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METHODS DEVELOPMENT FOR ENVIRONMENTAL CONTROL BENEFITS ASSESSMENT

Volume III

FIVE STUDIES ON NON-MARKET VALUATION TECHNIQUES

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OTHER VOLUMES IN THIS SERIES

Volume 1, Measurinq 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 fran 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 mortality or morbidity. They also find that significant relationships, mostly small, occasionally appear.

Volume 4, Measurinq 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, Measurinq Household Soiling Damages from Suspended Particulate: 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.

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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 willingness to pay in the form of higher utility bills to prevent visibility deterioration. The sampled responses were extrapolated to the entire U.S. to estimate the national benefits of visibility preservation.

Volume 9, Evaluation of Decision Models for Environmental 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 recanmends three models useful for environmental management with a focus on those that allow for a consideration of all tradeoffs.

Volume 10, Executive Summary, EPA-230-12-85-028.

This volume summarizes the methodological and empirical findings of the series. The concensus of the empirical reports is the benefits of air pollution control appear to be sufficient to warrant current ambient air quality standards. The report indicates the greatest proportion of benefits from control resides, not in health benefits, but in aesthetic improvements, maintenance of the ecosystem for recreation, and the reduction of damages to artifacts and materials.

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This report has been reviewed by the Office of Policy Analysis, U.S. Environmental Protection Agency, and approved for publication. Mention in the text of trade names or commercial products does not constitute endorsement or recommendation for use.

FOREWORD

This volume is one of the reports prepared by research institutions under cooperative agreements with the Economic Research Program of the united states Environmental protection Agency (EPA). The purpose of the Program is to carry out economic research that will assist EPA in carrying out its mission. Until very recently, most research sponsored by the Program sought to improve the methods and data available for determining the economic benefits of pollution control, thereby assisting EPA and other Federal Agencies responsible for preparing benefit-cost analyses of programs and regulations. Such benefit-wst analyses are required as part of the Regulatory Impact Analyses mandated for most major Federal regulations by Executive Order 12291. The availability of improved methods and data will make it possible for EPA and other Agencies to determine more accurately the economic efficiency of their regulations and programs. Very recently, the scope of the Program has been expanded to include a broader range of research on increasing the economic efficiency of pollution control.

The Economic Research Program was a part of the Office of Research and Development (ORD) until early 1983, when it was transferred to what is now the Off ice of Policy, Planning and Evaluation. The cooperative agreements under which this volume was prepared were concluded while the Program was still in ORD; accordingly, ORD's important contribution should be recognized.

This volume is one of a series under the title Methods Development for Environmental Control Benefits Assessment prepared mainly under cooperative agreement R805059 with the University of Wyoming, although several of the individual volumes were completed under later cooperative agreements or under subagreements with other institutions. Each of the other volumes in the series is l isted on the f rent and back inside covers of this volume. The overall purpose of the series is to report significant research results achieved under the cooperative agreement. The purpose of the agreement was to develop improved methods for assessing environmental benefits, with emphasis on air pollution benefits. An earlier series of interim reports prepared under the same cooperative agreement was published by EPA in 1979 under the series title of Methods Development for Assessing Air Pollution Control Benefits with report numbers EPA-600/5-79-001a through 001e.

This volume contains five analytical and empirical studies of alternative techniques for valuing goods that are not marketed, with emphasis on some of the difficulties with using benefit-cost techniques in analyses of air pollution control programs and measures. These studies are important to EPA because of the importance of determining the economic benefits of air (and other) pollution control programs and measures and the present difficulties of doing so. Only by solving these cliff iculties can EPA make reliable benefit-cost estimates of the many benefits of its programs and regulations which are not goods sold in markets.

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ADS TRACT

This volume presents analytical and empirical comparisons of alternative techniques for the valuation of nonmarketed goods. The methodological base of the survey approach--directly asking individuals to reveal their preferences in a structural hypothetical market--is examined for bias, replication and validation characteristics. Upon finding in an experiment in the South Coast Air Basin that the survey approach does not appear to be bias ridden, satisfies some replication tests and was crossvalidated by the property value hedonic technique, a simplified benefit-cost analysis was conducted. The results imply that ambient air quality standards in the South Coast Air Basin are probably economically justified, though uncertainty concerning the benefit and cost calculations exists. To provide a third basis for comparison, the wage--hedonic technique--where it is assumed that higher wages must be paid, everything else held equal, to induce people to live in polluted communities, was implemented on a trial basis for the Standard Metropolitan Statistical Areas of Denver and Cleveland. The purpose was to explore if a relative low cost technique could be utilized in achieving a national benefit estimate. Given the research presented in this volume, it appears the three techniques could be utilized in constructor.g a national benefit estimate.

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CHAPTER 1

INTRODUCTION

Benefit-cost analysis is a well established mode of applied economics extensively used for the evaluation of public investment projects and most recently environmental policies. This volume deals with some of the special difficulties in the use of benefit-cost analyses in programs designed to preserve or maintain air resources. The specific task is to estimate the benefits associated with alternative levels of air quality. If benefit-cost analysis is to be employed for decisionmaking, techniques need to be devised to impute economic values for changes in the quality of air resources.

Two approaches have been proposed for measuring the value of non-market goods . The most widely accepted approach has been the use of hedonic prices, where it is assumed, for example, that either wages or housing values 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 visibility. The necessity for an alternative approch, 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 of a power plant, information on the value of visibility at the site is needed prior to construction 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.

The empirical implementation of the survey approach, however, raised questions of bias, replicability, validation by other techniques, and appropriateness for benefit-cost analysis given the hypothetical nature of the technique. Before incorporation of survey approach results into benefit-cost analysis these questions require answers. Accordingly, the chapters that follow address the following topical areas.

In Chapter 2--Valuing Environmental Commodities: Some Recent Experiments, we evaluate the results of six recent experiments which have utilized the survey approach for estimating a nonmarket attribute associated with the environment. Where possible, the issue of replication of results is addressed. The range of environmental attributes valued in the six experiments was quite large--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 be an overriding problem. However, the studies indicate the need to establish a precise market, hypothetical in nature, for the survey approach to be useful.

In Chapter 3--Valuing Public Goods: A Comparison of Survey and Hedonic Approaches, we take up the central issue of validating the survey approach. Although the results of Chapter 2 suggest the survey approach is internally consistent, replicable and consistent with demand theory, no external validation had been undertaken whereby a comparative analysis using another approach independent of the survey had been conducted. Thus, the purpose of this chapter is to report on 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 due to the well defined air pollution problem and because of the existence of detailed property value data. 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 to fair air quality while those in fair areas were asked to value an improvement to 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 based on income and tastes. However, <u>ceteris paribus,</u> 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 associated with air quality improvement from hedonic analysis of the property value data must exceed estimates of household willingness to pay for the 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 be 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 either of the two hypotheses, thereby providing evidence towards the validity of survey methods as a means of determining the value of nonmarket goods.

In Chapter 4--The Advantage of Contingent Valuation Methods for Benefit-Cost Analysis, we address why the survey approach is especially useful in providing information to be utilized in environmental decisions. The chapter is taxonomic in nature discussing why survey methods may often be a superior means of generating data with which to value nonmarket goods. Specifically the issue of the hypothetical nature of the survey technique is addressed. We argue that within the constructs of economic theory, it is wrong to view hypothetical responses as fictional, and that the survey approach is quite often the only technique which can address future events without going through the costly exercise of actually constructing a market.

Chapter 5--An Examination of Benefits and Costs of Mobile Source Control Consistent with Achievement of Ambient Standards in the South Coast Air Basin, is an examination of the benefits and costs of the national ambient air quality standards as applied to all portions of Los Angeles, Orange, Riverside and San Bernardino Counties in southern California. The results set forth are based on the qualified arguments presented in Chapters 24 suggesting that both the survey approach and 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 require emission reductions of the 974 tons/day, 5963 tons/day and 503 tons/day of reactive hydrocarbons, carbon monoxide and nitrogen oxides. It is the share of these emission reductions attributable to on-road mobile source control which was evaluated using benefit-cost analysis.

Benefits were calculated through an examination of housing value differentials attributed to air quality (see Chapter 4). Achieving the ambient air quality standards was consistent with improving the "fair" and "poor" air quality regions to the "good" category as specified in Chapter 3. 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 and 3.0 billion dollars per year, independent of any benefits accruing to agriculture and ecosystems. The share of these benefits associated with on-road mobile source control was estimated to be 1.362.55 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 on-road mobile source controls consistent with a policy sufficient to achieve the ambient standards in 1979 would involve a cost of between .61 and 1.32 billion dollars, with a best estimate of 1.02 billion dollars.

The benefits from on-road 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 are not without some economic justification, though the uncertainty concerning the benefit and cost calculations prevents one from accepting the controls outright. However, on-road mobile controls consistent with the air quality standards cannot be rejected as economically inefficient either. Therefore, although the mid-range benefit estimate exceeds the mid-range cost estimate, the situation is best characterized as highly 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 supported by a solid cost data base.

In Chapter 6--Effects of Air Pollution and Other Environmental Variables on Offered Wages--we report on 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.

Annual benefit estimates from pollution abatement in the two cities are positive according to the calculations made here. 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 <u>household head</u> in the two cities are $426.35 for Denver and $212.60 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.

Chapter 2

VALUING ENVIRONMENTAL COMMODITIES: SOME RECENT EXPERIMENTS

INTRODUCTION

During the past few years, economists have been attempting to apply a variety of techniques to reveal preferences of individuals on nonmarket environmental commodities [Bradford (1970); Bohm (1971); Randall, et al. (1974a); Brookshire, et al. (1976)]. These techniques, in general following Davis (1963), have attempted through a set of questions to obtain bids from individuals which would represent their maximum willingness to pay for a nonmarket commodity. Almost simultaneously, other economists have made substantial contributions to conceptually assessing the demand for nonmarket commodities and public goods [Rosen (1974); Muellbauer (1974); Hori (1975)]. The consumer of nonmarket commodities in these studies is viewed as a utility maximizer who combines purchase of private goods (and use of public goods), constrained by a household technology, to produce a set of desired characteristics [Lancaster (1966)]. Given this basic structure, methods were suggested for calculating implicit prices for the household characteristics and nonmarket goods used or produced by the consumer [Hori (1975)]. This paper is an assessment of six recent experiments which have attempted to reveal preferences for environmental goods, where each experiment in some way utilized a mix of both the techniques and the theory of demand for nonmarket commodities. Each experiment was designed to estimate a nonmarket attribute associated with the environment and also analyze potential biases in the techniques employed. In order to evaluate these studies, a rather general model of the consumer behavior is proposed. Potential biases are then discussed for various methods used to discover environmental preferences. Following this, the six experiments are examined on the basis of their methodological structure and types of biases encountered. Where possible, the issue of replication of results is addressed. In this paper, we do not attempt to evaluate all types of environmental effects or possible ways of measuring them. Rather, a limited set of possibilities is examined both as to technique and type of effect.[1]

Many environmental policy issues involve changes in environmental attributes resulting from population growth and energy development. For example, operation of coal fired electric power plants may significantly reduce visibility and disturb landscapes in addition to inducing possible health effects. Strip mining coal may have substantial detrimental effects on wildlife populations in addition to the expanded demand for wildlife arising from a larger local population. The construction of geothermal plants adjacent to existing forest recreation areas may, through siting and noise, disturb an otherwise pristine, quiet recreation area. Essentially, recreational use and benefits would be changed by these developments but there are no existing markets to adequately price the changes. Similarity, population growth in some urban areas has caused significant problems with photochemical air pollution. If benefit-cost analysis is to be employed for decisionmaking, techniques need to be devised to impute economic values for these and other environmental changes. The six experiments evaluated here are tests to determine the feasibility of deriving implicit prices and/or valuations for the types of changes mentioned above.

The techniques to be examined range from purely hypothetical direct evaluations asking for dollar bids to hypothetical questions asked of households and recreators concerning changes in behavior to enable the imputing of their preferences. In each case, the household was confronted with a possible change in an environmental attribute and asked for a valuation. Since the valuation was contingent on the specific hypothetical change identified (through photographs, brochures and other means), we propose that such approaches be called contingent valuations.[2] Individuals can be queried as to willingness to pay, minimum compensation, evasive behavior, past experiences, current experiences, potential site or activity substitutions, potential expenditure adjustments, income compensation coupled with potential behavioral adjustments, etc. which can be utilized with appropriate theoretical structures to estimate demand curves for environmental attributes.

In some of the experiments, the household valued the change in environmental attribute directly by bidding for alternative provision levels [Brookshire, et al. (1976)]. In others, the individual was not only asked to bid, but also provide information on behavioral adjustments and sale of the environmental attribute [Randall, et al. (1974a); Rowe, et al. (1980); Brookshire, et al. (1980)].

To obtain accurate information for individual valuation of nonmarket environmental commodities can be costly. In many cases to actually derive true values, a “market” must be set in a place where one did not exist and operated to record prices and demands where the environmental attribute is actually purchased or sold. However, to construct and operate such a market may be extremely costly, especially if there are irreversibilities associated with its operation. A less costly approach is to use a contingent valuation study where prices can be imputed without the actual operation of an organized market, but a hypothetical market is structured. However, because of its hypothetical nature, several potential biases may occur. The major types of biases are: (1) strategic bias whereby the individual may attempt to influence the outcome or result by not responding truthfully; (2) information bias, which is a potential set of biases induced by lack of, or type of, information given to the consumer in the contingent market; (3) instrument bias, which is bias introduced by the process or procedures employed to discover preferences; (4) hypothetical bias, which is the potential error induced by not confronting the individual with an actual situation, i.e., an organized market with well-defined prices; or sampling, interview or nonrespondent bias.[3] Clearly, asking someone what they will do or pay a priori is not the same as confronting them with a recognized and well-understood market and observing what they actually pay. It is more analogous to the individual making decisions on contingent events, e.g., if air quality deteriorates, I will move to a cleaner community. Of the list of studies summarized herein, the list directly compares a contingent valuation study with a more traditional property value study to assess the magnitude of these potential biases and attempts to resolve the actual versus hypothetical payment question [Brookshire, d'Arge, Schulze, and Thayer (forthcoming(d))].

A THEORETICAL FRAMEWORK FOR VALUING ENVIRONMENTAL AMENITIES

The variety of empirical approaches used to value environmental amenities, whether examining contingent or actual behavior or market prices, have typically been based on a particular ad hoc theoretical structure. This section attempts to provide a common theoretical basis for the variety of approaches outlined earlier and serve as a focus in evaluating the six experiments presented in later sections. Both Freeman (1979a,b) and Maler (1974) have also examined available approaches from a consistent theoretical perspective.

A general modeling structure must include the possibility of consumer substitution across activities and locations; and must include site or activity specific levels of environmental quality. Individual utility is thus specified as a function of levels of activities, $A_1, \ldots, A_i, \ldots, A_n$; as a function of a composite commodity X, "unaffected" by activity specific environmental quality; and (where the subscripts denote different activities) as a function of environmental quality for each activity, $Q_1, \ldots, Q_i, \ldots, Q_n$, where we take increases in Q_i as increasing environmental quality. Note we can allow possibly different environmental quality levels both by varying Q_i for a specific activity A_i which can occur over many sites or by defining a site specific activity in which case different Q_i's are associated with different sites. Utility is then a quasiconcave function,

$$U(A_1, \ldots, A_n; Q_1, \ldots, Q_n; X) \tag{1}$$

where $\partial U/\partial A_i = U_A^i > 0$, $\partial U/\partial Q_i = U_Q^i > 0$, and $\partial U/\partial X = U_X > 0$ so utility is increasing in A_i, Q_i, and X. Of course, assumptions on the separability of U are obvious, given that environmental quality is related to specific activities in the model." However, we do not pursue that issue here. Rather, we focus on the form of an individual's marginal willingness to pay for environmental quality.

The budget constraint necessary to specify the consumer's optimization problem is given as:

$$Y - \sum_{i=1}^{n} P_i A_i - X \geq 0 \tag{2}$$

or income Y minus the sum of expenditures on activities $\sum_{i=1}^{n} P_i A_i$ (P_i is taken as the price of activity i which may, in fact, represent joint consumption of several market commodities; for example, activities might include driving to work, recreating, shopping, etc.) minus expenditures for the composite consumption commodity X (price for X is taken as unity to simplify the analysis) must be nonnegative.

For a given vector of environmental quality, the household will then choose to allocate activities such that (1) is maximized subject to (2) which in turn implies that:

$$\frac{U_A^i}{U_X} \leq P_i, \quad \left(\frac{U_A^i}{U_X} - P_i\right) \cdot A_i = 0 \quad A_i \geq 0 \quad i = 1,2, \ldots, n \tag{3}$$

or the marginal rate of substitution between activity i and the composite commodity X equals the price of activity i, if that activity is chosen (A_i > 0). We, of course, assume X > 0.

To determine the marginal willingness to pay for environmental quality for a particular activity, for example i = 1, we set utility as given in equation (1) equal to a constant and totally differentiate the resulting expression. By then taking the total differential of equation (2), setting $dQ_i = 0$ for all $i \neq 1$, $dP_i = 0$ for all i, and by using (3) we obtain

$$\frac{U_Q^1}{U_X} = -\frac{dY}{dQ_1} \qquad (4)$$

as the change in income necessary to offset a change in environmental quality for activity 1.[5] If the objective is to determine the marginal willingness to pay for environmental quality (U_Q^1/U_X), one obvious approach is to simply postulate in a survey questionnaire that Q_1 increases by a small amount dQ_1, where market prices are hypothetically held constant, and request information on the contingent willingness of the individual to give up income for an increase in quality (so dY would be negative in this case). This direct approach, however, is open to questions of bias, a topic we take up in more detail later.

A second approach is to actually assume that prices of activities do not change in response to a change in environmental quality. For many recreation situations this may well be a reasonable approximation. For example, if an energy development such as a power plant disrupts a recreation site, recreators may respond by driving further to other alternative sites. If no entrance fees are employed or if such fees are institutionally fixed, if driving costs--the price of gasoline, etc.--and prices of recreation equipment do not change, then the assumption that $dP_i = 0$ for all i appears to be a good one. In that case the marginal willingness to pay can be determined by again setting utility in equation (1) equal to a constant and totally differentiating the resulting expression, by using equation (3) and by assuming $dQ_i = 0$ for all $i \neq 1$ and that $dP_i = 0$ for all i, to obtain:

$$\frac{U_Q^1}{U_x} = -\sum_{i=1}^{n} P_i \frac{dA_i}{dQ_1} + \frac{dX}{dQ_1} \qquad (5)$$

Where prices are known, an estimate of the value of environmental quality can then be obtained empirically by collecting data on dA_i/dQ_1, the compensated change in the pattern of, for example, recreation activities in response to a change in quality, and on dX/dQ_1, the compensated change in expenditures not related to recreation activities. Note that here we assume Q_1 is tied to a specific recreation site. Of course, the change in environmental quality can be hypothetical, resulting in contingent changes in activities, or actual crosssectional or time series data can be employed where environmental quality varies over space or time. In any case, all studies to date focusing on substitution of activities or commodities in response to changes in environmental quality that we are aware of have assumed prices to be fixed.

In contrast to the above approaches, the hedonic approach, focusing on price effects of changes in environmental quality, assumes that P_1, the price associated with A_1 and in turn Q_1, varies, but that all other prices still remain fixed. Thus, again assuming utility is constant and by totally differentiating equations (1) and (2) where $dP_i/dQ_1 = 0$ for all $i \neq 1$, using (3), we obtain:

$$\frac{U_Q^1}{U_X} = A_1 \frac{dP_1}{dQ_1} \qquad (6)$$

where we also assume $dY = 0$ since compensation is achieved at the margin through the hedonic price gradient, dP_1/dQ_1. Thus, individuals are compensated for lower levels of environmental quality by a lower price. As an example of this approach, consider a study which uses differences in property values to value air quality. Serious questions must be raised concerning the reality of the assumptions that other prices remain unchanged in response to differences in air quality. For example, if wages or golf fees vary with air quality levels, property values may not fully capture the willingness to pay for air quality. Note that in this case we assume that Q_1 is environmental quality associated with an activity or activities.

In summary, the marginal willingness to pay of consumers for environmental quality can be determined as shown in our theoretical context by three approaches. First, consumers can be directly asked to provide their marginal willingness to pay, dY/dQ_1. Second, assuming no price changes occur, information can be collected on dA_j/dQ_1 and dX/dQ_1, the substitution of activities and expenditures which occurs in response to a change in environmental quality. From these data one can impute a marginal willingness to pay. Third, assuming all prices but one are invariant, the change in the single remaining price, dP_1, can be used to impute environmental benefits. Of the three approaches, the one which requires the fewest a priori assumptions and minimal data collection is the first, contingent bids derived utilizing survey instruments. However, serious questions of possible bias remain. The next section discusses possible biases in the survey questionnaire approach.

CONTINGENT VALUATION AND BIAS

Economists have argued that valuing public goods through a direct demand revealing process such as a contingent market would yield biased results. The principle theoretical support for this contention is the possibility of strategic bias. However, as survey techniques to elicit contingent behavior or bids have come into use--in part because development of energy resources in formerly pristine environments allows no other techniques to be used-- other types of bias have come to be regarded as just as important. These include information bias, instrument bias, hypothetical bias and traditional problems of sampling, interviewer, and non-respondent bias. This section reviews our current understanding of such biases.

Strategic Bias

Beginning with Samuelson's seminal work on public goods, it has been supposed that direct revelation of consumer preferences for such goods--and, of course, environmental quality is a public good--would be impossible [Samuelson (1954)]. In particular, the free-rider problem would give individuals incentives to misstate their preferences. For example, if nearby residents were asked how much they were willing to pay to clean up the air near a power plant and if they suspected that control costs would be borne by consumers and owners elsewhere, local residents would have an incentive to overstate their willingness to pay. On the other hand, if residents suspected that they would be individually taxed an amount equal to their own willingness to pay, then a clear incentive would exist to understate their own true value, hoping that others would bid more.

Each approach for eliciting willingness to pay will potentially generate its own bias. Thus if recreators are told that the average of their bids to prevent construction of a nearby power plant will be used to set an entrance fee, those individuals who suspect their bid to be greater than the average bid will have an incentive to overstate their willingness to pay. They, in fact, have an incentive to raise the average bid as close as possible to their own true bid. In other words, individuals will have incentives to misstate their own preferences in an attempt to impose their true preferences on others. This will require a substantial amount of information to actually behave in this manner [See Brookshire and Eubanks (forthcoming (a))]. Of course, if the respondents to such a survey do not believe the survey will have any impact on policy or outcomes, then no incentives for bias exists. The hypothetical nature of such surveys may then, in actuality, aid in eliciting bids which are not strategically biased. Alternatively, since payment is not required, a tendency to exaggerate willingness to pay for a preferred outcome might also exist.

Empirical evidence thus far does not support the existence of strategic bias among consumers. Bohm (1971) in an experimental approach utilizing actual payments for public television failed to find strategic bias significantly affecting the outcome. Scherr and Babb (1975) utilized three different mechanisms for valuing public commodities and found little evidence supporting the existence of strategic bias. Smith (1977) in laboratory experiments also failed to find strategic bias "as a significant problem. The case studies to be reported in the next section, where tested for, also do not find strategic bias to be a problem.

