appllied. The empirical consequences of these casual, even pretheoretical, treatments of underlying biological and economic processes are forcefully demonstrated in the aggregate mortality study of Volume II and the agricultural damage study of Volume VI. When using observed behavior as the data source for the benefits assessment exercise, the biological and the economic adjustments to pollution-induced stress that the organism can make must be taken into account when designing the research problem. This accounting will require the use of more complex models and estimation procedures than have heretofore dominated if reliable measures for policy guidance are to be obtained.

All policy relevant environmental benefits assessment issues are not amenable to treatment by simpler, unchanged, or more complex versions of <u>existing</u> techniques. As was emphasized in the health studies of Volume II, the acid precipitation study of Volume VII, and the national parks visibility study of Volume VIII, there are conceptual and measurement issues (e.g., irreversibilities, nonconvexities, existence values, ecological diversity) that limit, sometimes severely, the suitability and/or believability of existing methods. Until resolved to a greater degree, the analytical and empirical compromises practitioners now make could, with distrubing frequency, result in seriously misleading estimates of pollution control benefits. Because partial or, as with ecological diversity, complete neglect of economically relevant facets of the environment is involved, these misleading estimates will generally be biased dowrward: they will underestimate control benefits.

BIBLIOGRAPHY

Adams, R.M., N. Thanvibulchai, and T.D. Crocker, A Preliminary Assessnent of Air Pollution Damages for Selected Crops Within Southern California, Washington, D.C.: USEPA-600/5-79-00lc (February 1979).

Benedict, H.M., C.J. Miller, and J.S. Smith, Assessment of Economic Impact of Air Pollutants on Vegetation in the United States -- 1969 and 1971, Menlo Park, California: Stanford Research Institute, (1973).

Brookshire, D.S., R.C. d'Arge, and W.D. Schulze, Experiments in Valuing Non-Market Goods, Washington, D.C.: USEPA-600/5-79-001b (February 1979).

Crocker, T.D., W.D. Schulze, S. Ben-David, and A.V. Kneese, Experiments in the Economics of Air Pollution Epidemiology, Washington, D.C.: USEPA-600/5-79-001a (February 1979).

Cropper, M.L., W.R. Porter, B.J. Hansen, R.A. Jones, and J.G. Riley, Studies on Partial Equilibrium Approaches to Valuation of Environmental Amenities, Washington, D.C.: USEPA 600/5-79-001d (February 1979).

Hrubec, Z. and L.V. Neel, "The National Academy of Sciences--National Research Council Twin Registry: Ten Years of Operation," Twin Research: Biology and Epidemiology, New York: Alan R. Liss, Inc.: (1978), 153-172.

Millecan, A.A., A Survey and Assessment of Air Pollution Damage to California Vegetation 1970 through 1974, Sacramento, California: California Department of Food and Agriculture (April 1976).

Randall, A., B. Ives, and C. Eastman, "Bidding Games for Valuation of Aesthetic Environmental Improvements," Journal of Environmental Economics and Management, 1(1974), 132-149.

Rowe, R.D., R.C. d'Arge, and D.S. Brookshire, "An Experiment on the Economic Value of Visibility," Journal of Environmental Economics and Management 7(March 1980), 1-19.

Survey Research Center, A Panel Study of Income Dynamics, Ann Arbor, Michigan: Institute for Social Research, The University of Michigan, (1972).

Thompson, C.R., and O.C. Taylor, "Effects of Air Pollutants on Growth, Leaf Drop, Fruit Drops, and Yield of Citrus Trees," Environmental Science ard Technology 8(1967), 644-650.