Information Bias

Since contingent behavior or valuation is hypothetical, it is clear that answers obtained through surveys are not based on information similar to that which would apply if consumers based answers on real experiences. One is an *ex ante* response while the other is an *ex post* statement.[6] Typically, consumers do reevaluate decisions on the basis of experience and gained knowledge. Thus, an individual or household might respond to a hypothetical decrease in environmental quality at one location with a low bid, thinking that other nearby sites would make good substitutes. However, in a real situation the individual might have found that other sites involved more travel costs and were less satisfactory than imagined. The information presented to the respondent in a survey situation relating to substitution possibilities and alternative costs may well change the stated willingness to pay relative to other types of information. Thus information bias can refer to the structural content of the contingent market being different than the valuation problem at hand. That is, the respondent must be made aware of proposed alternatives in terms of quality or quantity. Other variants of information bias might include giving the respondent information as to how other respondents behaved, whether in the aggregate their bid was sufficient to achieve (or not achieve) the stated goal (i.e., possibly prevention of visibility deterioration) or alternative sequencing of questions.

Instrument Bias

Related to information bias is instrument bias whereby characteristics of the mechanism for obtaining willingness to pay possibly influence the outcome. Two characteristics of the survey bidding approach are vehicles for payment and a starting point for initiation of the bidding process. Studies have recognized that the mechanism used to collect the bid or pay compensation may influence its magnitude [Randall, et al. (1974a)]. That is, if the recreator pays a higher park entrance fee rather than another type of tax, his bid for an environmental attribute may differ. From economic theory, the bid should differ, if the price of the commodity represented by the bidding vehicle changes, provided the recreator's substitution possibilities associated with alternative payment mechanisms are different. When a payment vehicle allows the individual to substitute over a wider range of current commodities purchased, then the bid should be higher or compensation lower than where the range is smaller. Ideally, the bid or compensation should be related to adjustments in disposable income or wealth, where the individual has the greatest latitude for potential substitution. Practically, however, a believable payment mechanism related to income adjustment, in general, cannot be applied. For example, surveys are often taken at recreation sites away from the individual's locale or state. In this case, a wage tax may not be viewed as realistically payable by the recreator. Thus, there is a tradeoff between accuracy associated with a less than ideal method of payment and the believability of the vehicle for payment or compensation. The reduction in substitution possibilities for a more believable payment mechanism is likely to reduce the contingent expenditure or increase the compensation estimate.

A second type' of instrument bias is starting point bias. The contingent valuation approach commences with questions on payment (and/or compensation) for hypothetical changes in environmental attributes. Contingent bidding surveys to date have asked the recreator (or any type of interviewee) a question with a "yes" or "no" answer rather than a question requiring explicit calculations [See Randall, et al. (1974a), Brookshire, et al. (1976)]. It is presumed the recreator can more accurately respond to the yes/no question framework, although to our knowledge, this proposition has not been formally tested for individuals responding to contingent valuation questions. Given the proposition that yes/no responses are desirable, often a starting bid or minimal level of compensation has been suggested. The potential bias arises in suggesting a starting point from at least two possible sources. First, the bid itself may suggest to the individual the approximate range of "appropriate bids." Thus the individual may respond differently depending on the magnitude of the starting bid. Second, if the individual values time highly, he may become "bored" or irritated with going through a lengthy bidding process. In consequence, if the suggested starting bid is substantially different from his actual willingness to pay, the bidding process may yield inaccurate or only roughly approximate results. The effect of these two types of starting point biases may substantially influence the accuracy of contingent valuation and therefore the usefulness of this approach for assessment of environmental preferences.

Hypothetical Bias

The discussion on information bias suggested that the contingent valuation approach will give answers dependent upon the information or "state of the world" described. The contingent valuation approach requires postulating a change in environmental attributes such that it is believable to the individual and accurately depicts a potential change. The change must be fully understandable to him, i.e. , he must be able to understand most, if not all, of its ramifications. The individual also must believe that the change might occur and that his contingent valuation or behavioral changes will affect both the possibility and magnitude of change in the environmental attribute or quality. If these conditions are not fulfilled, the hypothetical nature of contingent valuation approaches will make their application utterly useless.[7] A test of hypothetical bias would require that the perturbation proposed would occur and then the respondents actual reaction would be evaluated in terms of the previous hypothetical statements of willingness to pay. This, however, makes it extremely difficult to measure the extent of hypothetical bias within a contingent experiment since it depends not only on the structure of the experiment, but also on the "uncontrolled" factors of the future.[8]

Other Bias

Any survey approach, including the contingent valuation approach, is subject to sampling bias, non-respondent bias and interviewer bias. Any of these certainly can subject the results of an experiment to question even if all previously mentioned bias are non-existent. Given the acknowledgement of these biases, we will not discuss them in detail here given their wide recognition in the survey literature. However, in discussing the case studies in the next section, the possible existence of these biases will be discussed in each study, where the information is available.

VALUING ENVIRONMENTAL QUALITY: RECENT CASE STUDIES

There have been numerous efforts to apply a variety of techniques for valuing non-marketed goods; public television [Bohm (1971)]; land-form alterations due to strip mining [Randall, et al. (1978)]; air pollution-induced health effects [Loehman, et al. (1979)]; wildlife [Hammack and Brown (1974), Bishop and Heberlein (1979)]; water pollution [Gramlich (1977)]; presentation of river headwaters [O'Hanlen and Sinden (1978) and Sinden and Wyckoff (1976)]; urban infrastructure allocations for expenditures and taxes [Strauss and Hughes (1976) and Cummings et al. (1978)]; airplane safety [Jones-Lee (1976)]; and recreation [Davis (1963)].

This section will summarize in chronological order six studies which have in common the use of a survey technique which had its first empirical application by Randall, et al. (1974a,b). (The Randall, et al. study was the first systematic presentation and empirical implementation of the contingent bidding survey approach which set the stage for further inquiries.) Tracing the methodology development which has occurred through these six studies aids in understanding issues relating to bias problems, replication issues and methodological cross checks. The last study discussed, the South Coast Air Basin Experiment, addresses the question of validation of the contingent market approach by direct comparison of contingent results with a hedonic--market data based-study.

The Four Corners Experiment

The Four Corners Experiment [Randall, et al. (1974a,b)] represented the first empirical application of the survey approach.[9] The roots of the effort can be traced to Davis (1963) and Bohm (1971). The focus of the study was to investigate the impacts of Navajo coal strip mine and the Four Corners electric generating plants in the Southwest region. Specifically, aesthetic benefits of abatement of environmental damage resulting from air pollution (visibility), power lines and land disturbance from mining activities were estimated. As such, the study laid the framework for future contingent valuation studies.

The analysis focused on the design of survey instruments exploring alternative mechanisms within the instruments for eliciting willingness to pay. No bias tests (i.e., hypothetical, information, instrument, interviewer, non-respondent sampling bias tests) were formally reported.

The Lake Powell Experiment[10]

Lake Powell, with an annual visitation now approaching two million visitor days, is an excellent example of the tradeoff between preservation and development. The lake was formed by the filling of Glen Canyon but retains the steep cliffs, rugged terrain features, and scenic vistas one associates with the Grand Canyon, and is now accessible to pleasure boaters and other recreators. Construction of the Navajo coal-fired generating station located at the southern end of Lake Powell was completed in 1976. Another larger plant, the Kaiparowitz Project, was also proposed for construction near Lake Powell and became an issue of substantial public concern.

As part of the Lake Powell experiment, during the summer of 1974, recreators at Lake Powell were interviewed in an attempt to determine the aggregate willingness to pay to prevent construction of the proposed Kaiparowitz plant [See Brookshire, et al. (1976)]. Photographs of the existing Navajo power plant which all of the recreators had seen stacks remain visible more than 20 miles up the lake were shown to recreators both with visible pollution emanating from the stacks and with the stacks alone. Recreators were then asked what entrance fee they would be willing to pay to prevent construction of another similar plant, first, where only pollution would be visible from the lake itself, and second, where both stacks and pollution would be visible.

The analysis of the data focused on strategic bias. As noted above, if recreators believed that a uniform entrance fee might actually be set on the basis of the average bid of the sample to prevent construction or believed that construction plans might be affected by the research results, then “environmentalists” might well bid very high, and “developers” might well bid zero dollars in an attempt to bias the results.[11] A theoretical model of strategic bias was constructed to explain the distribution of observed bids which would likely be bimodal rather than normally distributed if strategic bias was present. The fact that the actual distribution of bids was normally distributed was thus taken as evidence that strategic bias was not present. It was suggested by Brookshire, et al. (1976), that the absence of strategic bias might be due to the hypothetical nature of the experiment--few respondents felt that their answers would affect real world outcomes.

Hypothetical, information and instrument bias were not addressed in this experiment. Experimental biases such as interviewer, non-respondent bias and sampling bias did not appear significant. The interviewers taken separately had means and a distribution of bids that corresponded to the sample population as a whole. In sampling which was randomly conducted for the four principal users of Lake Powell, on the lake, in campgrounds, at motels and in the town of Page, the highest refusal rate for residents was less than one percent.

The remainder of the research was devoted to specifying an econometric model of the bidding game results to estimate income effects by groupre-creators were divided into four categories, developed and remote campers, and visitors to and residents of the nearby town of Page, Arizona. Although the effect of individual income by group on bids was statistically significant at least 99% level, the income effects were all very small. It was demonstrated that both theoretically and empirically the small income effect implied: (1) that a compensated surplus measure would not differ practically from the equivalent surplus measure used in the experiment; and, (2) that income redistribution between groups would not significantly affect the aggregate bid.

The average bid per family or recreator group was $2.77 in additional entrance fees in 1974 dollars, and the total annual bid--which can be interpreted as an aggregate marginal willingness to pay to prevent one additional power plant near Lake Powell--was over $700,000. An important point is that the results show impressive consistencies both with the one previous study [Randall, et al. (1974a)] in the region as well as with the succeeding Farmington experiment discussed below.

The Farmington Experiment[12]

This study reported in Blank, et al. (1977) and Rowe, et al. (1980) attempted to establish the economic value of visibility over long distances for Farmington residents and recreators at Navajo Reservoir. Clearly, the ability to observe long distances is almost a pure public good. In addition, efforts were made to examine the extent of certain biases which the Brookshire et al. (1976) study identified. These were information, strategic, starting point, and instrument biases on compensating and equivalent surplus measures of consumer surplus.

Recreators and residents in the Four Comers Region of New Mexico and Arizona were interviewed. The interviewee was shown a set of pictures depicting visible ranges. Picture set C had a visible range of 25 miles and picture sets B and A were 50 and 75 miles respectively. The pictures represented views in different directions from the same location, the San Juan Mountains and Shiprock.

The first part of the experimental bidding game was structurally similar to that of Randall, et al. (1974a,b) and Brookshire, et al. (1976). A sequence of questions on maximum willingness to pay and minimum compensation were asked via a survey instrument. The second method followed that of Rosen, (1974), Muellbauer (1974), and Hori (1975) in attempting to utilize the household production function. The motivation was to attempt a methodological cross check by collecting market type information via a survey instrument. The contingent behavior component of the questionnaire attempted through contingent changes in time allocation to infer an expenditure function and compensated demand curve, primarily by postulating an exact form of a utility function and estimating a time related household technology [Blank, et al. (1977)]. Thus, the first approach bidding game was an attempt to measure the right-hand-side of equation (4), while the second contingent behavior based on contingent behavioral changes, attempts to measure the components of the right-hand-side of equation (5). These estimates from the contingent bidding and contingent behavior portions of the experiment are not directly comparable because the contingent behavior estimates include residents in addition to recreators which should increase the magnitude of the estimate.

As part of the contingent bidding approach, direct tests were made for strategic bias, information bias, and instrument bias. First, for strategic bias investigation, the survey instrument was structured so the individual was told that he would have to pay the “average” bid, not his own.[13] The presumption was that if his bid were below the mean bid provided by the interviewer and he desired to increase the magnitude of the final aggregate bid strategically, he would bid higher in order to shift the final bid upward. Alternatively, if his goal in bidding strategically was to reduce the final mean bid, he would revise his bid downward. Only in the unlikely case when the individual’s maximum bid is identical to the mean bid would there be no incentive for the individual to change. In only one case was an individual observed acting strategically and he turned out to be an economics professor from the local Junior College! This additional indication along with the results of Brookshire, et al. (1976) suggests that individuals generally do not act strategically, at least in a meaningful manner to bias the outcome of the results.

For information bias, it was suggested to the individual that his or her bid was too low--that the bid was not sufficient to keep power plant emissions at present levels for sustained high quality ambient air. The individual was then asked if he or she would revise the bid. Fully one-third revised their bid when confronted with the possibility that their bid was insufficient. This latter result is indicative of the effect that new information possibly has on bidding behavior.

Analysis was made of various forms of instrument bias, essentially trying to establish influences of various aspects of the contingent market structure. It was observed that the higher the starting bid suggested by the interviewer, the higher the maximum willingness to pay (equivalent surplus) estimates derived from the study. Thus, if the interviewer suggested a bid of $1.00 higher, on the average, individuals would "bid" about $.60 more. Also,the choice of method of payment influenced the magnitude of the bid significantly. Individuals were willing to bid higher when confronted with a "payroll tax" than with an increase in entrance fees. Finally, it was observed that whether or not the individual was given previous information on average bids, has a substantial impact on the maximum bid. We do not wish to suggest these results indicate any final conclusions with regard to the information bias problem with the contingent valuation approach, but they are suggestive that for these approaches to be accurate, one must be very careful with the instrument used for payment and the amount and quality of information given to the interviewee upon initiation of the interview.

Other potential biases--sampling, non-respondent bias and interviewer bias--are also of interest. The sample design attempted a stratified sample with respect to household income, ethnic background, age, sex and resident/ nonresident. After identifying neighborhoods with certain characteristics and times of day appropriate for finding males and females at home, two approaches were utilized in obtaining interviews: randomly going door to door and telephoning to set up an interview time. A significant non-respondent bias might exist for the Farmington resident interviews. Up to 75% of the phone call requests for an interview were rejected and up to 50% of the door to door requests were declined. However, for the recreators' interviews at Navajo Reservoir, less than 5% of the requests for interviewing were declined. Why this disparity for responses between residents and recreators is not known. Finally, no records were kept that would enable an investigation of interviewer bias.

It is interesting to compare results of the Farmington study with previous studies. Randall, et al. (1974a) only reported, and Brookshire, et al. (1976), only obtained equivalent surplus bids. The following comparisons which are presented in Table 1, are, therefore, limited to the equivalent

Table 2.1
COMPARISON OF RESULTS FOR
SOUTHWEST VISIBILITY STUDIES[a]

Non-Market Valuation Studies	Public Good	Vehicle Employed	Yearly Mean Bids		Bid Per Day	
1. Four Corners Experiment (A. Randall, et. al., 1974a,b)	Visibility Spoil banks transmission lines (Aesthetics of the above.)	Sales Tax	$85[e] [4,3119	$50 [3.02]	(N/A)[f]	($1.79)[d] [.19]
2. Lake Powell Experiment (D. Brookshire, et. al., 1976)	Visibility (Aesthetics only)	Access fee	N/A	N/A	$2.95[b] [.20]	($1.52) [.29]
3. Farmington Experiment, (F. Blank, et. al., 1977 and Rowe, et..?]. , 1980)	Visibility (Aesthetics only)	utility bills or wage tax	$82 [9.10]	$57 [4.63]	$2.44[c] [.23]	(N/A)

[a]The Four Corners Experiment and the Lake Powell Experiment only obtained equivalent surplus bids, thus comparisons between studies are limited to sub-samples of the data sets from each study.

[b]Adjusted for 6.6% inflation.

[c]Mean bid for $1.00 starting points in the Farmington Experiment which is the starting point used in the Lake Powell Experiment.

[d]The comparison between the Four Corners Experiment and the Lake Powell Experiment required different comparisons with the Fa.rmington Experiment.

‘The comparisons between the Four Corners Experiment and the Farmington Experiment is for two alternative levels of environmental quality changes.

[f]N/A - No comparison can be constructed.

‘Standard errors in [ ].

surplus bids. Using the sales tax as the instrument, Randall, et al. (1974a), reported yearly mean bids of $85.00 [$4.31][14] for moves from the highest level of environmental damage, situation (A), to situation (C) representing lowest levels of environmental damage; situation (B) represented an intermediate level of damage. A yearly mean bid of $50.00 [$3.02] per household was reported for moves from situation (B) to situation (C). The Farmington experiment yearly mean bids for the most comparable situations were $82.20 [$9.10] and $57.00 [$4.631. If one considers that the Randall, et al. (1974a) figures should be higher as respondents are also bidding on soil banks and transmission lines, these figures are comparable.

The overall mean for situation (A) (good visibility) to (C) (poor visibility) in the Lake Powell Experiment, [Brookshire, et al. (1976)], was $2.77 [$.19] per day. Adjusted for the 6.6% inflation between the time periods of the studies, these values become $2.95 [$.20]. The overall mean for recreationists for the comparable situation in the Farmington Experiment was $4.06 [$1.111, which is considerably different. However, the mean bid was $2.44 [$1.23] when $1.00 starting bids were used in the Farmington Experiment, which corresponds to the Lake Powell starting bid. Thus, while still statistically different, for the same starting bids, the results are much closer. The Farmington Experiment, while not designed as a replication, demonstrated reasonable consistency with other studies. Finally, a comparison of values for similar subsamples between the Four Corners and the Lake Powell Experiments, respectively of $1.79 [$.19] and $1.52 [$.29], also suggest consistency.

The Geothermal Experiment[15]

The Jemez Mountains of New Mexico are both scenic--characterized by colored rock outcropping and forest areas--and a major recreation resource with fishing, campgrounds, hiking trails, and hot springs all located on U.S. Forest Service lands. However, the Jemez Mountains also contain one of the major geothermal resources in the Southwest. Geothermal leases have been let by the U.S. Forest Service on land which is now used solely by recreators.

Both a contingent bidding and a contingent site substitution approach were used to estimate environmental damages to recreators from possible geothermal development [Thayer (forthcoming)]. Recreators were shown both photographs of geothermal development in similar mountainous terrain and a map of the location of possible development relative to recreation areas. Noise levels and emission characteristics were described in detail. A bidding game was then conducted using a uniform entrance fee as the vehicle to prevent development. Additionally, respondents were asked to indicate what their contingent recreation plan would be (what sites would they visit including new substitute sites and how often) if development were to occur. The subsample which responded to the site substitution question, was then also asked what they would bid in the form of a uniform entrance fee to prevent development. Finally, starting point for the bidding game was varied from $1.00 to $10.00 in various subsamples. Thus, the study was structured to test: (1) if contingent bidding and site substitution results were consistent; (2) if information on alternative new substitute sites would affect bidding results; and (3) for starting point bias.

A set of theoretical models were constructed to estimate a consistent measure of willingness to pay to prevent development from two measures: (1) the contingent valuation bidding and; (2) additional travel costs associated with alternative recreation plans. This was an attempt at a methodological cross check.

The interviews were conducted randomly amongst recreators in the Jemez area. It is not known if this resulted in sampling bias. A simple distributional analysis of the data indicated no interviewer bias.

More surprising, however, were the results for information and starting point bias experiments. Neither bias was statistically significant. The obvious question is: Why are these results different from those of the Farmington Experiment, which indicated that both information and starting point would likely be serious problems? The best explanation that can be given at this point is that the value of the change in environmental quality proposed in the two studies was more precisely perceived by respondents in the Geothermal Experiment than in the Farmington Experiment. In other words, respondents could more easily relate the costs to themselves of “losing,” in part a recreation area than they could determine the costs of a change in visibility.

The results of the experiment were as follows: thirty-two percent of the respondents indicated they would no longer visit the Jemez area if development occurred. This resulted in about a 40% contingent decrease in visitation. About 65% of the respondents indicated they would visit alternative sites more frequently, usually the Pecos Forest area. Bids averaged $2.54 per visitor party day while the site substitution measure yielded a range of $1.852.59 depending on the assumed driving cost per mile. The results appear to be consistent for the two approaches and imply an annualized aggregate bid to prevent construction of about $300,000 for a 50 megawatt plant.

The Wildlife Experiment[16]

Through contingent bidding and site substitution approaches, this study attempted to develop a methodology for valuing wildlife experiences. The valuations were developed to enable policymakers to judge which sites should be reserved from energy developments so that energy development would not seriously impinge on wildlife. Hunters and wildlife observers were queried as to their willingness to pay for "encounters" with various types of wildlife. Encounters was chosen as the variable of perturbation. The hypothesis was that the more animals sighted the greater the satisfaction from the hunting experience.[17] The species examined were elk, cottontail, coyote, grizzly bear, bighorn sheep, trout, dipper, and brown creeper. The assumed utility function had as arguments the number of encounters and length of activity. Thus, the study attempted to measure both the left and right-hand-side components of equations (4) and (5). Prices for purchase of private goods for the hunting, fishing, or observation experience were presumed to be constant, which appears, except for inflationary factors, to be a reasonable assumption. A wide variety of surveys were tested utilizing alternative formats and structural components.

A type of instrument bias was observed in that bids were recorded through license fees, access fees, and utility bill adjustments, but difficulties were encountered in convincing some respondents that competition between energy development and wildlife herds would be sufficient reason for utility bill adjustments. Starting point bias was tested for, but was not found to substantially affect the bids on species commonly hunted. Thus, this experiment appears to substantiate the comparison between the Geothermal and Farmington Experiments which led us to propose that the more clearly identified the change in the environmental attribute is, the lower the probability of starting point bias.

Sampling was carried out in Laramie, Wyoming, drawing from hunting and fishing license lists provided by the Wyoming Game and Fish Department. Addresses were drawn randomly from the lists. Refusals by individuals to actually participate in all parts of the study was about 9%.

Interviewer bias was not present at the .05 level of significance. Non-response rates to individual bidding games where an individual permitted an interview but refused to play a particular bidding game under the stated rules ranged from 2% for willingness to pay games to 30% for some willingness to accept compensation games.

Results indicate that, for elk, the average willingness to pay equivalent surplus measure is $54.00 per year to increase expected encounters (i.e. , sightings) from 1 to 5 per day for elk hunting in Wyoming. The average willingness to accept compensating surplus measure for a reduction of 5 to 1 encounters per day of elk was $142.00. Some private clubs which specialize in elk hunting in Wyoming charge entrance fees ranging from $85.00 to $150.00 per year, roughly in the range of the compensating surplus measure for elk encounters obtained though the contingent valuation approach.

Before turning to the last case study, we would like to discuss an issue that has arisen in empirically implementing contingent bidding games. The issue that continually arises is the observed differences between willingness to pay (WTP) and willingness to accept (WTA) measures of welfare change. Willig (1976) derived conditions that suggest upper and lower bounds exist between the measures.[18] However, Gordon and Knetsch (1979) suggest that WTP and WTA differentials are, in fact, substantial. Empirically to date the results have been mixed. In the Four Corners Experiment [Randall, et al. (1976b)] it was noted that "the number of 'infinity' responses is striking" and that WTA answers "generally exceeded the willingness of respondents to pay for environmental improvement." It is suggested that this was not indicative that no amount of compensation was sufficient, but that abatement by the energy industry might be preferred. The Lake Powell Experiment [Brookshire et al. (1976)] derived a WTA measure from WTP responses and found the measures to be close. The Farmington Experiment [Blank, et al. (1977) and Rowe, et al. (1980)] again directly asked compensating measures, finding the WTP and WTA measures statistically different. Over 50% of the respondents in the Farmington study either refused to cooperate or bid infinity. Finally, the Wildlife Experiment [Brookshire, et al. (1976) and Brookshire, et al. (1980)] utilized different formats for obtaining WTP and WTA measures of consumer surplus. Again the results were statistically different. However, when the WTA measures were derived, similar in context to Brookshire, et al. (1976) the values were statistically the same.

What conclusions and explanations can be given for the above results? Differences between a WTP and WTA welfare measures potentially could be due to income constraint consideration, differing property rights structures, failure of the respondent to relate and be able to respond to the contingent market presented, and/or protest "votes" based on ethical considerations. To date, we know of no experiment that has been performed to attempt an explanation or identify which of the above reasons might be correct.

The South Coast Air Basin Experiment[19]

In some Los Angeles neighborhoods, deterioration in air quality has been slight, e.g. , communities adjacent to the Pacific Ocean, while in others, the deterioration has been relatively severe, as measured by concentrations of NO_x or total oxidants.

The previous case studies reported here, while internally consistent, failed to provide a methodological cross check to actual market data. This experiment, in contract, attempted to compare both the left-hand-side (contingent bid) and right-hand-side (hedonic measure of equation (8)). Thus, both a traditional property value study and a contingent valuation were conducted in an attempt to determine if people will actually pay (as exhibited by property values) what they say they are willing to pay. Finally, site substitution information pertaining to activities, location, duration, frequency and expenditures was collected as well.

A shortcoming of the visibility case studies discussed earlier was the potential confounding between health effects of air pollution and aesthetic effects. The contingent bidding and substitution approaches employed in this experiment attempted to value each of these components separately. Aesthetic considerations were represented by alternative levels of visibility, acute health effects by eye irritation and chronic health effects by reduction in life span. Additionally, the population of the South Coast Air Basin has become well informed through the years of the causes of air deterioration, the potential effects, and scope of the problem. Thus in valuing the non-market good, "air quality," the experiment was conducted with reasonably well developed market information for individuals.

In order to insure comparability of results and aid in aggregation, six pairs of neighborhoods were selected at the census tract level. The pairings were made on the basis of similarities of housing characteristics, socioeconomic factors, distance to beach and services, average temperature, and subjective indicators of the "quality" of housing. Thus, for each of the six pairs, an attempt was made to exclude effects on property values of factors other than differences in air quality. Each of the methodologies were implemented in the paired areas. The bidding game was conducted by randomly choosing homes within the paired areas. The air quality levels for the paired areas were determined using monitoring station data in the South Coast Air Basin. Focusing on total oxidants, nitrogen dioxide and total suspended particulates, isopleths were constructed for each pollutant. This allowed "good," "fair," and "poor" air quality regions to be designated for purposes of the experiment.

The data for the property value study, obtained from the Market Data Center,[20] pertained to 719 homes sold in the 12 paired communities from January, 1977 to March, 1978 (note the interviewing was conducted during the latter part of this time interval) and contains information on most important structural and/or quality attributes. Thus, the data was micro level in detail and yielded valuation estimates at the household level. The property value analysis encompassed three separate, and increasingly complex approaches. First, a comparison of average housing values in the sample paired communities, standardizing only for living space was conducted. Second, a linear relationship between a home's sale price and its supply of housing and community attributes was estimated. The value of an improvement in air quality was then deduced from the resulting hedonic housing value equation. Third, following Harrison and Rubinfeld (1978), a hedonic housing equation allowing for nonlinearities was estimated from which the willingness to pay equation, as a function of income and other household variables, was again estimated. This last procedure partly overcomes some of the strict assumptions of the more simplistic approaches such as identical preferences of all individuals.

The contingent bidding and site substitution data of the experiment were collected via a survey questionnaire. The survey questionnaire yielded valuations by individual for aesthetic and health effects. The survey questionnaire was designed to test for strategic, information and starting point biases. The postulated change in air quality was represented both through regional maps showing good, bad and fair air quality areas as-well as by photographs showing typical visibility levels. Two specific forms of information bias were investigated via a health pamphlet. The health pamphlet attempted to determine for a subsample of the respondents if detailed information about health effects would affect bidding and substitution behavior. Strategic (as in Brookshire, et al. (1976)), information and instrument bias were not statistically significant influences upon the results. Also interviewer bias was not present. No records were kept that would enable the testing for nonrespondent bias.

Accounting for factors such as distance to beach and differences in preferences, the property value study gave an estimated average bid of $40.00 per month per household for a 30% improvement in air quality. The bidding results gave an average bid of slightly less than $30.00 per month. Thus, reasonable comparability was obtained between the survey and property value estimates. Given various assumptions of location, income, aggregation by areas, specific housing characteristics and knowledge on health effects of air pollution, both the bidding game and property value studies yielded estimates ranging from $20.00 to $150.00 per month per household for a 30% reduction in air pollution. These results indicate that air quality deterioration in the South Coast Air Basin has had substantial effects on housing prices and that these negative price effects on housing are comparable in magnitude to what people say they are willing to pay for improved air quality.

CONCLUSION

The six case studies summarized above have shown some consistency in results and hopefully further the evaluation of problems in structuring contingent market experiments.

Table 2 presents a brief summary of the characteristics of each experiment. The range of environmental attributes valued is quite large--including visibility, wildlife, health and noise. Four out of six attempted some internal methodological cross check, however, only the South Coast Air Basin Experiment utilized an observed set of market prices for the comparison. Biases do not appear to be an overriding problem. Strategic bias was not observed in any experiment. Vehicle and starting point biases were highly significant in the Farmington Experiment. Starting point bias was not found in any other study. Vehicle bias was significant in the Wildlife Experiment. A probable explanation for these results, which offers advice for future experiments, is that the linkage within the contingent market between the environmental attribute, institutional setting and the bidding instrument must be realistic and be accepted by the respondent or biased results will be obtained. The studies further indicate the need to establish a precise contingent market--the "good" must be well defined.

Possibly the most important result of the studies summarized here is the replication of results utilizing a traditional property value study and a contingent bidding approach. At least for this first test case, individuals do appear to provide contingent valuations comparable to what actual market behavior implies they are willing to pay for an environmental attribute.

Finally, the studies reviewed in this paper are part of what has become an ongoing research tradition. It is thus worthwhile to place these efforts in the context of other recent comparable research. First, both the experimental research reported by Grether and Plott (1979) and that reported by Smith (1977) supports the general conclusion that strategic bias in revealing consumer preferences is not likely to be a major problem. Second, a rather different attempt at validation of a survey approach has recently been conducted by Bishop and Heberlein (1979). A market for repurchasing hunting permits was structured in a "bidding context" and the results are compared to a traditional travel cost methodology. Since no similar efforts have been undertaken utilizing mail surveys and repurchasing plans, the research is not directly comparable to that reported here, Bishop, et al. conclude, somewhat pessimistically, that since their survey approach might overvalue or undervalue goose hunting permits by as much as 60 percent and 55 percent respectively, while the travel cost methodology undervalues by 67 percent, that all of the available techniques show considerable bias and are thus of limited use. We, rather, take an opposing position, and view these results as quite encouraging for the following reason: In many cases, decisionmakers quite simply have absolutely no idea as to the economic value of preserving environmental quality. All evidence obtained to date suggests that the most

Table 2.2
OVERVIEW OF NON-MARKET
VALUATION EXPERIMENTS

Non-Market Valuation Studies	Environmental Attribute Being Valued	Location	Methodological Cross Check	Strategic Bias	Instrument Biases: Vehicle Bias	Instrument Biases: Starting Point Bias	Information Bias
1. Four Corners Experiment (A. Randall, et. al., 1974).	Visibility, spoil banks, transmission lines.	Four Corners Area, South West.	No	N/A[a]	N/A	N/A	N/A
2. Lake Powell Experiment (D. Brookshire, et. al. 1976).	Visibility	Four Corners Area, South West.	No	No	N/A	N/A	N/A
3. Farmington Experiment (F. Blank, et.al., 1977 and Rowe et.al., 1980).	Visibility	Four Corners Area, South West.	Yes	No	Yes[c]	Yes[c]	Yes[c]
4. Geothermal Experiment (M. Thayer, et. al., forthcoming).	Noise, Land Disturbance	Jemez Mountains.	Yes	No	N/A	No[d]	No[e]
5. Rocky Mountain Wildlife Experiment (D. Brookshire, et. al., 1977 and forthcoming).	Encounters with wildlife	Wyoming	Yes	No	Yes[f]	No[f]	N/A
6. South Coast Air Basin Experiment, (D. Brookshire, et. al., 1980).	Visibility, health Effects	Los Angeles Region, California	Yes	No	No[g]	No[g]	No[h]

[a] Not Available - The experiment did not consider either structurally or analytically this form of bias.

[b] Strategic bias tests were defined in Brookshire, et.al. (1976).

[c] Utilizing estimated bid curves the t ratios for these variables were respectively (3.05), (7 98) and (-4.54) where the vehicle variable was 0 = utility bill, 1 = payroll deduction; starting bid variable was either $1, $5, or $10 and information variable was 0 = no prior information, 1 = prior information. See Rowe, et.al. (1980).

[d] Utilizing an estimated bid curve the t ratio was .689 on the starting point variable indicating no significant influence.

[e] Information bias in this study pertained to whether the suggestion of alternative recreation cities would influence the bid.

A standard F-test was utilized with no statistical influence being observed.

[f] A T-test was conducted where the hypothesis that the final value data was influenced by the bidding vehicle (starting bids) was rejected.

[g] A T-test was conducted whereby the acceptance of the hypothesis that the mean bids for all paired areas combined for different bidding vehicles (starting points) are equal implies 1-α=.90 and higher.

[h] Information bias in this study related to alternative sequencing of health and aesthetic information. The test was as in footnote e.

readily applicable methodologies for evaluating environmental quality--hedonic studies of property values or wages, travel cost and survey techniques--all yield values good to well within one order of magnitude in accuracy. Such information, in our view, is preferable to complete ignorance.

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1. Maler (1974) has classified the possibilities for measurement of environmental goods or services into four broad categories: (1) asking individuals what they are willing to pay; (2) voting on the supply; (3) indirect methods based on observations on the relationship between private goods purchased and environmental goods; and (4) estimation of physical damage and evaluation on the basis of observed market prices. In this paper, we analyze methods only within Maler's categories (1) and (3).

2. In the recent literature, one approach within this set has been called "bidding games," [Randall, et al. (1974a); Brookshire, et al. (1976)]. However, because some types of responses are not bids but changes in behavior, e.g., site substitutions or minimum compensation, we prefer the more general "contingent valuations" to identify the set of approaches that directly query the individual for information in a series of hypothetical situations on markets.

3. An alternative listing of explanations for bias and other problems is given in D. Grether and C. Plott, (1979).

4. A detailed form for the utility function compatible with our arguments is $U(G_1(Q_1, A_1), G_2(Q_2, A_2), \ldots; X)$. The G_i can be concave increasing functions for each activity and imply the utility function is weakly separable over locations or activities.

5. This is equivalent to the compensating variation measure of consumer surplus where the initial level of utility is maintained. See, for example, Mishan (1971).

6. See Brookshire and Crocker [forthcoming (b)] for a discussion of the role of information in contingent markets and validity of the consumers response.

7. One survey of air pollution in the late 1960's for Los Angeles which we prefer not to cite asked the question "How much are you willing to pay for less air pollution?" Clearly, this question is too vague and subject

to multiple interpretations as to the change in environmental attribute. Alternatively, a question "How much are you willing to pay for an annual average reduction in oxidant concentrations of .10 parts per million in the seven block radius around Hollywood Boulevard and Vine Street?" may be too specific and not readily understandable by the interviewee. There appears to be a fine line where the general public can fully understand the question posed, yet the question is precise enough to be of scientific usefulness, i.e., be relatable to scientific measures of environmental change.

8. See Brookshire and Crocker [forthcoming (b)] for further discussion.

9. We present this extremely brief summary of Randall's work noting it was the first effort, and to set the stage and focus the discussion for the remaining case studies. See Randall et al. (1974a,b) for a complete discussion of the results.

10. This research was funded by the NSF-RANN Lake Powell Research Project.

11. The average bid concept was introduced in the survey instrument in the following manner; "Let's also assume that all visitors to the area will pay the same daily fee as you . . . ." The use of the terms "environmental" and "developers" is to distinguish two groups who might have widely divergent preferences with respect to environmental commodities.

12. This study was supported by the Electric Power Research Institute (EPRI), Palo Alto, California to the University of Wyoming. EPRI does not assume any liability for the completeness of research, or usefulness of the results.

13. For individuals to bid strategically to achieve a specific outcome when the respondent knows everyone must pay the final bid is extremely difficult. For instance, all previous bids by others must be known, the sample size and if the individual is not the "last" bidder, then future bids must be known. For more discussion see Brookshire and Eubanks [forthcoming (a)].

14. Standard errors in brackets. 15. The research reported here was supported by a NSF grant entitled "An Economic and Environmental Analysis of Solar and Geothermal Energy Sources."

16. Portions of this study were funded by the U.S. Fish and Wildlife Service contract numbers 14-16-0009-77-022 and 14-16-0009-77-003 with the University of Wyoming and parts were sub-contracted to the University of

Kentucky.

17. For a complete discussion of the study see Brookshire, et al. (1977) and Brookshire, et al. (1980).

18. Randall and Stoll (1979) have reformulated Willig's results from price to surplus space.

19. This study was supported by the U.S. Environmental Protection Agency EPA-600/6-79-OOOlb.

20. The Market Data Center is a computerized appraisal service centered in Los Angeles, California.

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CHAPTER 3

VALUING PUBLIC GOODS: A COMPARISON OF SURVEY AND HEDONIC APPROACHES

INTRODUCTION

Although the theory of public goods has progressed rapidly since Samuelson's seminal article (1954), the empirical measurement of the value of (demand for) public goods only recently has received increased attention. Perhaps the best known and most widely accepted empirical approach has been the use of hedonic prices wherein, for example, it is assumed that either wages or housing values reflect spatial variation in public good characteristics of different communities. This indirect approach, based on theoretical work of Tiebout (1956), Lancaster (1966), Rosen (1974) and others has proven quite successful. Among public goods or bads which have been valued using the hedonic approach are climate [Hoch (1974)], air pollution [Anderson and Crocker (1971) and Harrison and Rubinfeld (1978)], social infrastructure [Cummings, et al. (1978)] and other community characteristics such as noise level [Nelson (1979)] and ethnic composition [Schnare (1976)].

An alternative approach is to directly ask households or individuals to state their willingness to pay for public goods using survey techniques. Despite arguments that strategic bias will invalidate survey results, there exists the need for an alternative to the hedonic approach. As an example, consider the case of a remote and unique scenic vista, valuable to recreators, which is threatened by air pollution from a proposed coal fired 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 of a power plant, information on the value of visibility at the site is needed prior to construction for socially optimal decisionmaking on plant location and pollution control equipment. The hedonic approach is unavailable both because the scarcity of local population--as opposed to recreators--makes use of wage or property value data impossible and because scenic vistas may themselves be unique. For these reasons, Randall et al. (1974) first applied survey methods for valuing visibility and other environmental effects of large coal fired power plants in the Four Corners region of New Mexico. Since this initial application, the survey approach has been widely used to value environmental commodities where market data for hedonic analysis is difficult to acquire [see, for example, Brookshire, Ives and Schulze (1976), Rowe, et al. (1980), and Brookshire, et al. (1980)]. Other early attempts to value public goods using the survey approach include Davis (1963), Bohm (1972) and Hammack and Brown (1974).

Although results of using the survey approach for estimating the value of public goods appear to be internally consistent, replicable and consistent with demand theory [see Schulze et al. (forthcoming)], no external validation has been reported (i.e., a comparative analysis using another approach independent of the survey has not been conducted). Thus, the purpose of this paper is to report on 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 because of the well defined air pollution problem and because of the existence of detailed property value data. 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 to fair air quality while those in fair areas were asked to value an improvement to good air quality. Households in good air quality areas were asked their willingness to pay for a region-wide improvement in air quality. The region-wide responses are reported elsewhere [Brookshire, et al. (1980)].

For comparison to the survey responses, data was obtained on 634 single family home sales which occurred between January, 1977 and March, 1978 exclusively in the twelve communities used for the survey analysis. As we show in the next section, households, in theory, will choose to locate along a pollution-rent gradient, paying more for homes in clean air areas based on income and tastes. 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 associated with air quality improvement from hedonic analysis of the property value data must exceed estimates of household willingness to pay for the survey responses, if the survey responses are a valid measure of the value of air quality improvements. Section 3 describes the data analysis and experimental design in more detail.

We also conjecture that the willingness to pay for air quality improvements is greater than zero for residents in our sample communities based on statewide political support for air quality regulation. The State of California, principally in response to the air pollution problem in the Los Angeles Metropolitan area, has led the nation in imposing automobile emissions standards. The automobile industry, under pressure from the California Legislature, installed the first pollution control devises on California cars in 1961. This initial step was followed nationally in 1963. Again, California imposed the first exhaust-emission control regulations in 1966, leading the nation by two years. Over the decade of the 1970's, California has had more stringent automotive emission standards than Federal levels, resulting in higher initial costs and sacrifices in both performance and fuel economy. In spite of these difficulties, political support, as reflected both in the State Legislature and in several administrations, has remained strong for auto emission controls.

In Section 4 the results of the hypotheses tests are presented. As Table 2 illustrates, results of the experiment can be summarized as follows: In the nine census tracts where air quality improvements are possible (poor and fair communities) , we cannot reject our dual hypotheses that, in each census tract, household willingness to pay for air quality improvements, as estimated by surveying households, falls below equivalent property value rent differentials and lies above zero. We view these results as a qualified verification of the survey approach for estimating the value of public goods. Further interpretation of the results is contained in the concluding remarks offered in Section 5.

A THEORETICAL BASIS

The property value and the survey approaches for valuing public goods have received considerable theoretical scrutiny. Property value studies are conceptually based on hedonic price theory as developed by Rosen (1974) and recently summarized by Freeman (1979). The survey approach has been modeled using standard concepts of consumer surplus by Randall et al. (1974), Bohm (1972), and Brookshire et al. (1976) where the latter two analyses also focus on the possibility of strategic behavior. The considerable empirical evidence now available suggests that strategic bias may be of little consequence both in survey work [See Brookshire et al. (1980) and Rowe et al. (1980)] and in experimental economics [See Grether and Plott (1979), Scherr and Babb (1975) and Smith (1977)]. However, other types of bias may still invalidate a survey approach for valuing public goods. It has even been suggested that the survey approach produces “noise” since responses are purely hypothetical and have no necessary connection to actual budgetary decisions.

In this section, a simple theoretical model is developed for comparison of survey responses to a property value study for valuing air quality improvements in the Los Angeles region in order to determine if valid public good measures can be obtained from survey data.

We use the following notation:

Let P = the level of air pollution
X = consumption of a composite commodity excluding housing
C = unit cost or price of the composite commodity X
R = rent or periodic cost of housing
Y = household income

and U(P,X) = household utility, a decreasing function of pollution $U_P < 0$[1] an increasing function of consumption $U_X < 0$.

Each household maximizes utility, U(P,X), subject to the budget constraint:

$$Y - CX - R(P) = 0$$

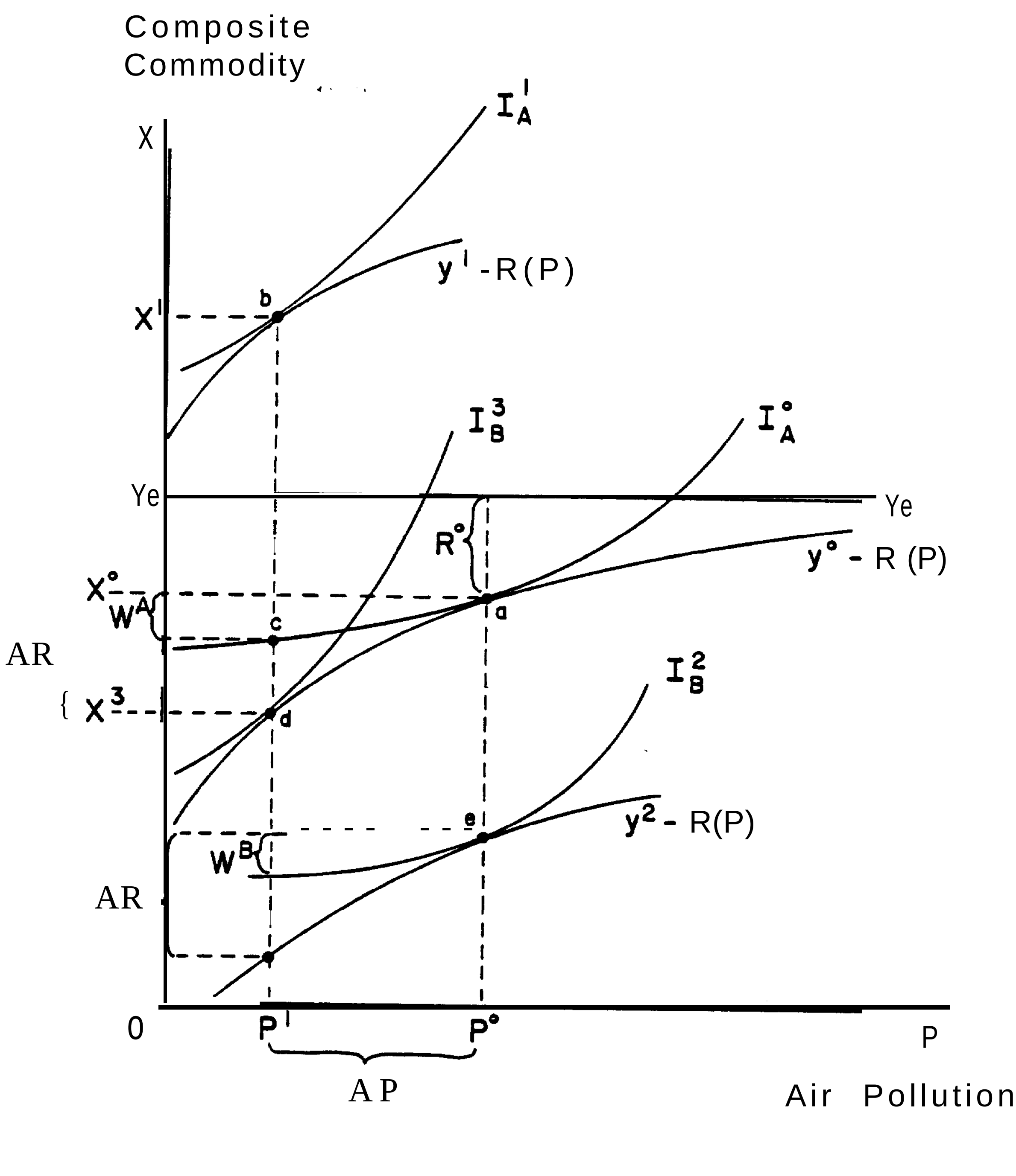
where we assume the existence of a continuous differentiable rent gradient R(P). [See Rosen (1974)] for a complete discussion of the generation and existence of rent gradients. Our model is a simple adaptation of Rosen’s, so we will not elaborate here.) Two distinct choices are modeled: consumption of the composite commodity, X, and that of housing location by pollution level, P. Presumably, lower rents will be paid for homes in more polluted areas, so R'(P)<0.[2] The first order conditions for choice of P and X imply that

$$C \frac{U_P}{U_X} = R'(P)$$

or that the marginal rate of substitution between pollution, P, and the composite commodity, X, valued at the cost of the composite commodity, C, equals the slope of the rent gradient R’(P) at equilibrium location and consumption levels.

Figure 1 illustrates the solution graphically and allows us to structure hypotheses for testing the validity of survey results in comparison to the property value approach. The vertical axis measures the quantity of the composite commodity, X, where we assume that the cost, C, of the composite

Figure 3.1



With identical housing attributes the identical rent differential, AR, exceeds individual willingness to pay, WA and wB.

commodity is unity; i.e., the vertical axis measures dollars as well. Pollution is on the horizontal axis. Given household income Y^o, the budget constraint, shown as $Y^o - R(P)$ in Figure 1, is obtained by vertically subtracting the rent gradient, R(P). Thus, household A with preferences shown by indifference curve I^o_A would maximize utility at point "a", choosing to locate at pollution level P^o, consume X^o and pay rent R^o. If household A's income were to increase to Y^1, the budget constraint would shift vertically to $Y^1 - R(P)$ and the same household would relocate, choosing point "b", at a lower pollution level P^1 with higher consumption, X^1, given tastes as represented by indifference curve I^1_A. Alternatively, another household, B, with income Y^o, but tastes as shown by I^3_B would choose point "d", locating at P^1 as well, but choosing lower consumption X^3. Thus, both tastes and income enter location decisions over pollution levels.

The survey approach used in the Los Angeles metropolitan area to obtain an estimate of the value of air quality asked households how much, at most, they would be willing to pay for an improvement in air quality at the site where they presently live. Thus, the household in equilibrium at point "a" in Figure 1 was asked how much X it would forego to experience P^1 rather than P^o while maintaining the same utility level. Presumably, household A would be indifferent between points "a" and "c" and be willing to pay W^A dollars (or units of X) to achieve a reduction in air pollution of ΔP. Unfortunately, as is illustrated in Figure 1, the budget constraint, $Y^o - R(P)$, obtainable by estimating the rent gradient function, R(P), does not provide information on the bid for improved air quality, W^A. Rather, the change in rent between locations with air quality levels P^o and P^1, ΔR in Figure 1, must, for any household located at "a", equal or exceed the bid, W^A, if the second order conditions for the household optimization problem are generally satisfied. Thus, we can establish an upper bound on the willingness to pay for air quality improvement by examining the rent gradient. For example, if household B had a lower income, Y^2, it would locate at point "e". Even though household B is now located at pollution level P^o like household A, its bid for an air quality improvement ΔP would be W^B, smaller than W^A yet still less than ΔR. Thus, if survey bids are a valid measure of willingness to pay for air quality improvements then ΔR > W.

This hypothesis holds for each household even if we consider the case of multiple housing attributes. Including other attributes such as square footage of the home, bathrooms, fireplaces, neighborhood characteristics, etc., denoted by the vector $\vec{Z}$, the model is revised as follows:

$$\max U(\vec{Z}, P, x)$$

$$\text{St. } Y - Cx - R(\vec{Z}, P) = 0$$

with first order conditions [3]

$$\frac{U_P}{U_X} = R_P(\vec{Z},P)$$

and

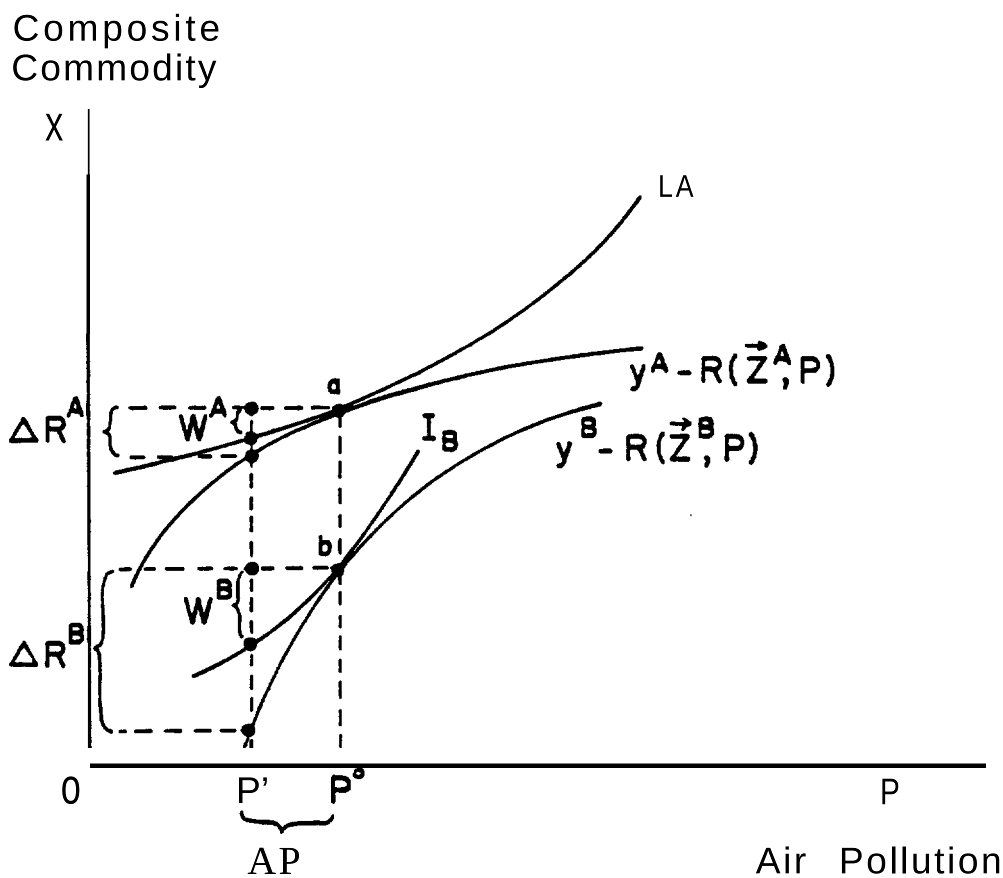
$$\frac{U_{\vec{Z}}}{U_X} = R_{\vec{Z}}(\vec{Z},P).$$

These first order conditions constitute, along with frequency distributions for housing characteristics and household preferences, a system of partial differential equations which solve for $R(\vec{Z},P)$.[4] Thus, a hedonic rent gradient is defined for pollution, P, and other household characteristics, $\vec{Z}$, as well.

As is illustrated in Figure 1, in which housing characteristics other than pollution are not incorporated, budget constraints for different households are obtained by vertically shifting the same rent gradient. Thus, all households face the same rent differential ΔR for a change in pollution level ΔP even though willingness to pay for that change may differ, i.e., $W^A \neq W^B$. However, turning to Figure 2, household A, located at P°, may occupy a house with attributes $\vec{Z}^A$ while household B also located at P° may occupy a house with a different set of attributes $\vec{Z}^B$. Household A, with income Y^A, would then face a rent gradient like that shown in Figure 2 defined by $R(\vec{Z}^A, P)$ and choose point "a", but household B with income Y^B, would now face a different rent gradient of $R(\vec{Z}^B, P)$ and choose to locate at point "b". Therefore, households. with different housing characteristics may face different rent gradients over pollution when projected in the (X, P) plane. In general, ΔR, unlike the case shown in Figure 1, will no longer be constant across households at the same location. However, for each household i (i = A, B in Figure 2), it is still true that the rent differential, ΔR^i, for a change in pollution ΔP, calculated for the fixed vector of housing characteristics $\vec{Z}^i$, will exceed that household's willingness to pay, W^i, for the same change in pollution level at the same location. Note that households were asked their willingness to pay with the specific assumption that they remained in the same house and location. Thus, $\vec{Z}^i$, for a particular household was truly fixed - allowing the simple analysis in the (X,P) plane as shown in Figure 2.

The first hypothesis for testing the validity of the survey approach can be constructed as follows: for each household i in a community, $\Delta R^i \geq W^i$. It then follows that in each community the average rent differential across households, $\overline{\Delta R}$, must equal or exceed the average willingness to pay $\overline{W}$ for an improvement in air quality. In other words, if survey bids are a valid measure of willingness to pay, then for each community in our sample, $\overline{\Delta R} \geq \overline{W}$, i.e., average willingness to pay cannot exceed the average rent differential. Our second hypothesis is that, given the political history of air pollution control in the State of California as described in the introduction, mean bids

Figure 3.2



With differing housing attributes across households each individual rent differential exceeds that households willingness to pay.

in each community are nonnegative, $W > 0$.

Our dual test of the validity of survey measures must remain somewhat imprecise because hedonic rent gradients themselves only provide point estimates of the marginal rates of substitution (slopes of indifference tunes) between pollution and other goods (money) for individuals with possible differing tastes and income. One does not have information necessary to estimate, for example, the shape of 1°_{A} in Figure 1 solely on the basis of the slope of the budget constraint, $R'(P^{\circ})^{A}$, at point "a". Attempts to estimate individual willingness to pay (W^{A} in Figure 1) from hedonic rent gradients must thus introduce strong assumptions about the nature of preferences. (See, for an example of an hedonic approach which derives willingness to pay by making such assumptions, Harrison and Rubinfeld [1978].

SAMPLING AND DATA ANALYSIS

The previous section has presented a theoretical framework for a comparison between the survey technique and the property value approach for valuing public goods. In order to empirically implement the comparison, the two approaches require a consistent sampling procedure. This section describes the sampling procedure and results of the separate studies.

Sampling was restricted to households within the Los Angeles metropolitan area. The first concern was air pollution data. Air monitoring stations are located throughout the Los Angeles area providing readings on nitrogen dioxide (NO_2), total suspended particulate matter (TSP) and other pollutants. The objective was to relate as closely as possible the readings of two constituents of air pollution (NO_2 and TSP) to census tracts used both for the property value and survey studies. The air shed was divided into the following air quality regions: "good" (NO_2 < 9 pphm) (TSP < 90 $\mu g/m^3$); "fair" (NO_2 911 pphm) (TSP 9110 $\mu g/m^3$); and "poor" (NO_2 > 11 pphm) TSP > 110 $\mu g/m^3$). Improvements from poor to fair and fair to good across the region are each associated with about a 30% reduction in ambient pollution levels. Consideration was given to wind patterns and topography of the area in making these distinctions.

Many variables may affect the value households place on air quality. To control for as many of these as possible in advance of the actual experiment, the sample plan identified six community pairs where each pair was relatively homogeneous with respect to socioeconomic, housing and community characteristics, yet allowed for a significant variation in air quality.[5]

The property value analysis attempts to provide external validation for the survey approach. The absence of such validation explains in our view, the lack of general acceptance of survey techniques. The objective, then, is to estimate the hedonic rent gradient $R(\vec{Z}, P)$ and calculate rent differentials associated with the poor-fair and fair-good air quality improvements for sample census tracts. These results are then utilized for comparison to the survey results.

A hedonic rent gradient was estimated in accordance with literature as recently summarized by Freeman (1979).[6] Housing sale price is assumed to be a function of housing structure variables (living area, bathrooms, fireplaces, etc.), neighborhood variables (crime rate, school quality, population density, etc.), accessibility variables (distance employment to centers and beach) and air quality as measured by total suspended particulate (TSP) or nitrogen dioxide (NO_2).[7] The primary assumption of the analysis is that variations in air pollution levels as well as other household, neighborhood and accessibility attributes are capitalized into home sale price. Implicit or hedonic prices for each attribute are then determined by examining housing prices and attribute levels.

The property value analysis was conducted at the household level in order to provide an appropriate comparison to the survey instrument. Thus, the household data used were at the micro level of aggregation and include a large number of characteristics.[8] Data was obtained for 634 sales of single family homes which occurred between January, 1977 and March, 1978 in the communities used for the survey analysis. In addition to the immediate attributes of the household, variables which reflected the neighborhood and community were included to isolate the independent influence of air quality differentials on home sale price.

As indicated by Maler (1977) even under the presumption of correct model specification, estimation of a single equation hedonic rent gradient may be hindered by severe empirical difficulties, primarily multi-collinearity. With respect to this problem, in each of three data categories--household, neighborhood, and air quality--multicollinearity forced the exclusion of variables and the usage of proxy variables. For instance, collinearity between number of rooms, number of bedrooms and living area as quantitative measures of house size allowed the use only one--living area which serves as a proxy for all. Further, since housing density and population density measure essentially the same phenomenon, only the former is used in the estimated equations. The estimation procedure was not able to separate out the independent influence of each air pollutant. Thus, only one pollution measure, either NO_2 or TSP, was utilized to describe the level of air quality. In order to provide information concerning the sensitivity of our analysis, results are presented for each of these pollutants. Finally, contrary to expectation a collinearity problem did not exist between distance from beach and air pollution. This can be attributed, in part, to the success of the sample plan in isolating the effects of air quality.

Two alternative nonlinear specifications are presented in Table 1 alternatively using NO_2 or TSP to represent pollution level.[9] A number of aspects of the equations are worth noting.

First, approximately 90% of the variation in home sale price is explained by the variation in the independent variable set. Second, with only a minor exception, all coefficients possess the expected relationship to the dependent variable and are statistically significant at the one percent level. The exception is the crime rate in both the NO_2 and TSP equations. Third, in their respective equations, the log form of the pollution variables have the expected negative influence on sale price and are highly significant. The estimated relationship between house sale price and pollution is therefore consistent with the graphical analysis of Section 2; that is, the rent gradient is convex from below in the pollution/dollars plane. Finally, the stability or relative insensitivity of the regression coefficients to the particular pollution variable indicates that individuals have an aversion to pollution in general rather than to any one pollutant.

Estimation of the rent gradient was also completed using other forms of the pollution variables (linear, squared, cubic). Whereas the squared and cubic terms did not demonstrate statistical significance, the first order terms performed only marginally worse than the log formulation. Rent differentials have also been calculated for these and other forms with results nearly identical to those presented here.

The next step was to estimate the rent differential ΔR_i for each individual household for each census tract. The rent differential specifies the premium an individual household would have to pay to obtain an identical home in the next cleaner air region (poor to fair for six communities, fair to good for three communities). Due to the estimated functional form of the rent gradient, the calculated rent differential is dependent upon the value of all other variables.[10] The average home sale price change based on individual data in each census tract associated with an improvement in air quality, _ceteris paribus,_ is shown in column two of Table 2 of the next section. Column one of Table 2 lists communities by air quality level. The table only shows for the log-linear NO_2 equation since, as noted above, other specifications give nearly identical results. The figures shown are derived by evaluating the hedonic housing expression, given the household's characteristics, for a pollution change from poor to fair or fair to good as the case may be. The resulting sale price differential is then converted to an equivalent monthly payment through the standard annualization procedure and

Table 3.1

Estimated Hedonic Rent Gradient Equations[a]

Dependent Variable = Log (Home Sale Price in $1,000)

Independent Variable	NO_2 Equation	TSP Equation
Housing Structure Variables		
Sale Date . . .	.018591 (9.7577)	.018654 (9.7727)
Age	-.018171 (2.3385)	-.021411 (-2.8147)
Living Area	.00017568 (12.126)	.00017507 (12.069)
Bathrooms	.15602 (9.609)	.15703 (9.6636)
Pool	.058063 (4.6301)	.058397 (4.6518)'
Fireplaces	.099577 (7.1705)	.099927 (7.1866)
Neighborhood Variables		
Log (Crime)	-.08381 (-.5766)	-.10401 (-1.9974)
School Quality	.0019826 (3.9450)	.001771 (3.5769)
Ethnic Composition -(Percent White)	.027031 (4.3915)	.043472 (6.2583)
Housing Density	-.000066926 (9.1277)	-.000067613 (-9.2359)
Public Safety Expenditures	.00026192 (4.7602)	.00026143 (4.7418)
Accessibility Variables		
Distance to Beach	-.011586 (-7.8321)	-.011612 (7.7822)
Distance to Employment	-.28514 (-14.786)	-.26232 (14.158)
Air Pollution Variables		
log (TSP)		-.22183 (-3.8324)
log (NO_2)	-.22407 (4.0324)	
Constant	2.2325 (2.9296)	1.0527 (1.4537)
R^2	.89	.89
Sum of Squared Residuals	18.92	18.97
Degrees of Freedom	619	619

[a] t - Statistics in Parentheses

Table 3.2

Tests of Hypotheses

Community	Property Value Results[a]		Survey Results		Tests of Hypotheses	
	$\overline{\Delta R}$ (Standard Deviation)	Number of Observations	$\overline{W}$ (Standard Deviation)	Number of Observations	t-statistics $\mu_{\overline{W}} > 0$[b]	t-statistics $\mu_{\overline{\Delta R}} \geq \mu_{\overline{W}}$[c]
Poor - Fair						
El Monte	15.44 (2.88)	22	11.10 (13.13)	20	3.78	1.51
Montebello	30.62 (7.26)	49	11.42 (15.15)	19	3.28	7.07
La Cañada	73.78 (48.25)	51	22.06 (33.24)	17	2.74	4.10
Sample Population	45.92 (36.69)	122	14.54 (21.93)	56	4.96	5.54
Fair - Good						
Canoga Park	33.17 (3.88)	22	16.08 (15.46)	34	6.07	5.07
Huntington Beach	47.26 (10.66)	44	24.34 (25.46)	38	5.92	5.47
Irvine	48.22 (8.90)	196	22.37 (19.13)	27	6.08	5.08
Culver City	54.44 (16.09)	64	28.18 (34.17)	30	5.42	11.85
Encino	128.46 (51.95)	45	16.51 (13.38)	37	7.51	12.75
Newport Beach	77.02 (41.25)	22	5.55 (6.83)	20	3.63	7.65
Sample Population	59.09 (34.28)	393	20.31 (23.0)	186	12.02	14.00

[a] Rent differentials for the hedonic housing equation in which log (NO_2) is the relevant pollution variable are presented here. Essentially identical results are obtained using NO_2, TSP or log (TSP).

[b] The hypotheses to be tested were $H_0: \mu_{\overline{W}} = 0; H_1: \mu_{\overline{W}} > 0$. All test statistics indicate rejection of the null hypothesis at the 1% significance level.

[c] The hypotheses to be tested were $H_0: \mu_{\overline{\Delta R}} \geq \mu_{\overline{W}}; H_1: \mu_{\overline{\Delta R}} < \mu_{\overline{W}}$. All Test statistics indicate that the null hypothesis could not be rejected even at the 10% significance level.

division by twelve.[11] Since our hypothesis test is posed in terms of the average rent differential in the relevant communities, then a community mean and standard deviation are calculated. Column three of Table 2 shows the number of homes for which data was available to calculate average rent differentials and standard deviations for each community. Monthly rent differentials ranged from $15.44 to $45.92 for an improvement from poor to fair air quality and $33.17" to $128.46 for an improvement from fair to good air quality. The higher figures in each case are associated with higher income communities. Again, these average differentials should provide an upper bound for the survey results.

The survey approach followed the work of Davis (1963) and Bohm (1972) in gathering the information necessary for estimating a Bradford (1972) bid curve. The approach involves the establishment of a hypothetical market via a survey instrument. Through the work of Randall, et al., (1974) and Brookshire, et al., (1976), the necessary structure for constructing a hypothetical market for the direct determination of economic values within the Hicksian consumer surplus framework has been developed. The survey reported here is consistent with this previous literature.

The hypothetical market was defined and described both in technical and institutional detail. The public good (air quality) was described by the survey instrument to the respondent in terms of easily perceived levels of provision such as visual range through photographs[12] and maps depicting good, fair and poor air quality levels over the region. Respondents had little difficulty understanding the levels of air quality represented to them because of the sharp pollution gradient across the region.

Payment mechanisms[13] were specified within the survey instrument and the respondent was asked to react to alternative price levels posited for different air quality levels. In every case the basis for the bid for better air quality was the existing pollution situation as determined by location of their home shown on a map of the Log Angeles metropolitan area which depicted regional air quality levels. Various starting points for the bidding prices and differing information structures were included in the survey format. Biases from alternative starting points and information structures were not present in the results [See Brookshire, et al. (1980)].[14]

The survey was conducted over the period of March, 1978. A total of 290 completed surveys were obtained for the above mentioned areas. Sampling was random within each paired area.[15]

Table 2 in the next section presents the mean bids and standard deviations and number of observations in Columns four and five respectively for each community for an improvement in air quality. Two types of bids are presented: proposed improvements from poor to fair air quality and from fair to good air quality. In poor communities--El Monte, Montebello and La Canada--the mean bids ranged from $11.00 to $22.06 per month. For the fair communities--Canoga Park, Huntington Beach, Irvine, Culver City, Encino and Newport Beach communities--the mean monthly amounts range from $5.55 to $28.18 to obtain good air quality.

TEST OF HYPOTHESES

The previous sections have described a theoretical structure and two different empirical estimation techniques for determining the value of urban air quality improvements in the Los Angeles metropolitan area. The theoretical relationship between the valuation procedures ($\overline{\Delta R} \geq \overline{W}$) and the hypothesis that survey bids are non-zero ($\overline{W} > 0$) are tested in this section.

Table 2 presents the community average survey bids (column four) and corresponding rent differentials (column two). As is indicated, in each community the sample survey bids are non-zero and less than the calculated rent differentials in absolute magnitude. This establishes that the survey bid bounds are consistent with our theoretical arguments but does not indicate statistical significance, which is provided below.

With respect to the test of equality of mean survey bids to zero, Table 2 (column six) presents the experimental results. The calculated t-statistics indicate rejection of the null hypothesis (that the population mean, $\mu_{\overline{Y}}$ equals zero at the one percent level in every community sampled.) These results are in accordance with the political situation of the region and indicate that individual households are willing to pay amounts significantly greater than zero for an approximate 30% improvement in air quality.

The comparison of the survey bids to the estimated rent differentials is presented in Table 2 (column seven). In this instance the compound hypothesis that population average rent differential ($\mu_{\overline{WR}}$) equals or exceeds the population average survey bid ($\mu_{\overline{\Delta}}$) is again tested using the t-statistic. Rejection of the null hypothesis requires that the calculated t-statistics be negative and of sufficient magnitude.[16] The standard t-test calculations (column seven, Table 2) imply that the hypothesis $\mu_{\overline{\Delta R}} \geq \mu_{\overline{W}}$ cannot be rejected for the population means $\mu_{\overline{R}}$ and $\mu_{\overline{W}}$ even at the 10% critical level. Although we present only the results for the hedonic housing equation in which log (NO_2) is the pollution measure, these results remain essentially unchanged for all communities, for all estimated hedonic rent gradients, regardless of the variable (NO_2 or TSP) utilized as a proxy for the general state of air quality. The results then are quite insensitive to the particular hedonic model specification, providing a degree of generality to the results.

The hypotheses tests indicate that the empirical analysis is entirely consistent with the theoretical structure outlined above. This conclusion, when combined with the absence of any identified biases [see Brookshire, et al. (1980)] suggests that survey responses yield estimates of willingness to pay for environmental improvements in an urban context consistent with a hedonic- market analysis. A further implication is that individual households demonstrated a non-zero willingness to pay for air quality improvements rather than free riding. This conforms to the previous survey resuits of Brookshire, et al. (1976) and Rowe, et al. (1980) as well as the experimental work of Scherr and Babb (1975), Smith (1977) and Grether and Plott (1979) concerning the role of strategic behavior. This seems to indicate that the substantive effort to devise a payment mechanism free of strategic incentives for consumers [see Groves and Ledyard (1977)] has been directed towards solving a problem not yet empirically observed. However, the conclusions of this experiment are not without qualifications. In the next section possible limitations of survey analysis and conclusions concerning the efficacy of employing surveys to value a wide range of non-market commodities are discussed.

CONCLUSION

There are a number of limitations in generalizing our results to all survey work. First, this experiment was conducted in the South Coast Air Basin where individuals have both an exceptionally well-defined regional pollution situation and a well-developed housing value market for clean air. The effect of clean air on housing values appears to be exceptionally well understood in the Los Angeles metropolitan area. Thus, the Los Angeles experiment may be a special case in which an informed populace with market experience for a particular public good allowed the successful application of the survey approach. In particular, situations where no well-developed hedonic market exists may not be amenable to survey valuation. Biases due to lack of experience must then be considered a possibility. However, existing studies by Randall et al. (1974) and Brookshire et al. (1976) and Rowe et al. (1980) of remote recreation areas certainly suggest that survey approaches provide replicable estimates of consumer's willingness to pay to prevent environmental deterioration, without prior valuation experience.

In summary, this paper set out to both theoretically and empirically examine the survey approach and to provide external validation for survey analysis. The theoretical model described in Section 2 predicts that survey responses will be bounded below by zero and above by rent differentials derived from the estimated hedonic rent gradient. In order to test the dual hypotheses a survey and a traditional analysis of the housing market were undertaken. Each was based upon a consistent but random sampling procedure in the Los Angeles Metropolitan area. The empirical results do not allow the rejection of either of the two hypotheses, thereby providing evidence towards the validity of survey methods as a means of determining the value of public goods.

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1. Alternatively we could define the utility function U(-P, X) which would be an increasing quasi-concave function of both arguments.

2. Primes or subscripts denote derivatives or partial derivatives respectively throughout the paper.

3. The second expression is, of course, a vector of conditions, one for each attribute.

4. For a continuous model one could specify a taste parameter in the utility function and specify a distribution of households over that parameter. To complete a closed model one also needs the distribution of housing units over characteristics.

5. The paired areas with associated census tract marker and air quality level are respectively (1) Canoga Park - #1345 - fair/El Monte - #4334 poor, (2) Culver City - #2026 - fair/Montebello - #4301.02 and part of #5300.02 - poor, (3) Newport Beach - central #630.00 - fair/Pacific - northeast portion of //2627.02 and southwest intersection good; (4) Irvine - part of #525 - fair/Pales Verdes - portion of good; (5) Encino - portion of #1326 - fair/La Canada - south-central portion of #4607 - poor; (6) Huntington Beach central portion of #993.03 poor/Redondo Beach - eastern portion of #6205.01 and #6205.02 - good. For a map showing the monitoring station locations in relation to the paired sample areas and the air quality isopleths see Brookshire, et al. (1980).

6. The estimation of a hedonic rent gradient requires that rather restrictive assumptions are satisfied. For Example, Maler (1977), has raised a number of objections to the hedonic property value approach for valuing environmental goods. These include the possibility that transaction costs (moving expenses and real estate commissions) might restrict transactions leaving real estate markets in near constant disequilibrium; and that markets other than those for property alone might capture part of the value of an environmental commodity. The first

of these criticisms is mitigated by the extremely fluid and mobile real estate market of the late 1970's in Los Angeles, where rapidly escalating real property values increased homeowner equity so quickly that "house jumping" became financially feasible. The second of Maler's concerns, that other prices, e.g., golf club fees and wages capture part of the willingness to pay can be addressed empirically. For example, attempts to test if wages from our survey data across the Los Angeles area reflected differences in pollution level produced negative results.

7. Note that we use sale price or the discounted present value of the flow of rents rather than actual rent as the dependent variable. Given the appropriate discount rate the two are interchangeable.

8. Housing characteristic data was obtained from the Market Data Center, a computerized appraisal service with central headquarters in Los Angeles, California.

9. Although the nonlinear equations provide large t values on the air pollution coefficients, the coefficients on the pollution variables in the linear equations possessed the expected relationship and were significant at the 1% level. Also, the calculated rent differentials associated with the linear specifications were larger than those from the nonlinear equations.

10. It should be noted that the nonlinear estimated equations will give biased but consistent forecasts of rent differentials. However, the linear estimated equations in all cases forecast larger rent differentials than the nonlinear estimated equations presented here.

11. A capital recovery factor equal to .0995 which corresponds to the prevailing .0925 mortgage rate in the January, 1979 - March, 1978 period is used.

12. In developing photographs, two observational paths from Griffith Observatory in Los Angeles were chosen: (1) toward downtown Los Angeles, and (2) looking down Western Avenue. The approximate visibility (discernible objects in the distance, not visual range) for poor visibility was 2 miles, for fair visibility 12 miles, and for good visibility 28 miles.

13. Payment mechanisms are either of the lump sum variety, or well specified schemes such as tax increments or utility bill additions. The choice in the experimental setting varies according to the

structure of the contingent market.

14 Questions have been raised as to problems of biases in the survey approach. Strategic bias (i.e., free rider problems), hypothetical bias, instrument bias all have been explored. Generally speaking, problems of bias within the survey approach have not been prevalent. For a general review of the definition of various biases and results of different experiments see Schulze et al. (forthcoming) and for investigations of strategic bias utilizing other demand revealing techniques see Scherr and Babb (1975) and Smith (1979).

15. Interviewer bias was not present. No records were kept that would enable the testing for non-respondent bias.

16. For instance, rejection of the null hypothesis ($\mu_{A-R} \geq \mu_{W}$) at the one percent level would require a calculated t-statistic less than -2.326 given a large number of observations. Since none of the calculated t-statistics are negative the null hypothesis cannot be rejected [See Guenther (1973)].

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CHAPTER 4

THE ADVANTAGES OF CONTINGENT VALUATION METHODS FOR BENEFIT-COST ANALYSIS

INTRODUCTION

Historically, policy decisions regarding the alteration or manipulation of natural systems have relied to some extent upon the methods of benefit-cost analysis to provide information about the efficiency attributes of selected alternatives. Construction programs of the Army Corps of Engineers and the Bureau of Reclamation are probably the best examples. These programs have usually had explicit market price information on the value of additional water or electricity that could be used to analyze the benefits and costs. When non-marketed goods, such as loss of wildlife habitat, were to be influenced by the project, they were not formally incorporated into the benefit- cost analysis.

A developing emphasis, however, on valuing non-marketed goods and incorporating these values into formal benefit-cost analyses can be traced in part to recent Federal and State legislation oriented toward environmental quality regulation and preservation. Quantification of non-market benefits to establish the economic efficiency of regulatory decisions is required, for example, under the Occupational Safety and Health Act of 1970, the Safe Drinking Water Act, the Clean Air Act Amendments of 1977, the Toxic Substances Control Act, the Endangered American Wilderness Act, and others.

The implications of this requirement for policy and for benefit-cost analysis are severe. First, many of the key components of the benefits are several steps removed from a direct relation with a marketed good. When considering potential degradation of a Class I visibility area such as the Grand Canyon National Park, how is value to be placed on the scenic beauty of the colors and the pristine visibility? What is the value of being able to see 120 miles versus 90 miles? Additionally, what are the benefits of permanently preserving ancestral habitat for bighorn sheep versus utilization of the area for a natural resource development when both preservation and development can benefit current and future generations? What are the benefits of reduced risk to life? What are three less years of life worth, or 20 illness days per year? These types of questions either implicitly or explicitly are raised by today's legislative mandate. Thus, recent legislative history asks of benefit-cost analysis to assess various trade-offs for which many of the key value components of the tradeoff process are not readily observable in the market place. Further, many of the valuations necessary do not have readily observable market surrogates available to impute the value of non-market commodities. For instance, property value studies have been proposed as a manner to impute the value of air quality in urban regions. How could such an approach possibly work in the Four Comers region of the sparsely populated Southwest? How could travel cost methodologies possibly impute the value of critical habitat preservation? The answer, of course, is that they cannot.

An additional issue in valuing non-market environmental goods is that the policy alternatives frequently involve the provision of some quantity of the good or the restructuring of property claims on the good in a fashion outside the realm of recent historical experience. If behavior and valuations are sensitive to these institutional and quantity perturbations, retrospective observations have little to offer to the benefit-cost analyst. For example, the development of a massive synthetic fuel industry in the Rocky Mountain area could, if atmospheric emissions are uncontrolled, cause major deteriorations in the area's atmospheric visibility. However, because there has historically been little degradation of visibility in the area, that record which could allow the economic value of any change to be empirically determined does not exist. To acquire the record, one must either develop the synthetic fuels industry, hoping that the development can be reversed if the value of atmospheric degradation proves excessive, or undertake small scale experiments that generate data by artificially perturbing the essential features of the problem. On the presumption that the former course can be exceedingly expensive., we present heuristic arguments for the use of experiments. Our attention is focused upon contingent valuation studies of complex natural processes rather than upon carefully controlled laboratory studies. Plott (1979) has recently written a valuable review and defense of laboratory studies.

Contingent valuation studies are distinguished from traditional benefits assessment practices by their use of survey questionnaires to acquire the data for analysis. Despite a paucity of empirical evidence to support or deny its significance, the systematic misrepresentation of preferences is widely recognized among economists as being potentially a serious disadvantage of using survey questionnaires for valuation purposes. Our purpose is to raise the possibility that economists, by their near-exclusive devotion to the strategic behavior problem, may, at their own apparently unrecognized cost, have neglected many of the analytical and empirical advantages to be reaped through the use of survey instruments to acquire valuation information. We will examine these advantages in terms of the contribution survey questionnaires can make to filling the informational void the policymaker now often faces, and in terms of the conformity of their data-generating process with the economic-theoretic foundations of benefit-cost analysis. Any thorough assessment of the relative reliabilities and validities of data generated by survey questionnaires'and by observed behavior must weigh these advantages.

CONTINGENT VALUATION APPROACHES

The key to contingent valuation approaches to valuing a non-marketed good is the construction of a hypothetical market for that good. The procedure is as follows:

a. The non-market commodity is described in quantity, quality, location and time dimensions. Various types of supplementary information including maps and photo graphs are introduced when appropriate.

b. The rules of operation of the hypothetical market are established. Then a representation of the available quantity of the environmental good is perturbed and the respondent is asked to state willingness-to-pay or required compensation, or the activity substitutions and expenditure adjustments he would make. Both a status quo quantity of the good and price are explicitly stated by the interviewer prior to any respondent statements. The first is a direct approach, while the second provides infor mation for using the indirect techniques commonly employed with data on actual observed behavior.

c. The market rules of operation, bidding vehicles, and status quo prices and quantities may differ across respondents. Each respondent is presented a status quo price and/or quantity of the non-marketed good; the price and/or quantity of the good is then altered by the interviewer until a combination is reached to which the respondent is indifferent.

Thus, a series of contingent markets are established with a mechanism of payment suggested for the alternative levels of the non-market good in question. For instance, a proposed power plant of 1000 kilowatt capacity located ten miles from a site is said to result in a 25 mile reduction in the visual range, and the respondent is asked whether he would be willing to pay perhaps fifty dollars over some specific time period to prevent the reduction.

An important element in the process is clearly defining the non- marketed good in a manner that establishes a clear linkage to physical parameters. For atmospheric visibility, this would include linking power plant emissions to ambient concentrations, and ambient concentrations to the representation of ambient concentrations used in the interview.

Bradford (197?)) has set forth the analytical basis of the direct version (bidding games) of the contingent valuation technique. Davis (1963) and Randall, et al. (1974), made the first empirical applications to environmental goods. Instruments that collect information on time and budget adjustments and then employ this information to infer valuations of a non-marketed good, have the bulk of their analytical foundations presented in Hori (1975) and Freeman (1979).

Published papers employing these contingent claims games to acquire information have valued non-marketed goods as diverse as public television programming [Bohm (1972)]; atmospheric visibility [Randall, et al. (1974, Brookshire, et al. (1976), and Rowe, et al. (forthcoming)]; land-form alterations due to strip mining [Randall, et al. (1978)]; air pollution-induced health effects [Loehman, et al. (forthcoming), and Brookshire, et al. (forthcoming (a))]; wildlife [Hammock and Brown (1974) and Brookshire, et al. (forthcoming (b))]; water pollution [Gramlich (1977)]; preservation of river headwaters [O'Hanlon and Sinden (1978), and Sinden and Wyckoff (1976)]; urban infrastructure allocations for expenditures and taxes [Strauss and Hughes (1976)]; and airplane safety [Jones-Lee (1976)]. In addition, there are a number of as yet unpublished reports and papers that have used the technique to value atmospheric visibility [Horst and Crocker (1978)1; power plant cooling towers [Curry, et al. (1979)]; boomtown infrastructure [Cummings and Schulze (1978), Brookshire and d'Arge (1979)]; urban public parks [Vaughn (1974)]; odors [Loehman, et al. (1978)]; and geothermal steam development in wilderness areas [Ben-David, et al. (1977)].

One might reasonably conclude from this listing that in spite of the persistently held belief that valuations established through contingent (hypothetical) claims games are systematically biased, there have nevertheless been some economists who have overcome their skepticism.[1] However, they have not yet offered a coherent presentation of the advantages of their technique. In succeeding sections, we present some of the elements on which advantages might stem.

CONTINGENT VALUATIONS AND THE CONSUMER SURPLUS FRAMEWORK

Buchanan (1969) distinguishes between _ex ante_ and _ex post_ costs. He argues that it is the former that is relevant to choice. We employ the distinction to establish the place of contingent valuations in a consumer surplus framework. Contingent valuations are seen as providing a means for the potentially affected individual to participate in the choice of the provision The choice to be used for valuation purposes is based upon "what could be," rather than upon "what might have been."

In making a decision about cost (either a bid in direct valuation, or reallocation of time and budget components in indirect valuation), an individual in the contingent valuation approach is setting forth his evaluation of the prospective sacrifices or gains in utility as a result of the proposed contingencies. Thus, cost is a choice-bound concept, and choices are based on prospects referenced in the type of information provided. Cost, then, in its relationship to choice must be based on expectations, not experience. This viewpoint suggests that : (1) the oft-discussed discrepancies between observed and proposed behavior [e.g., Fromm (1968) and Mills and Feenberg (1977)] are not an issue in valuing non-market commodities unless the information underlying the proposed behavior is identical to the information leading to the actual behavior; (2) for given information, the contingent valuation framework provides valuations in terms of expected value to the individual, i.e. , willingness-to-pay for the prospective outcome.

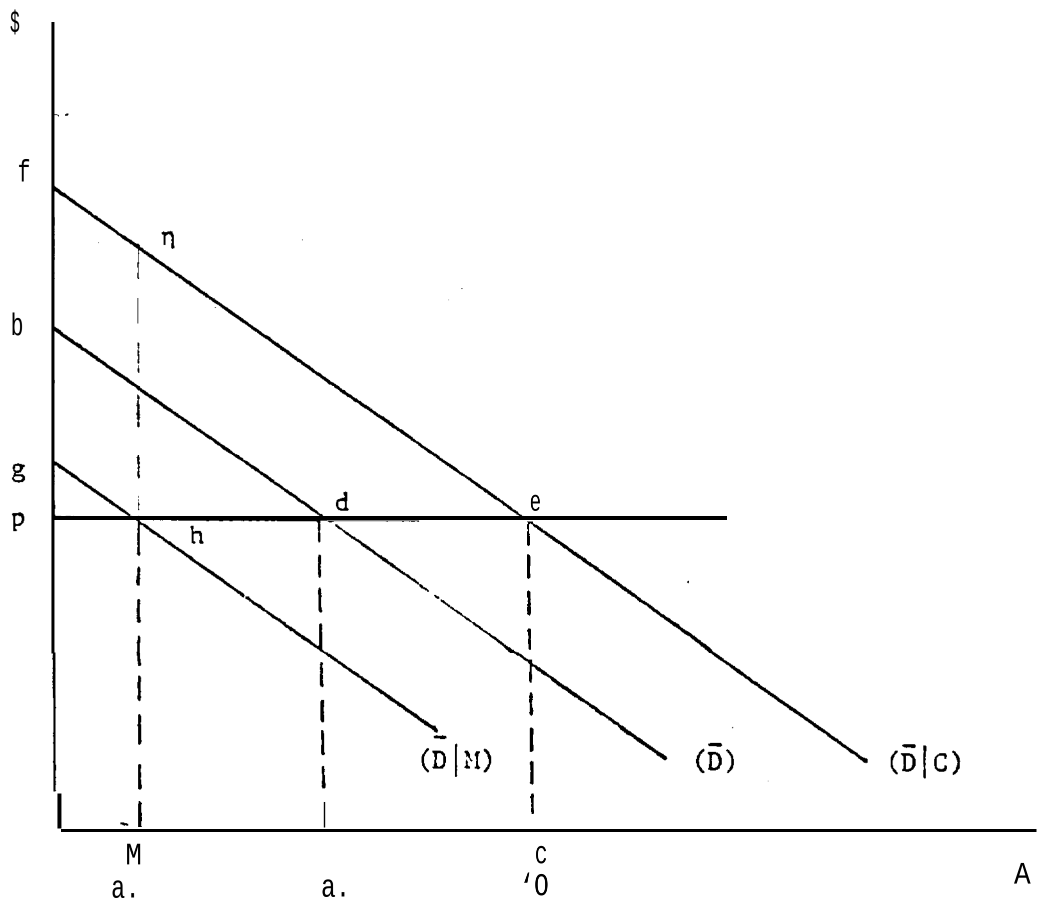
Let us consider an example that illustrates these points in the context of a contingent valuation market. Assume that a respondent's demand for a marketed activity (e.g., camping in a national park) is weakly complementary in the non-marketed commodity (e.g., visibility as measured by the distance that can be seen in and around a national park).[2] Participation in camping is assumed to have an invariant opportunity cost of P, which is independent of the level of availability of atmospheric visibility in the national park. In Figure 1, the $\bar{D}$ curve represents the individual's income-compensated demand function for the camping activity (A), averaged over all possible levels of atmospheric visibility.

The ability to observe distant mountains from the camping site enhances the utility of camping. The efficient plan for the camper with no forecast of the availability of clear vistas is to undertake the activity at activity level a_0 in Figure 1, where a_0 represents average visibility versus a pristine or murky level of visibility. The marginal value attached to an additional planned unit of camping just equals the individual's opportunity cost. The consumer surplus expected from camping, once the activity begins, is the area above the opportunity cost line and beneath the "average demand" function $\bar{D}$. The latter is the individual's mathematical expectation of the valuation attached to camping levels, once realized.

Now suppose a formal contingent market is constructed where the non-

Figure 4.1

Effect of An Improvement in Information
on Consumer's Surplus.



marketed commodity, atmospheric visibility in and around the national park, is described to the would-be camper in the requisite detail. For instance, coal fired power plants will either be installing control devices or shutting them down for maintenance. Visibility in and around the park will thus be clear (C) or murky (M) during the camping trip. The manner in which the camper will revise his estimates about the probability of clear or murky conditions can be described by Bayes' (1764) rule. If the information leads to the conclusion of clear visibility, the camper's subjective evaluation of his average compensated demand function will be (D/C), with a planned increase in camping activity to a_0^C. The area (b-d-e-f) gives the increase in expected utility if "clear" is the forecast. If the forecast is "murky," the planned activity level will be reduced to a_0^M, and the area (b-d-h-g) gives the loss in expected utility.

Now suppose that M is forecast, implying a planned activity level of a_0^M, and an expected consumer surplus of g-p-h. If, instead, C is realized and the camper is unable to adjust his activity level accordingly, he will have obtained a consumer surplus of p-h-f-n, an amount greater by g-h-n-f than the consumer surplus on the basis of which he made his decision to go to the park. This latter consumer surplus, which is established from observed behavior, has no correspondence to the basis of the camper's choices. In fact, according to the opportunity the camper has to adjust his activities, any activity level from the origin to a^C might be observed.[3] Only if clear skies had been forecast and actually realized would the camper's expected and realized consumer surpluses coincide, thus allowing the investigator to infer the utility basis of the camper's choices from his observed behavior. In contrast, contingent valuation techniques place the individual in a representation of the context in which he actually makes choices. Unless policy maker decisions about levels of provision of non-marketed goods are to be only randomly connected to the nexus the individual confronts, the appropriate state for measuring consumer surplus is that corresponding to the instant of the individual's decision.

HYPOTHETICAL BEHAVIOR AND MARKETS

If different answers can be anticipated based upon alternative information structures, what "state" is the appropriate one for measuring consumer surpluses for benefit-cost analysis? Can a contingent market be developed that is "appropriate" to the policy question at hand? What happens if informational content of an observable market is identical to that of a contingent market.

Fromm (1968) and many other economists believe that hypothetical questions generate fictional and, therefore, inaccurate responses. The dictionary defines a hypothetical proposition as a conditional proposition, i.e., an "if X, then Y" statement. A hypothetical question would then be a conditional statement in the subjunctive mood, an "if X were . . . ., then . . . ." statement. In the contingent valuation setting, a hypothetical market is constructed, perturbed and then the respondent states conditional behavior based on the specified market structure or events. Fundamentally, the problem is not hypothetical, but 'one of the relation between information and choice as set out for the camper in the immediately preceding section.

The individual's ultimately realized benefits and his prospective evaluations are neither jointly instantaneous nor coincidental. Frequent discrepancies should then be expected between response to contingencies embodying one form of information and eventual observable behavior carried out upon the basis of altered information. The key point is that the contingent answer is still acceptable given the well-defined circumstances that were presented to the respondent. The question of inaccuracy is then not whether, given a change in circumstance, the observable behavior pattern changes, but whether the contingent answer can be observed when the defined circumstances have not changed. Only if the answers relate to past rather than intended behavior will a simple comparison of answers with actual behavior suffice to ascertain the accuracy of the answers. Otherwise, one must explain how the individual responds to new information and circumstances in order to perform the comparison.

An empirical rebuttal of these points would require evidence that the provision of additional information about future states does not change contingent values and that contingent values and observed market values fail to coincide when the defined circumstances in the hypothetical market and the actual market are similar. In this section, we offer brief summaries of two studies that contribute to this empirical evidence.

The first study was performed in Farmington, New Mexico, where a hypothetical market for alternative levels of visibility due to additional energy development [Rowe, et al. (forthcoming)] was developed. The appropriate "states" corresponded to energy development scenarios for the Four Corners area. To investigate the role of information, after direct valuation responses had been received, a subsample of respondents was told either that others had bid a certain amount or that the bid of the subsample was so low that the proposed change in the allocation of the non-market good was impossible. In both instances, respondents were given the opportunity to revise their valuation. The results indicated that the valuation measures were affected by the structure and the information content of the contingent market. Thus, at least in this case, information about the behavior of other market participants affected valuations. This behavior is, of course, consistent with the strategic behavior predictions of the free-rider decision problem in public choice theory.

The second study was conducted in the South Coast Air Basin of southern California [Brookshire, et al. (forthcoming (a))]. A residential property value study based on sales of individual properties in a sample of paired communities where mcst of the variation in physical attributes within a pair was due to air pollution was performed. Similarly, during the same time period that the property sales occurred, a contingent valuation study within the same paired community sample was undertaken. The set of circumstances depicted in the contingent valuation study was those actually prevailing in the Basin at the time of the property value sales. Within a factor of less than two, the two independent studies produced similar valuations. For an approximate 30% improvement in the ambient air quality of the Basin, the property value study gave an average dollar bid per household per month of $42, while the bidding game study yielded a mean bid of $29 per household per month.

COSTLESS VERSUS COSTLY EXCHANGE

Even if the information available to participants in an everyday actual market and in a contingent valuation exercise were identical, there remains at least one reason why the two types of valuations might still diverge: the institutional structures of the contingent valuation market and the everyday market may differ. Plott (1979) reviews several empirical laboratory and field experimental studies indicating that market outcomes are highly sensitive to differences in institutional structures. Given this sensitivity, if meaningful measures of the gains and losses from the provision of a non-marketed environmental good are to be established, the measures must be derived within an institutional structure conforming to that posited in the welfare-theoretic basis of benefit-cost analysis. In this section, we argue that this conformity is often more readily achieved with the use of contingent valuation techniques.

Benefit-cost analysis is an attempt to ascertain the quantity of some numeraire (e.g., current dollars) that the gainers and losers from some proposed public investment will consider equivalent in value to their respective gains and losses. The price structure, where price is a sufficient measure of social as well as private value, represents the only terms with which the world with or without a public investment is evaluated. Prices, as generated by market exchange and adjusted in proportion to excess demand, embody all relevant information about relative economic scarcities and are a sufficient means of allocating resources to their socially most highly valued uses.[4] The benefit-cost analyst is trying to ascertain what individuals are willing to pay and/or would have to be paid for the public investment in a world where markets are pervasive.

If realized market behavior is used as the data base to establish these valuations, the analyst uses propositions from economic theory for two purposes: (1) to infer what the price structure would be in a world of pervasive markets; and (2) to reason from the pervasive market price structure to the implied consumer valuations. When contingent valuation responses are employed for the data base, the first step can be avoided, if the conditions posited in the questionnaire instrument correspond to a world of pervasive markets. One might reasonably question whether the conditions corresponding to a world of pervasive markets are sufficiently close to a respondent's experiences to be meaningful to him. This justifiable doubt must be weighed however, against the difficulties of carrying through the analytical exercises necessary to construct a pervasive market price structure from initial knowledge of the price structures of a world where markets for many goods are not pervasive. The way in which this difficulty is customarily avoided when using observable, realized prices is to assume (for simplicity?) that the observed prices correspond to those in a world of pervasive markets.

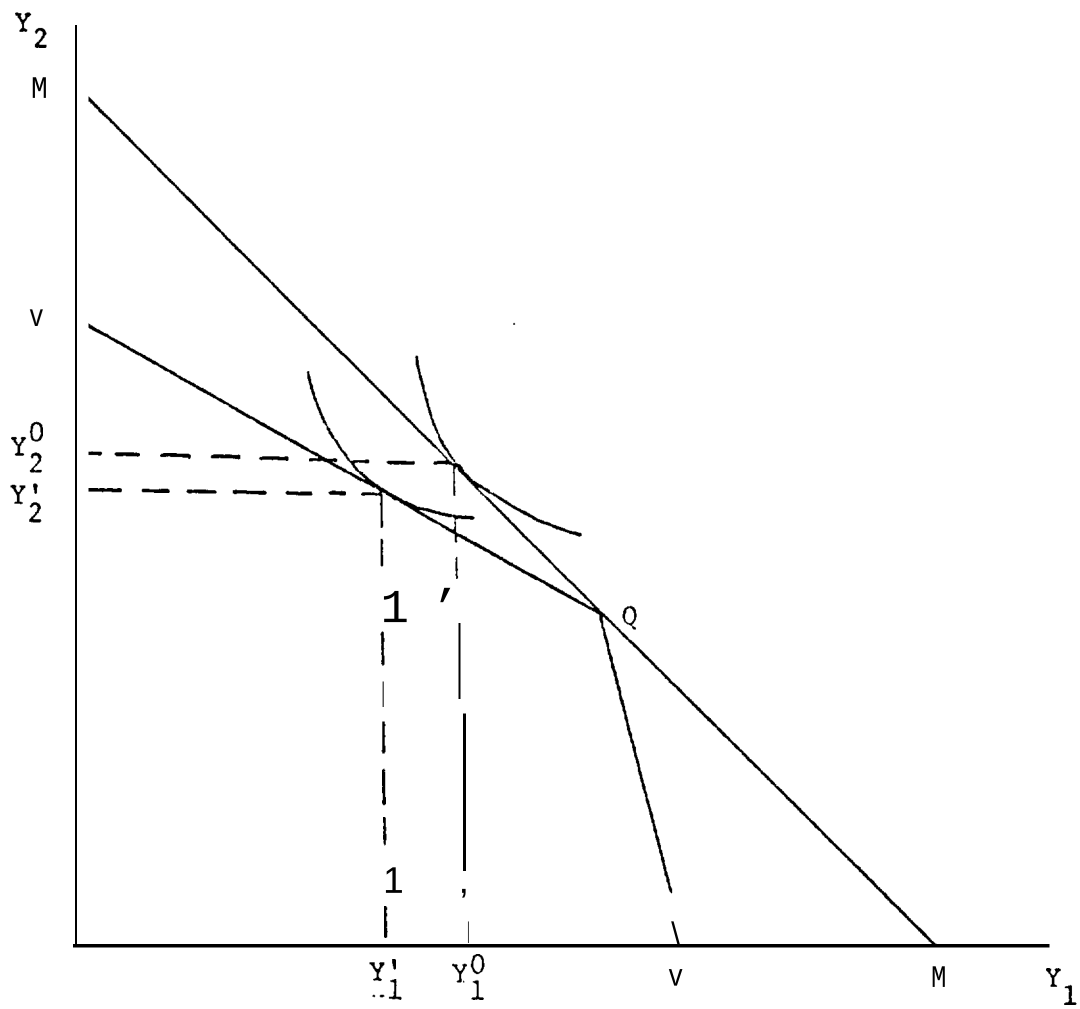
It is a relatively easy task to construct examples that make apparent the difficulties of reasoning to pervasive markets from observations on non-pervasive markets. Consider costs of exchange, a phenomenon present whenever valuable resources (e.g. , time, information, legal and police services, etc.) must be expended to perform the exchange process.

In Figure 2, the individual's initial endowment of Y_1 and Y_2 is at Q.
When exchange processes become costly, the individual's budget constraint will vary according to his initial endowment. This is because the costs of the act of exchanging Y_1 and Y_2 differ from the costs of exchanging Y_2 for Y_1. For example, from the perspective of a single individual, the cost of engaging in a transaction in which he is to exchange automobiles that he owns for clean ambient air may differ from these same costs in a transaction where he is exchanging clean air for automobiles. If the exchange act is costly, an initial endowment of Q implies a budget constraint of VQV, whereas if the exchange act is costless, the budget constraint is MM, the customary form which is an integral part of derivations of demand functions and their associated consumer surpluses. Then the individual completes his exchanges during the period, he will select Y_1^O and Y_2^O as an optimum if MM is operative. If VQV is the operative budget constraint, he will select Y_1' and Y_2'. If some point on MM other than Q constitutes the initial endowment, costly acts of exchange will mean that a budget constraint different from either VQV or MM may be operative because the costs of exchange acts may differ by the relative quantities of the goods in the initial endowment as well as by types of goods. Thus, the individual's budget constraint may vary according to the form in

Figure 4.2

. . .

Effect of Costly Exchange



which his initial endowment was accumulated, although the market value of this endowment may be identical for many combinations of Y_1 and Y_2. Since costs of the exchange act differ according to the original (Y_1, Y_2) combination, each combination will result in a different and generally nonlinear budget constraint. It follows that, from the individual's perspective, a dollar is not an invariant pecuniary measure. Instead, the subjective value of an additional dollar depends on the fm of the income change, i.e., on the good in which the increment is embodied.[5] Moreover, it appears that realized market behavior is dependent not only on money incomes and relative market prices of goods, but also upon the combination of goods the individual starts with and the relative and absolute costs of exchange associated with those goods. These costs of exchange acts are probably neither trivial nor similar across individuals.

If realized market behavior depends on the costs of the exchange act for the bundle of goods an individual holds, if, for the same bundle of goods, these costs differ across individuals, and if individuals do not hold similar goods bundles, then the analytical effort required to infer what the price structure would be in a world of pervasive markets must clearly be greater (probably much greater) than when all individuals have no exchange act costs and when budget constraints are therefore invariant with respect to the bundle of goods held. Rather than facing these and similar analytical complexities directly in order to construct the price structure of a world of pervasive markets, or rather than simply dismissing the problem as an offensive bother, it may often be more effective to construct, using contingent valuation techniques, an artificial market for the environmental good to be valued. For the contingent valuation exercise participant, the number of goods for which markets are non-existent or incomplete is thereby reduced by one. This reduction clearly cannot remove all sources of distortion since the participant's valuation continues to depend in part upon the price structure for all remaining goods. Nevertheless, it is well known that the direct effects of a parameter change upon a variable of interest exceed the indirect effects. This suggests that the introduction of the artificial market reduces rather than enhances the impact upon valuation of the presence of incomplete markets.[6]

BENEFIT-COST ANALYSIS, PROPERTY RIGHTS, AND CONTINGENT VALUATIONS

The fact of incomplete markets says nothing about the degree of distortion in the observed price structure for marketed goods. Some recent qualitative literature [e.g., Norgaard and Hall (1974), and Smith and Krutilla (1979)] suggests that the extent of distortion could be substantial. The great bulk of goods having actual market prices are thought to be primary commodities and the goods chemically and mechanically fabricated from them.

Because the costs of participating in direct exchanges involving the aesthetic, health and ecological support system aspects of natural environments are high, they frequently have no explicit market prices even though they are economically scarce and contribute in a non-separable fashion to the production of the fabricated goods. As a result, the market prices of fabricated goods are typically less than their opportunity costs of production. In short, those who attach high relative values to environmental goods have historically subsidized the consumers of fabricated goods. To use a price structure that has evolved at the expense of environmental goods to impart values to them has no basis in economic logic. The values must be established in a setting where the opportunity costs of environmental goods register in the plans of those who would use them.

Attempts to bring about this registration must generally involve the reassignment and/or the restructuring of claims on common property or public environmental goods. There exist analytical devices in economics allowing one to ascertain the effects upon consumer valuations of property rights reassignments for goods, whether marketed or non-marketed.[7] However, where the conditions of use, exclusion, or alienation are altered (i.e., property rights are restructured), there is no everyday behavior to observe, except insofar as one is willing to draw analogies from observed behavioral responses to changes in the property rights structures of other goods. If one knew what the availability of the non-market good would be under the property rights restructuring, it might seem one could, if one had everyday behavioral observations on consumer time and budget allocations at the same level of availability, determine the change in consumer valuation due to the property right restructuring. However, if the restructuring reduces the costs of the act of exchange this reduction can, as we argued in the previous section, alter the value the consumer attaches to a given level of availability. Furthermore, since consumer valuations will, through either the market or the political process, influence the level of availability, how is one going to reason from the level of availability to consumer valuations for the restructured property right? Economic analysis does not yet have a sufficient understanding of the reciprocal relations between costs of the act of exchange and property rights structures, nor between these costs and various demand phenomena, to permit the ready testing of detailed empirical generalizations in a wide variety of settings. Thus, the only really sound way of obtaining an estimate of whether the net benefits of a particular property rights restructuring are positive, if one insists upon employing observed everyday behavior, would be to perform the restructuring and observe the results. In some circles, this is simply known as trial and error. Trial and error can be an extremely costly way to perform research because the errors are real rather than hypothetical. In contrast, contingent valuation methods allow one to investigate the behavioral responses to a wide variety of property rights structures without involving the citizenry in the traumas of what often is euphemistically termed social experimentation.

One obviously cannot directly observe everyday behavioral responses to property rights structures that have never existed. Similarly, one cannot directly observe the everyday behavioral responses of individuals who have never participated in activities involving the non-marketed good at levels at which the good has been historically available. If some of the proposed levels of availability have not been historically available, and if some former nonparticipants would become participants at these new levels, the use of data on observed behavior to ascertain valuations would mean that the valuations of the would-be participants play no part in determining the valuation. For each proposed level of availability, the use of observed, realized behavior to establish valuation will mean that only historical participants are to count. Those who have not participated historically have no opportunity to communicate their preferences. Contingent valuation methods, because they allow the researcher to introduce ranges of availability of the non-marketed good that are broader than historical experience, permit the values of historical non-participants to become relevant.

CONTINGENT METHODS AND A PRIORI ASSUMPTIONS

Previous sections have stressed the usefulness of contingent valuation methods in traveling from prices. established within incomplete markets to value measures that are meaningful in welfare-theoretic and policy terms. In this section, we argue that these methods are useful even when the trip is unnecessary as when expected and realized utility are similar and when markets are nearly pervasive. The methods can be useful in even these cases because they assist in reducing the dimensionality of the reality the investigator must grasp.

Economists who have worked with problems of consumer analysis are thoroughly familiar with three fruitful a priori restrictions (additivity, homogeneity, and symmetry) that come from the neoclassical demand theory of Slutsky (1915) and Hicks (1934). Further reductions in dimensionality of the parameter space in which estimation is to be carried out can be achieved by judicious invocation of various separability conditions. Finally, some recent developments in the application of mathematical duality principles (the envelope theorem) to consumer theory sometimes allow one to reduce the number of parameters to be estimated without having to impose particular monotonicity and curvature properties upon the consumer's maximization problem (See Diewert, 1974).

Contingent valuation methods can provide additional restrictions by allowing the investigator to control the number and levels of different physical contexts and adaptation opportunities to which the participant must respond. Disturbances imposed by confounding variables upon the responses of interest are therefore at least partially controlled for in the data generating exercise. This contrasts with the standard practice of placing sole reliance in an ex post fashion upon the application of multi-variate parametric estimation techniques. For a given number of observations, these methods can thus increase degrees of freedom and the efficiency of estimators. For instance, in the South Coast Air Basin Experiment previously mentioned, the contingent value approach was able to obtain separate dollar valuations for aesthetic as well as acute and chronic health effects. In contrast, one can only guess what the relative magnitudes are for the property value component cross check.

The use of contingent valuation techniques to reduce the parameter space may be advantageous for reasons in addition to statistical considerations. Often, as noted above, the investigator imposes, ex post, various separability conditions upon market-generated data in order to make it more tractable. These separability conditions may imply, for example, that beer drinking at the local tavern is not a substitute for cross-country skiing. The conditions are imposed without consulting the individuals whose responses are registered in the market data. They are instead generated by what the investigator intuitively feels to be "reasonable," and what is required for analytical convenience. It is not obvious that the investigator's "feelings" and the framework he uses in accounting for what is and what is not important is to be preferred to actually providing the respondent with the opportunity to state how he would respond to alternative contingencies. The details to be abstracted from are presented to the respondent rather than being left to the investigator. In both situations, simplifications are made that will permit the investigator to work with the data. In the contingent valuation case, however, the respondent gets the opportunity to weigh the importance of these confounding variables in making his choices. In the observed behavior case, the investigator is presuming he knows as well as the respondent what, from the respondent's perspective, is and is not an irrelevant alternative. The closed questions employed to gather data with contingent valuation methods allow the domain in which the response data is generated to conform to the structures of the underlying analytical model rather than forcing, via a set of possibly tenuous assumptions (e.g. , the absence of jointness, the presence of perfect competition, etc.),[8] the real world generated data to conform to the preconceptions of the model. At the same time, the user of the methods must accept ultimate responsibility for the origin of the data, as well as the analytical model and the estimation procedures used to test hypotheses.

SUMMARY AND CONCLUSIONS

The preceding is a taxonomic discussion of some reasons why contingent market methods may often be a superior means of generating data with which to value non-market commodities. We have argued that economists have erred in viewing the situations these methods posit as necessarily fictional; that the data generated by the methods may, for non-marketed goods and the activities with which they are associated, accord more closely with the conditions of received economic theory; that the methods can make it easier to remove the difficulties of estimation and interpretation introduced by confounding variables; and that they often permit one to deal more readily with phenomena that have not been in the range of historical experience. Nevertheless, whatever the advantages, a major disadvantage remains. Until detailed analytical knowledge is acquired of the manner in which expectations are formed, there exists no way to refute empirical propositions established from contingent markets. Nevertheless, the previously mentioned South Coast Air Basin experiment (Chapter 3), where the bids obtained for clean air conformed fairly closely to the values implied in a residential property value study, suggest that contingent valuations have a basis in the real decision processes of consumers.

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1 Issues of potential bias in any mechanism that elicits preferences have long been raised (Samuelson, 1955). It is not our purpose to address these, as series of contingent valuation experiments suggest the problem is not significant [Brookshire, et al. (forthcoming (a))].

2 According to Maler (1974, pp. 183-189), weak complementarily exists if the quantity demanded of a marketed good is zero when the marginal utility of the non-marketed good is zero. Bradford and Hildebrandt (1977) have recently expanded the Maler (197,4) result to show that under weak complementarily all information required for efficient provision of the non-marketed good is imbedded in the demand functions of marketed goods .

3 Adaptive behavior, once having committed one's self and experiencing unanticipated regret or satisfaction thereby, can be treated as the acquisition of further information.

4 As used here, "social" refers solely to a world in which all voluntary gains from exchange, given the initial distribution on income, are exhausted. Only under classical conditions (an absence of nonconvexities, irreducible uncertainty, coordination costs leading to externalities, and less than complete contingent claims markets), does current economic knowledge demonstrate that market prices alone would be sufficient to make efficient (Pareto-optimal) allocations attainable.

5 Empirical evidence to support this is widely available. Newhouse, et al. (1974) find that the demand for health care is sensitive to modes of payment. Keeley, et al. (1978) obtain the same result in the demand for leisure when the form of a negative income tax is altered. In contingent valuation exercises, Rowe, et al. (forthcoming), and Brookshire, et al. (forthcoming) have found statistically significant differences in bids when utility bills, income changes, and hunting license fees are employed as bidding vehicles. Indeed, the standard undergraduate problem of whether one would prefer a housing allowance to an income subsidy of equivalent money value implies that the former is not readily converted

to the latter.

6 Consider the simple consumer's utility maximization problem of:

$$\text{maximize } U = u(X_1, X_2)$$

$$\text{subject to } M = p_1x_1 + p_2x_2$$

where the x_i $(i=1,2)$ are goods, the p_i are their respective unit prices, and M is money income. An interior maximum requires that $U_{11}U_{22} - (U_{12})^2 \geq 0$, where the subscripts indicate partial derivatives taken with respect to the good in question. This says that the effects upon the utility obtained from one good due to a change in another good cannot dominate the direct utility effects of a change in either good.

7 If, for example, there is an increase in pollution, the amount the sufferer would have to be paid in order to be willing to accept the increase is consistent with the polluter being liable for the damages he causes. The amount the consumer would be willing to pay to prevent the increase implies that the polluter has zero liability for any harm he imposes upon the sufferer.

8 As Medawar (1979, p. 15) has remarked: "It is a truism that a 'good' experiment is precisely that which spares us the exertion of thinking; the better it is, the less we have to worry about its interpretation, about what it really means."

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CHAPTER 5

AN EXAMINATION OF BENEFITS AND COSTS OF MOBILE SOURCE CONTROL CONSISTENT WITH ACHIEVEMENT OF AMBIENT STANDARDS IN THE SOUTH COAST AIR BASIN

INTRODUCTION

Chapter 3 described an experiment conducted in the South Coast Air Basin to quantify and validate benefit measures of air quality improvements. The qualified success of that effort suggests that a policy application of those benefit measures may be appropriate. Thus, the intent of this chapter is to examine national ambient air quality standards in a benefit-cost analysis framework as applied to the South Coast Air Basin which consists of all or portions of Los Angeles, Orange, Riverside and San Bernardino Counties in Southern California.

The national ambient standards for oxidant (formerly .08 and now .12 ppm maximum hourly concentration) and nitrogen dioxide (.05 ppm annual average concentration) are consistently violated throughout the basin with the notable exception of the immediate coastal areas which we have described as characterized by "good" air quality in Chapter 4 [See Figures 3.13.4 in Brookshire, et al. (1978) for a map of air quality areas]. Thus, in a broad context, if the entire South Coast Air Basin were to be brought into compliance with ambient standards, areas we have characterized as having "fair" or "poor" air quality would then be characterized as having "good" air quality. The development of an aggregate benefit measure for achieving ambient standards for the entire basin is then a straightforward extrapolation (given the original experimental design) where benefits are taken to be the aggregate willingness to pay for all households in both "poor" and "fair" air quality areas to have "good" air quality, as defined both for the preceding property value and survey studies. Of course, any extrapolation to a basin-wide population of about 2.4 million households (homes) from a sample of 719 home sales or from interviews with about 400 households can come under serious question. In particular, the communities chosen for sampling, although characterized by considerable variation in income and social characteristics, may not represent a random sample of communities in the South Coast Air Basin. However, the property value study does allow calculation of household willingness to pay as a function of income and air pollution. It is this relationship that we use for benefit calculations assuming, in effect, that income and population affect willingness to pay for air quality improvement in the same way throughout the basin as they did in our limited sample. Note that these estimates exclude any agricultural or ecosystem effects.

Since benefits are calculated for moving from the current (1976 emissions inventory) level of air quality to the ambient standards, costs must be calculated on the 'same basis. However, our preliminary analysis indicated that costs for on-road mobile source control measures were substantially more defensible than those associated with stationary and institutional controls. Therefore only the benefits and costs attributable to on-road mobile source control are examined to the exclusion of other control measures.[2] Benefits are then those corresponding to the share of total emissions reductions which are accomplished by on-road mobile source control. Costs are calculated for only these measures also.

Although a careful engineering-cost study for using mobile source control to achieve ambient standards would be desirable, the objective here must be quite limited in that we are forced to use available cost evidence which in many cases is quite uncertain. For the most part, we have relied on manufacturer statements and government publications for cost calculations. In developing control cost estimates, given the large uncertainty which exists, we simply present available data on the range of costs per ton of reduced emissions for hydrocarbons, carbon monoxide and nitrogen oxides and, using these numbers, estimate a broad range for basin-wide control costs to compare to the range of benefit measures.

In addition, we have used the <u>Air Quality Management Plan</u> (January, 1979) as the basis for the calculation of required emissions reductions. Calculations presented in the plan indicate that to achieve ambient standards in 1979 would require reductions of 974 tons per day in reactive hydrocarbons, 5963 tons per day of carbon monoxide and 503 tons per day of nitrogen oxides. Of these amounts we have estimated that mobile source controls are responsible for 728 tons/day, 6023 tons/day and 397 tons/day of hydrocarbons, carbon monoxide and oxides of nitrogen, respectively. Our principle conclusions can then be summarized as follows:

> Benefits of achieving ambient standards for air quality in the South Coast Air Basin for 1979 fall in a range of 1.6 to 3.0 billion dollars per year. Of this total on-road mobile source control is responsible for approximately 1.36-2.55 billion dollars.

Assuming that to achieve the ambient standards in 1979 the on-road mobile source emission reductions are those stated above, then corresponding total basin-wide control costs fall in the range of .6. - 1.32 billion dollars.

Benefits of control efforts to achieve ambient air quality standards in the South Coast Air Basin appear to be of the same order of magnitude as control costs. Given uncertainties over benefits and costs, this implies that ambient air quality standards cannot be rejected as economically inefficient on the basis of benefit-cost analysis.

Continued growth of population and economic activity in the South Coast Air Basin could well alter the relative magnitudes of benefits and costs of achieving the ambient standard in an unknown direction by the attainment date of 1987.

The next section briefly discusses the use of this type of benefit-cost study in policy analysis. Section 3 describes the construction of aggregate benefits, costs of control are presented in Section 4, and Section 5 concludes with a comparison of benefits and costs.

THE APPLICATION OF BENEFIT-COST ANALYSIS TO ENVIRONMENTAL STANDARDS

The application of benefit-cost analysis to environmental standards has been described in great detail in the economics literature (see for example Kneese and Herfindahl, 1974). An ideal or optimal standard is one where net benefits -- the difference between benefits of improved air quality and control costs -- are the greatest. For example, Figure 1 shows the optimal standard as S_1, where the degree of air pollution control provides a level of improved air quality (as measured on the horizontal axis) such that benefits, B_1, exceed control costs, C_1, (or both measured on the vertical axis) to the greatest extent. Note that in Figure 1, benefits are assumed to increase at a decreasing rate with air quality improvement while control costs are assumed to increase at an increasing rate. The slopes of these relationships are presumed to arise respectively from (i) the diminishing rate of increase of value to consumers of improved air quality as air quality approaches "perfection" and (ii) because costs of additional emissions control will rise increasingly rapidly as a level of zero emissions (i.e., perfect air quality) is approached. At the optimal or economically efficient standard, S_1, given our assumptions, benefits strictly exceed costs ($B_1 > C_1$). Thus, in evaluating the role that on-road mobile controls play in achievement of the national ambient air quality standards as applied in the South Coast Air

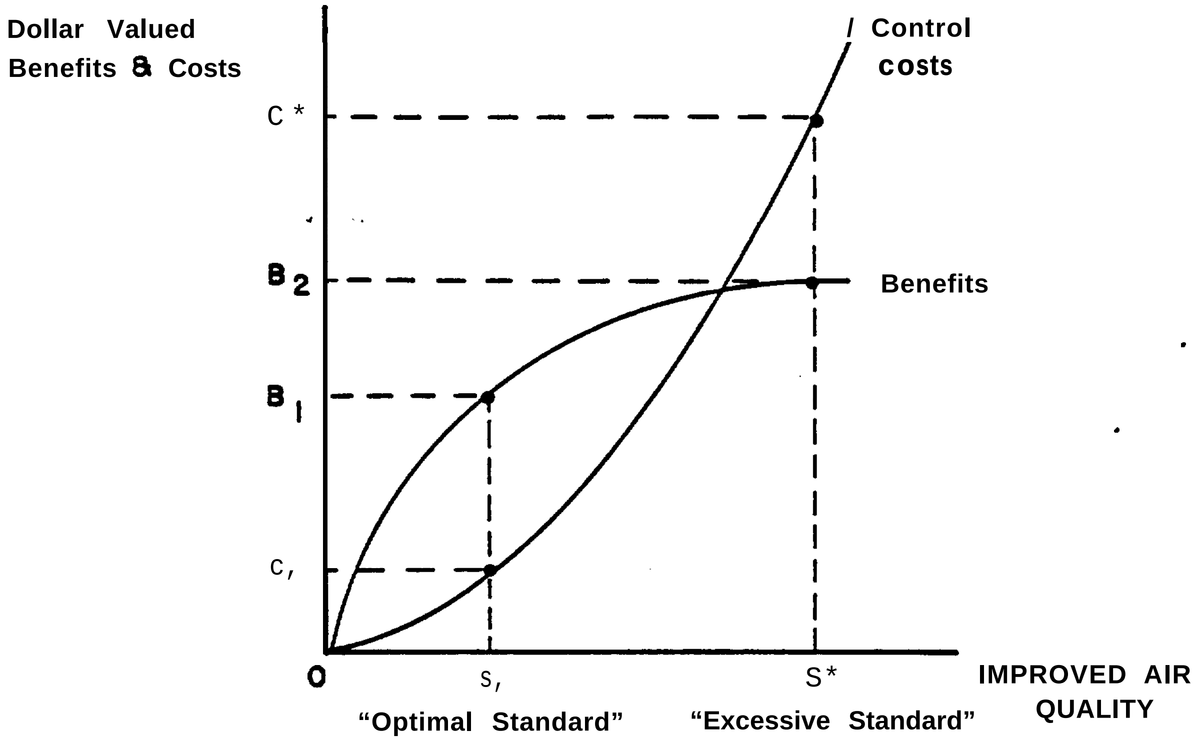


Figure 5.1

Optimal and Excessive Standards

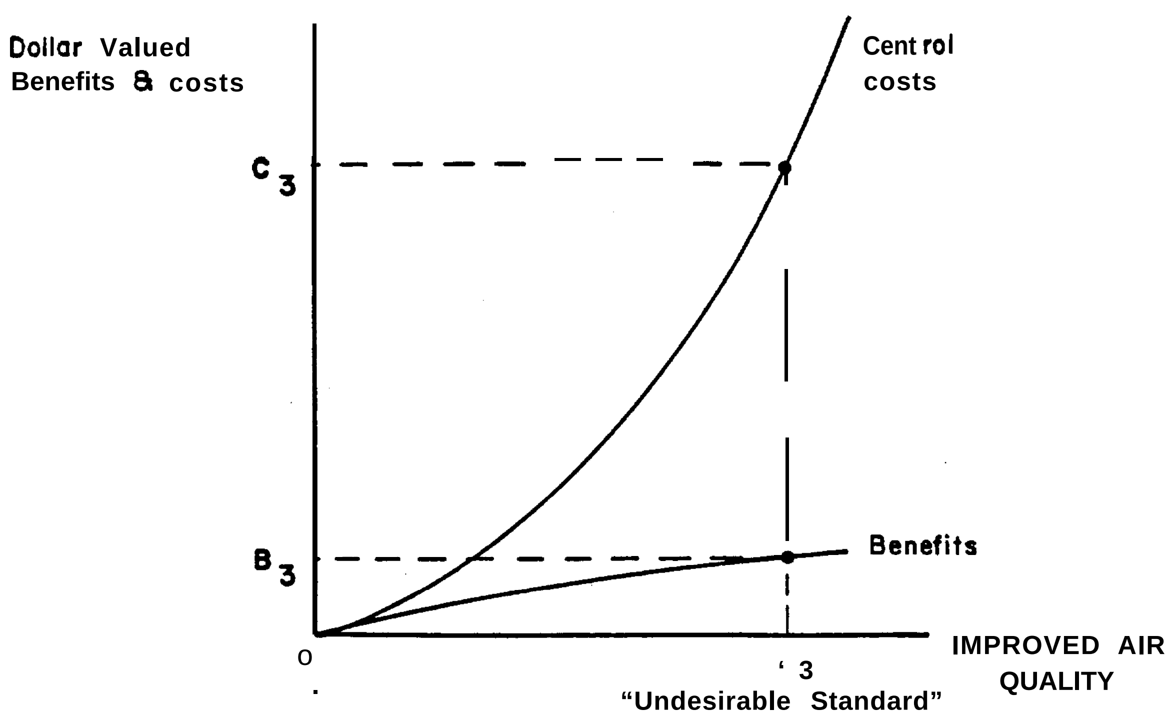


Figure 5.2

The Case of an Undesirable Standard

Basin, the first test for economic efficiency is simply to check if benefits exceed costs. Obviously, it would be desirable to construct benefit and cost curves as shown in Figure 1 to pick the best standards for comparison to actual standards. However, the uncertainty over benefits and especially costs makes such an effort of doubtful value. Rather, given the likelihood of broad ranges for benefits and costs as calculated for the ambient air quality standards, we are interested, from the perspective of economic efficiency, in avoiding either a situation like S_2 in Figure 1 or S_3 in Figure 2. In both these cases, costs far exceed benefits and it is clear that the standards, S_2 or S_3, are economically inefficient. In the first case (S_2 in Figure 1) the standard has been pushed too far -- to the point where costs of control have risen above benefits, implying excessive standards ($B_2 < C_2$). In the second case (S_3 in figure 2), control costs are always above benefits and any standard is undesirable. Given that control costs typically rise very sharply as emission controls become stringent, it is worthwhile, even with uncertain estimates, to check if benefits are at least of the same order of magnitude as costs.

Thus, placed in this perspective our objective is not to develop precise and defensible cost estimates for comparison to benefit measures developed in the preceding chapter, but rather to see if claimed ranges for control cost options to achieve ambient standards possibly allow ambient standards to be met at costs less than benefits.

BENEFITS FROM AIR QUALITY IMPROVEMENT

Description of the Study Region[3]

The study area -- the South Coast Air Basin (SCAB) -- consists of Orange and Los Angeles Counties and portions of San Bernadino and Riverside Counties of California. This area has a long history of air quality problems. For instance, Spanish explorers in the sixteenth century noted smoke from Indian campfires in the basin, trapped by inadequate horizontal and vertical air mixing. The post World War 11 period, characterized by Southern California's rapid population growth and industrial development, was marked by the emergence of photochemical smog as a threat to the regional environment. In response, air pollution abatement programs for stationary sources began in the late 1940's. Control of mobile source emissions commenced in the early 1960's, a response to the discovery of the automobile's role in the smog formation mechanism. Thus, air quality deterioration in the SCAB has multiple causes: topography, meteorology, and dense population and economic activity with correspondingly large emissions.

The SCAB is essentially a coastal plain with connecting valleys and low lying hills bounded by the Pacific Ocean to the south and west and mountain ranges along the inland perimeter [Southern California Association of Governments, et al., (1979)]. Elevation varies from slightly above sea level in the coastal areas to greater than 11,000 feet in the mountainous inland. Intra-basin transport of air pollutants generally follows inland valley pathways.

The main meteorological characteristics of the South Coast Air Basin are mild temperatures, limited precipitation, low wind speeds and persistent inversion layers with low mixing heights. Annual average temperatures range from the low to mid 60's throughout the basin. Variation in temperature is much greater in the eastern portion of the basin due to the decreased oceanic influence. Rainfall amounts vary little throughout the basin and are generally small, typical of a coastal desert. Sunshine is a critical element in the formation of photochemical oxidants, and possible sunshine is generally high. For instance, 73 percent of possible sunshine is recorded annually in downtown Los Angeles.

Low wind speeds with little seasonal variation are a common occurrence throughout the basin. An average wind speed of 5.7 miles per hour has been recorded in downtown Los Angeles over the period 1950 to 1976. The dominant diurnal wind pattern, broken only by the Santa Ana winds and winter storms, is a daytime sea breeze and a nighttime land breeze. Horizontal air movement is, therefore, limited. Vertical dispersion of air pollutants is also limited due to frequent existence of temperature inversions near the surface.

The topographic and meteorological conditions inherent in the South Coast Air Basin imply that the region is limited in its ability to disperse pollutants, both horizontally or vertically. Therefore, pollution emissions have a relatively large impact upon ambient air quality. The situation is further exacerbated since the emission of air pollutants is considerable due to the region's dense population and prosperous economy.

Table 1 presents the air pollution emissions for 1975-76 by major source category for an average summer weekday in the SCAB. Also included are the relative percentage contributions by mobile and stationary sources. These figures represent the baseline emissions for the benefit-cost analysis which follows; that is, the reductions required to attain the federal primary air standards are determined from these baseline statistics. As is illustrated, on-road mobile sources (light duty autos and trucks, medium and heavy duty trucks, heavy duty diesel trucks, and motorcycles) contribute in excess of 50% of total emissions for all pollutants except sulfur oxides and particulate. In these latter categories, stationary sources are the dominant contributors. Offroad mobile sources (aircraft, railroads, ships, etc.) contribute negligible amounts in all cases.

Table 5.1

BASE YEAR EMISSIONS 1975 & 1976

BY MAJOR SOURCE CATEGORY (TONS/DAY)

AVERAGE SUMMER WEEKDAY

SCAB

SOURCE	THC			C			CO		I		SO_x		PART	
	TONS/DAY	% of Man-Made	% of Total	ONS/DAY	% of Man-mad	% of TOTAL	TONS/•	% of TOTAL	TONS/DAY	% of TOTAL	TONS/DAY	% of TOTAL	TONS/DAY	% of TOTAL
STATIONARY														
(Area & Point)	676	38.9	23.5	510	34.5	30. I	215	2.6	464	36.2	313	81.9	I 50	56.2
On Road Mobile	% 9	55.8	33.9	884	59.8	52.2	7699	91.2	694	54.1	37	9.7	94	35.2
Off-bad Mobi 18	92	5.3	3.2	84	5.7	5.0	527	6.2	125	9.1	32	8.4	23	8.6
Subtotal (Man-Made)	1737	100.0		1478	100.0		644 I	100.0	1 283	100.0	382	100.0	267	100.0
Natural Sources*	1132		39.5	215										
TOTAL	2869		100.0	1693		00.0	8441	100.0	1283	100.0	382	100.0	267	100.0

● Inc.lude> vegetative, landfills ● nd ● nimal waste.

Referent.; AQMP

In Table 2 the emissions inventory is disaggregate by county. As is indicated in the Table, Los Angeles and Orange Counties have a disproportionate share of total emissions, but this corresponds to their shares in population and economic activity.

The existing emissions inventory is such that on virtually every day, at least one of the federal air quality standards is violated at some location in the South Coast Air Basin. For example, the federal oxidant standard (.08 ppm) was exceeded on 252 days in 1976. In addition, the State oxidant first stage episode level of .20 ppm was violated on 204 days in 1976, with a maximum reading of .38 ppm. The nitrogen dioxide standard (.05 ppm) was also consistently violated, with the greatest number of violations occurring in the densely populated areas of Los Angeles and Orange Counties [Southern California Association of Governments, et al., (1979)]. Therefore, significant reductions in existing emissions levels of all pollutants, with the exception of sulfur oxides are required if the South Coast Air Basin is to become an attainment region.

It should be noted that reactive hydrocarbons, nitrogen oxides and carbon monoxide are the pollutants of most importance in the South Coast Air Basin. Significant reductions of total suspended particulate (TSP) are also required to meet the corresponding ambient standards. However, total suspended particulate pollution is primarily background [Southern California Association of Governments et al., (1979]). For this reason, the benefit-cost analysis which follows concentrates on the required reduction of reactive hydrocarbons, nitrogen oxides, and carbon monoxide.

In order to determine the emissions reductions to satisfy the federal standards, one must have knowledge of the relationship between emissions and air quality. However, this is an area characterized by substantial uncertainty and controversy.[4] The estimates used in this analysis are from the <u>Air Quality Management Plan</u>.

This modelling indicated that reactive hydrocarbon emission of 506 tons/day, nitrogen oxides emissions of 800 tons/day and carbon monoxide emissions of 2480 tons/day would allow the federal ambient standards to be satisfied. Therefore, the baseline emissions of reactive hydrocarbons, nitrogen oxides and carbon monoxide would have to be decreased by 974 tons/day, 503 tons/day and 5963 tons/day, respectively [Southern California Association of Governments, et al., (1979)].

Since, the primary concern of this exercise is the evaluation of on-road mobile source controls then the proportion of the required reductions in emissions attributable to these controls was necessary information. This was

Table 5.2

197s-76 Emissions-Major Sources by County
SCAB Average Sumner Weekday

	Los Angeles County	Orange County	Riverside County	San Bernardino County
Total Hydrocarbons”				
Stationary Manmade	520.3	91.7	21.5	33.0
Natural	699.3	250.2	89.8	101.1
On-Road Mobile	686.9	187.1	38.4	54.6
Off-Road Vehicles	65.1	17.7	3.6	5.2
TOTAL	1971.6	546.7	153.3	193.9
Reactive Hydrocarbons				
Stationary-Manmade	393.1	69.3	16.2	24.9
Natural	91.2	24.6	60.7	43.3
On-Road Mobile	626.7	170.8	35.1	49.8
Off-Road Vehicles	59.6	16.2	3.3	4.7
TOTAL	1170.6	280.9	115.3	122.7
Carbon Monoxide				
Stationary	18.9	9.1	23.2	164.2
On-Road Mobile	5462.2	1451.5	352.1	439.0
Off-Road Vehicles	373.1	99.5	24.2	30.2
TOTAL	5854.2	1560.1	399.5	633.4
Nitrogen Oxides				
Stationary	347.8	32.7	6.7	50.0
On-Road Mobile	482.2	135.5	33.0	42.9
Off-Road Vehicles	86.4	24.3	5.9	7.7
TOTAL	943.4	192.5	45.6	100.6
Sulfur Oxides				
Stationary	234.2	22.8	---	55.6
On-Road Mobile	26.0	7.1	1.7	2.3
Off-Road Vehicles	22.8	6.2	1.5	2.0
TOTAL	283.0	36.1	3.2	59.9
Total Suspended Particulate				
Stationary	75.5	20.7	27.0	27.2
On-Road Mobile	65.5	18.3	4.3	5.8
Off-Road Vehicles	16.2	4.5	1.1	1.4
TOTAL	157.2	43.5	32.4	34.4

Reference: AQMP

calculated as follows. First, baseline emissions (1975-1976) were inflated to reflect the expected growth from the present to 1987, the expected attainment date. This yielded the emissions levels in the absence of control. The inflated emissions were divided into the on-road mobile, off-road mobile and stationary categories assuming that growth in each was proportional to its existing share of the emissions inventory.

Second, from these 1987 emissions levels we subtracted the projected 1987 emissions levels which assume currently mandated controls.[5] The result was the impact of the control measures in each category. Therefore, on-road mobile source controls account for .747, .789 and 1.01 of the reduction in emissions of HC, NO_x, and CO from the present to 1987.[6] Finally, these factors were applied to the required emissions reductions stated above. Thus in the scenario analyzed here on-road mobile source controls are responsible for reducing emissions approximately 728 tons/day, 397 tons/day and 6023 tons/day of reactive hydrocarbons, nitrogen oxides and carbon monoxide, respectively. Off- road mobile, stationary and controls make up the balance of the control effort designed to attain the Federal Ambient Standards.

The Benefits of Emissions Reductions

The benefits from air quality improvements are derivable from either the housing value method or the survey approach detailed in the previous chapter. However, the housing value approach, which allows the derivation of an estimated relationship between pollution abatement benefits and the independent variables income and initial pollution concentration, is more amenable to this policy application. For this reason, the housing value approach is the primary method employed to estimate benefits from the air quality improvement associated with the stated emissions reductions.

The housing value analysis used is a multi-step procedure:[7] (i) estimation of a hedonic housing value equation which relates home sale price to a set of home and neighborhood variables; (ii) derivation of marginal willingness to pay for air quality improvement; (iii) estimation of a marginal benefit equation which relates marginal willingness to pay to income and existing pollution levels (i.e., this is the inverse demand curve); and (iv) mathematical integration of the marginal benefit equation to determine total household benefits for any stated air quality improvement. This final step is equivalent to determining the area under the inverse demand relationship. It is this latter relationship that is used to determine basinwide benefits for any decrease in pollutant concentrations by applying the household benefits to the relevant population.

The multi-step nature of the housing value approach produces a resulting benefit equation which is inherently dependent upon previous steps. For instance, collinearity among the various pollution measures dictated the use of nitrogen dioxide (NO_2) as a proxy for overall pollution. Also, there existed no significant difference in statistical performance in the hedonic housing equation between NO_2 measured as NO_2, NO_2^2, or NO_2^3. However, the resulting benefit estimates were substantially affected by the choice of measurement. Variation in the third procedural step estimation of the marginal benefit relationship was found not to alter the benefit results measurably; that is, benefit estimates were essentially invariant to the form of the estimated relationship (linear-linear, log-log). Therefore, benefits from air quality improvement are not determined uniquely, rather a range results are obtained depending upon the particular estimation procedure used.

In total, six estimated benefit equations, determined by the pollution variable used in the initial step (NO_2, NO_2^2, NO_2^3) and the form of the marginal benefit equation (linear-linear, log-log), were utilized to calculate household benefits. The general structure of the benefit equations corresponding to the linear-linear marginal benefit equations is

$$HB = C_1 \cdot (P_B - P_A) + C_2 \cdot (P_B - P_A) \cdot Y + C_3 \cdot (P_B^2 - P_A^2)$$

where

HB = household benefits in dollars
P_B = initial pollution (NO_2) level in pphm
P_A = pollution (NO_2) level after proposed improvement in pphm
Y = income in dollars

C_1, C_2, C_3 = estimated coefficients determined by integration of the appropriate marginal benefit function.

The general benefit equation corresponding to the log-log marginal benefit equations is

$$HB = C_1 \cdot Y^{C_2} \cdot P_B^{C_3} - P_A^{C_3} \cdot C_3$$

Table 3 presents the estimated coefficients.

In order to demonstrate the use of the benefit equations, consider Figure 3. The figure shows a family of constant benefit curves which indicate all combinations of income and existing pollution that yield an identical willingness to pay (dollar amount over the life of the home) to achieve the ambient standard. As is evident, those individuals with high income and poor air quality would be willing to pay the most for the stated air quality

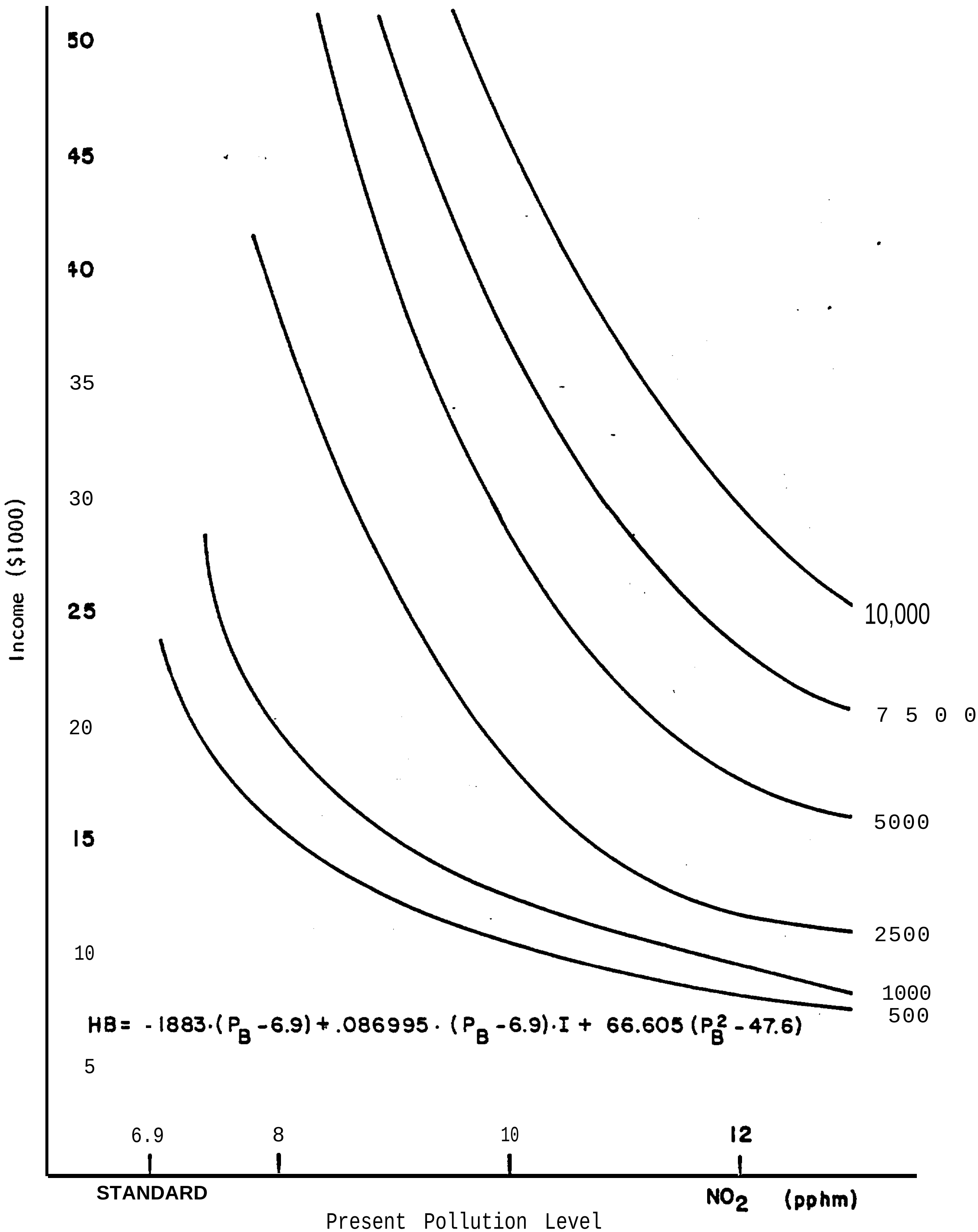
TABLE 5.3

Benefit Equation Coefficients

	Pollution Variable Used in Hedonic Housing Value Equation		
Linear - Linear Marginal Benefit Function	NO_2	NO_2^2	NO_2^3
C_1	**53.996**	**-1883.1**	**-2294.5**
C_2	**.11513**	**.086995**	**.057521**
C_3	**-31.204**	**66.605**	**95.145**
Log - Log Marginal Benefit Function			
C_1	**.024134**	**.001785**	.000115
C_2	1.1983	1.1985	1.1988
C_3	.69054	1.69195	2.691

Figure 5.3

VALUE OF IMPROVED AIR QUALITY ($)



improvement. Further, an individual with relatively high income and good air quality would be willing to pay as much as an individual characterized by poor air quality and low income.

Benefits derivable from moving to the ambient standard can be calculated given values for income and baseline pollution in all areas. In the context of the earlier discussion, this constitutes improving the "fair" and "poor" air quality areas to the "good" category. The fair and poor regions are assigned values of 9.55 pphm and 12.38 pphm, respectively, as determined by the sampling procedure outlined in Chapter 3. Therefore, if all regions were to upgrade to the "good" level, it would involve an approximate 30% improvement in the fair communities and a 45% improvement in the poor air quality communities.

With respect to income data, two methods were initially utilized. In the first method each household was allocated the county average income. The second procedure assumed that the good air quality region was inhabited by an income group wealthier than average. Thus, on the basis of the survey responses the good air quality area income was determined and then separated out from total county income. Each household in the poor and fair air quality regions was then allocated the average of the remaining income. This second method, although somewhat lowering average income per household in the poor and fair communities had little effect on aggregate benefit estimation. Thus, results are presented for the first method only.

With all data inputs specified, household benefits are calculated using the estimated benefit equations. These benefits which accrue over the life of the home, represent differences in home sale price attributable to variations in air quality. In order to transform these into annual benefits the standard annualization procedure is employed (1978 interest rate = .10). Aggregation is then accomplished for each county by deflating by persons per household and multiplying by county population. This generalization to the entire county assumes that the household sample analyzed is representative of the population at large.

Aggregate benefits associated with achieving the federal air quality standards in the South Coast Air Basin are presented in Table 4. As is illustrated, aggregate benefits range from 1.5 to 3.8 billion dollars annually. Further, the bulk of the benefits occur in populous Los Angeles and Orange counties. The upper bound estimate corresponds to the benefit equations derived from the use of NO_2 in the hedonic housing equation (initial step of the multi-step procedure) whereas the lower bound corresponds to the use of NO_2. The form of the estimated marginal benefit function has no significant impact on the benefit estimates.

Table 5.4

Annualized Benefit Estimates for Achieving the Federal Ambient Standard (1978 $000)

Functional Form		County				
Pollution Variable in Hedonic Housing Equation	**Functional Form** of Marginal Benefit Function	**San Bernardino**	**Riverside**	**Orange**	Los Angeles	Total
NO_2	Linear - Linear	295708	234345	638571	2711045	3879669
NO_2^2	Linear - Linear	194455	153284	414687	1776702	2539128
NO_2^3	Linear - Linear	118541	93117	245573	1065688	1522919
NO_2	Log - Log	287443	228393	615769	2611015	3742620
NO_2^2	Log - Log	204302	162331	413405	1789905	2569943
NO_2^3	Log - Log	129231	102681	246916	1092596	1571424

For purposes of comparison, the survey approach which accompanied the property value analysis, yields an aggregate benefit estimate of approximately 1.65 billion dollars annually, whereas a housing value analysis which utilized total suspended particulate as the proxy variable yields estimates in the 2.2 to 2.7 billion dollar range. Based on this evidence, a narrowing of the probable range of benefits to 1.6 to 3.0 billion dollars annually seems in order.

Apportionment of these benefit figures between the on-road mobile, off-road mobile and stationary categories is accomplished through application of the percentage figures described above. Using the percentage averages over reactive hydrocarbons, nitrogen oxides and carbon monoxide then on-road mobile controls are assigned approximately 85% of the benefits. Therefore, the benefits from air quality improvement associated with on-road mobile controls range from 1.36 - 2.55 billion dollars annually. Again, the remainder of air quality improvement benefits are a function of off-road and stationary and institutional control measures.

Before proceeding to the next section two qualifications should be noted. First, the benefit calculations are inherently tied to both the air pollution modeling efforts contained in the Air Quality Management Plan and the estimation procedures outlined in Chapter 3. Second, it should be noted that these benefit calculations were derived assuming a one year cleanup period. This essentially static analysis is somewhat unrealistic given the magnitude of the air quality problem in the SCAB.[8] A dynamic approach which examined the benefits resulting from a multi-year clean-up would indicate expanded benefits due to increased population and economic growth and associated increased emissions levels. The increased emissions would imply a larger required emission reduction to satisfy the federal standards and a corresponding larger benefit per household. The greater population would increase aggregate basin-wide benefits.

In the next section, dollar per ton removed cost estimates are presented for on-road mobile pollution control methods. These cost estimates are then used to determine total clean-up costs for the required emissions reductions.

ESTIMATED COSTS OF AIR QUALITY IMPROVEMENT

Institutional Background

Control of vehicular emissions began in 1961, when the automakers, under pressure from the California legislature, installed positive crankcase ventilation (PCV) systems in order to reroute "blowby" fumes back into the engine intake.[9] These emissions had been discovered two years earlier to account for 20-25 percent of hydrocarbon emissions. Positive crankcase ventilation was adapted nationwide in 1963 [Mills, et al. (1978), and Wakefield, (1980)].

The 1965 amendments to the Clean Air Act directed the secretary of HEW to set emissions standards for automobiles effective January 1, 1968. The Clean Air Act was further amended in 1970 setting goals of 90 percent reductions in emissions from automobiles by 1975-76. The objective of such legislation seemed reasonable; fewer pollutants, more efficient engines. However, the attainment of such objectives has been a difficult process.

Emission standards were first set for hydrocarbons (HC) and carbon monoxide (CO); the 1970 standards were 2.2 grams/mile and 23 grams/mile respectively (7-mode test). In the early years the control of those pollutants focused on modification of existing engines. The original modifications (leaner air-fuel mixtures, retarded ignition timing and higher coolant temperatures) were relatively unsuccessful, causing associated side effects (reduced fuel economy and engine response). Later modifications proved more successful both in combatting pollution and reducing the unwanted side effects.

California was the first to set a limit on nitrogen oxide (NO_x) emissions -- 4.0 grams/mile for the 1971 year. This was in response to NO_x being identified as an important element in the formation of photochemical smog. However, the control of NO_x introduced an inherent conflict. Hydrocarbon and carbon monoxide control had been achieved by afterburning through air injection, delaying spark, leaner mixtures or hotter combustion. Nitrogen oxide control required reducing temperature since they were a byproduct of very hot, relatively efficient combustion. This was accomplished by exhaust gas recirculation (EGR) which had dramatic negative impacts on fuel mileage and driveability (response to acceleration and performance under constant speed [Wakefield, (1980)].

Even though the original 1975-76 standards were delayed considerably the 1975 federal emission regulations were so stringent (1.5/15/3.1 grams per mile of HC/CO/NO_x using the Constant Volume Sampling - 75 test) as to require a technological revolution. The catalytic converter was introduced. Since the catalytic converter was downstream from the engine operation it freed the engine from earlier modifications. This meant better engine response and fuel economy from a given engine controlled with a catalyst rather than controlled without a catalyst.

The first catalytic converters controlled HC and CO leaving NO_x to be controlled by conventional means. However, 3-way catalytic converters in which two separate catalyst beds control HC, CO and NO_x now exist. This latter innovation, together with advances in electronic monitoring have allowed control of vehicular emissions while minimizing the effects on driveability and fuel economy. However, this is sophisticated and costly technology. It is the costs we turn to next.

The Costs of Emissions Reductions

The estimation of control costs is characterized by controversy and a large degree of uncertainty. The difficulty in estimation is concentrated around two central problems. The first is determining the actual cost of any particular control technique. In many instances, with very little construction experience, the cost of specific control devises is unknown. Also, marketing strategies affect the direct cost to the consumer. For example, the cost of California systems which requires larger emission reductions than their federal counterparts may be spread out among all automobile consumers rather than those located in California. Further, control techniques generally imply associated secondary costs and savings which often escape quantification. These secondary implications can have a significant impact on the cost of any proposed control option.

The second problem is the determination of actual, rather than alleged, emissions reductions corresponding to any particular control strategy. For instance, control strategies may cause synergistic reductions or may negate each other. In addition, control strategies may be credited with either overstated or understated emission reductions. The former problem, phantom decreases in emissions, seems to occur more often in practice.

Therefore, any cost analysis which is not fortified by detailed engineering cost evaluation and experience is subject to significant error. This problem is further exacerbated in that estimation errors are generally not randomly distributed.[10]

Given the background of controversy and substantial uncertainty, the objective here is to provide a range of cost estimates to be used for comparison to the benefit calculations presented in the previous section. The cost estimates contained herein were derived from a variety of sources, primarily from Environmental Protection Agency (EPA) publications and automobile manufacturer statements. All costs are stated in 1978 dollars per ton removed.

Due to the automobile's substantial role in the South Coast Air Basin air quality problem (see Tables 1 and 2) mobile source control must be the central element in any attainment plan. However, control cost figures associated with any level of control vary widely, dependent upon one's assumptions regarding initial capital cost, size of any mile per gallon benefit or penalty, unleaded fuel cost differential, etc. In order to offset some of the variation we standardized the cost estimates by assuming the following: (1) control cost devices have a lifetime of 50,000 miles; (2) the cost of gasoline is $1.00/gallon; (3) the unleaded fuel cost differential is $.04/gallon [Lloyd, (1979)]; (4) baseline mileage is 20 miles per gallon[11]; (5) maintenance savings are $25 over the life of the emissions system [Lloyd, (1979)]; (6) evaporative emissions and altitude control add $15 to initial capital costs; and (7) the capital costs of going from totally uncontrolled vehicles to the 1977-79 standard of 1.5/15/2.0 of HC/CO/NO_x is $140 [Lloyd, (1979)], where uncontrolled vehicles correspond to the 1973 federal standard (Constant Volume Sampling-72 test) of 3.4/39/3.0.[12] Further, we examined the total cost of moving from this 1973 level of control to the 1981 federal standard of .41/3.4/1.0.

Even with this degree of standardization there exists significant variation in mobile control costs dependent upon the source of information, the assumed fuel mileage savings or penalty and the assumed allocation of total costs to hydrocarbon, carbon monoxide and nitrogen oxide control. Tables 5, 6, and 7 present this range of cost estimates for light duty vehicles.

Each of the tables uses the same references to generate total control costs. The General Motors estimate is based upon initial capital costs of $460 and a three percent mileage penalty, whereas the EPA estimate is $415 for initial capital cost with a seven percent mileage improvement. The American Motors and manufacturer average sticker price estimates for first cost are $557 and $475 respectively. These are combined with the General Motors and EPA mileage penalty or saving estimates to obtain two of the estimates presented. The third estimate assumes an eight percent mileage penalty [California Air Resources Board, (1979)]. Cost effectiveness is then determined by dividing the total cost per car by the emission reduction over 50,000 miles.

In Table 5 the lower bound figure of the range for each cost-effectiveness estimate is based upon an allocation of 30.4 percent of the total control cost to hydrocarbon measures [Schwing, et al., (1980)]. The upper bound figures assume one-third of total cost is allocated to hydrocarbon control. In Table 7, the upper bound figures for each estimate correspond to an allocation of .33 and .362 to nitrogen oxides control [Schwing, et al., (1980)]. The figures in Table 6 assume one-third of total cost is allocated to carbon monoxide control.

As is illustrated in the tables, the cost effectiveness range ($/ton

Table 5.5

Hydrocarbon Cost Estimates for Mobile Source Control

($1978/ton removed)

Control Category	cost	Reference
Light Duty Vehicles	$ 160- 257	General Motors (GM)[1]
	620- 680	EPA[2]
	880- 965	American Motors[3], EPA Mileage
	1340- 470	American Motors, GM Mileage
	1610- 770	American Motors, Eight Percent Mileage Penalty
	730- 800	Manufacturer Average[4], EPA Mileage
	1190-1310	Manufacturer Average, GM Mileage
	1460-1600	Manufacturer Average, Eight Percent Mileage Penalty
Heavy Duty Vehicles	3400-3450	AQMP[5]
	3720-3770	EPA
Inspection and Maintenance	1410-1590	AQMP

References: 1. General Motors Corporation, "Estimated Effects of Exhaust Emission Standards on Potential Hardware, Fuel Economy, Fuel Consumption and Additional First Cost to Consumer," May 1979.

2. Lloyd, Kenneth H., Cost and Economic Input Assessment for Alternative Levels of the National Ambient Air Quality Standard for Ozone, USEPA, February 1979.

3. American Motors Corporation Cost Information contained in "Automobile Emission Control - The Development, Status, Trends and Outlook as of December 1976," USEPA, April, 1977.

4. California Air Resources Board, "Status Report on the Need for Land Feasibility of a 0.4 NO_x standard for Light Duty Motor Vehicles, December 1979.

5. Southern California Association of Governments and South Coast Air Quality Management District, Draft Air Quality Management Plan, January, 1979.

Table 5.6

Carbon Monoxide Cost Estimates for Mobile Source Control

($1978/ton removed)

Control Category	cost	Reference
Light Duty Vehicles	160	General Motors (GM)[1]
	85	EPA[2]
	120	American Motors[3], EPA Mileage
	184	American Motors, GM Mileage
	220	American Motors, Eight Percent Mileage Penalty
	100	Manufacturer Average[4], EPA Mileage
	163	Manufacturer Average, GM Mileage
	200	Manufacturer Average, Eight Percent Mileage Penalty
Heavy Duty Vehicles	290-310	AQMP[5]
	320-340	EPA
Inspection and Maintenance	175-195	AQMP (Revised)

References: 1. General Motors Corporation, "Estimated Effects of Exhaust Emission Standards on Potential Hardware, Fuel Economy, Fuel Consumption and Additional First Cost to Consumer," May 1979.

2. Lloyd, Kenneth H., Cost and Economic Input Assessment for Alternative Levels of the National Ambient Air Quality Standard for Ozone, USEPA, February 1979.

3. American Motors Corporation Cost Information contained in "Automobile Emission Control - The Development, Status, Trends and Outlook as of December 1976," USEPA, April, 1977.

4. California Air Resources Board, "Status Report on the Need for Land Feasibility of a 0.4 NO_x standard for Light Duty Motor Vehicles, December 1979.

5. Southern California Association of Governments and South Coast Air Quality Management District, Draft Air Quality Management Plan, January, 1979.

Table 5.7

Oxides of Nitrogen Cost Estimates for Mobile Source Control

($1978/ton removed)

. . .

Control Category	cost	Reference
Light Duty Vehicles	1910-2070	General Motors (GM)'
	1010-1100	EPA[2]
	1440-1570	American Motors[3], EPA Mileage
	2200-2390	American Motors, GM Mileage
	2640-2870	American Motors, Eight Percent Mileage Pena 1 ty
	1195-1300	Manufacturer Average[4], EPA Mileage
	1950-2120	Manufacturer Average, GM
	2390-2600	Manufacturer Average, Eight Percent Mileage Penalty
Heavy Duty Vehicles	2020-2120	AQMP[5]
	2210-2320	EPA
Inspection and Maintenance	1310-1600	AQMP

References: 1. General Motors Corporation, "Estimated Effects of Exhaust Emission Standards on Potential Hardware, Fuel Economy, Fuel Consumption and Additional First Cost to Consumer," May 1979.

2. Lloyd, Kenneth H., Cost and Economic Input Assessment for Alternative Levels of the National Ambient Air Quality Standard for Ozone, USEPA, February 1979.

3. American Motors Corporation Cost Information contained in "Automobile Emission Control - The Development, Status, Trends and Outlook as of December 1976," USEPA, April, 1977.

4. California Air Resources Board, "Status Report on the Need for Land Feasibility of a 0.4 NO_x standard for Light Duty Motor Vehicles, December 1979.

5. Southern California Association of Governments and South Coast Air Quality Management District, Draft Air Quality Management Plan, January, 1979.

removed) for hydrocarbon control is approximately $600 - $1800 while carbon monoxide control is $80-$200 and NO_x control is $1000-$2600. The predominant source of this wide variation is the assumption concerning fuel use over the 50,000 mile life of the control device.

The cost effectiveness of heavy duty vehicle emissions control were calculated in a manner similar to that described above for light duty vehicles. In this instance total cost per vehicle figures published in the Air Quality Management Plan (January, 1979) and an EPA report [Lloyd, (1979)], were utilized. The former reference was also the source for the corresponding emissions reductions. Total vehicle cost includes all capital costs and costs for the associated inspection and maintenance program. Cost effectiveness estimates for heavy duty vehicles are presented in Tables 5, 6, and 7 for the pollutants HC, CO, NO_x, respectively. Again, the range of costs is dependent upon the allocation method used; either one-third to each pollutant or .329 to HC, .354 to CO and .317 to NO_x, [Schwing, et al., (1980)].

The final component of on-road mobile source control is the light duty vehicle inspection and maintenance program. The importance of this program cannot be understated for without it, auto owners have no incentive to maintain the performance of their emission control systems. Furthermore, the lack of performance invalidates the cost-effectiveness figures presented above which assume that the control devices work as designed. For example, if control mechanisms on light duty vehicles deteriorate linearly over 50,000 miles from their designed operations levels then the cost effectiveness of such mechanisms doubles. This situation is worsened if systems deteriorate more quickly or are tampered with. The success of any control system is therefore inherently dependent on an effective inspection and maintenance program.

The annual cost of the program is the sum of the inspection fee multiplied by number of automobiles plus the cost of repairing failed automobiles. The air quality management plan assumes a $9 inspection fee, and a 35 percent failure rate with associated $23 repair cost. However, recent evidence shows that the failure rate may be closer to 42 percent.[13] The cost calculations contained in Tables 5, 6, and 7 assume this latter figure with a corresponding repair cost range of $20 - $25. Emissions reductions associated with the inspection and maintenance program were obtained from the Air Quality Management Plan (January, 1979). Allocation of total cost among the pollutants was based on either one-third to each pollutant or the proportions used for light duty vehicles [Schwing, et al., (1980)].

Any control strategy devised to meet the ambient standard would use a variety of control options, each with an associated cost effectiveness.

Therefore, the cost effectiveness figures for light duty vehicles, heavy duty vehicles and the inspection and maintenance program form the basis for the derivation of aggregate cost estimates to achieve the federal ambient standards.

It is not the objective of this exercise to cost out a specific air quality improvement program, but rather to develop a range of costs for comparison to benefits. This can be accomplished by an examination of an upper and lower bound for costs. In either case, a weighted average of light and heavy duty vehicle costs and the inspection and maintenance costs is utilized, where light duty vehicle costs are the dominant component.

As was stated in the previous section on-road mobile controls account for approximately 85 percent of the required emissions reductions. This translates into 728 tons/day of HC, 6023 tons/day of CO and 392 tons/day of NO_x. In order to estimate total control costs these emissions reductions are further apportioned into the light duty vehicle, heavy duty vehicle and inspection and maintenance categories. Reductions associated with inspection and maintenance are determined directly from the Air Quality Management Plan (January, 1979). The shares corresponding to light duty vehicles and heavy duty vehicles are determined by their relative shares in annual vehicle sales. Therefore, three percent of the required reductions minus the effect of inspection and maintenance are allocated to heavy duty vehicles with the remainder to light duty vehicles.

A lower bound total cost estimate would correspond to the EPA capital cost, a seven percent mileage improvement and one-third allocation to each pollutant. In this case total cleanup costs for on-road mobile controls would be approximately .61 billion dollars. Conversely, an upper bound estimate would be 1.32 billion dollars. This latter estimate would utilize American Motors capital costs, an eight percent mileage penalty and one-third allocation to each pollutant. Thus, the total cost of using on-road mobile controls to achieve the above stated pollution reductions range from approximately .61 to 1.32 billion dollars. A best estimate (manufacturer average capital cost, three percent mileage penalty) would be 1.02 billion dollars.

Before proceeding to the concluding section it should be re-emphasized that these cost figures are subject to a great deal of uncertainty. There could be significant error in the estimates. It should also be noted that, as in the case of the benefit estimate, this is an essentially static analysis. In a dynamic context, one would expect the costs to increase significantly as a result of larger emission reductions necessitated by expanded population and economic activity. The costs would likely increase non-linearly as more costly control measures were employed to achieve the required reductions.

This latter aspect exists because many of the easy technological fixes have already been made.

COMPARISON OF BENEFITS TO COSTS - CONCLUDING REMARKS

There has been much discussion of the desirability of achieving the federal air quality standards. This study constitutes an attempt to evaluate a portion of these standards in the South Coast Air Basin of Southern California from an economic or benefit-cost perspective. Based upon modeling contained in the Air Quality Management Plan, achievement of the ambient standards in 1979 would require emission reductions of the 974 tons/day, 5963 tons/day and 503 tons/day of reactive hydrocarbons, carbon monoxide and nitrogen oxides. It is the share of these emission reductions attributable to on-road mobile source control which was evaluated using benefit-cost analysis.

Benefits were calculated through an examination of housing value differentials attributed to air quality. Achieving the ambient air quality standards was consistent with improving the "fair" and "poor" air quality regions to the "good" category as specified in the previous chapter. 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 and 3.0 billion dollars per year, independent of any benefits accruing to agriculture and ecosystems. The share of these benefits associated with on-road "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 on-road mobile source control consistent with a policy to achieve the ambient standards in 1979 would involve a cost of between ,61 and 1.32 billion dollars, with a best estimate of 1.02 billion dollars.

It seems then, that the benefits from on-road 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 are not without some economic justification, though the uncertainty concerning the benefit and cost calculations prevents one from accepting the controls outright. However, on-road mobile controls consistent with the air quality standards cannot be rejected as economically inefficient either.

Therefore, although the mid-range benefit estimate exceeds the mid-range cost estimate, the situation is best characterized as highly uncertain. Further, the static analysis performed herein 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 supported by a solid cost data base.

Appendix 1
Air Quality Modelling in the
Air Quality Management Plan

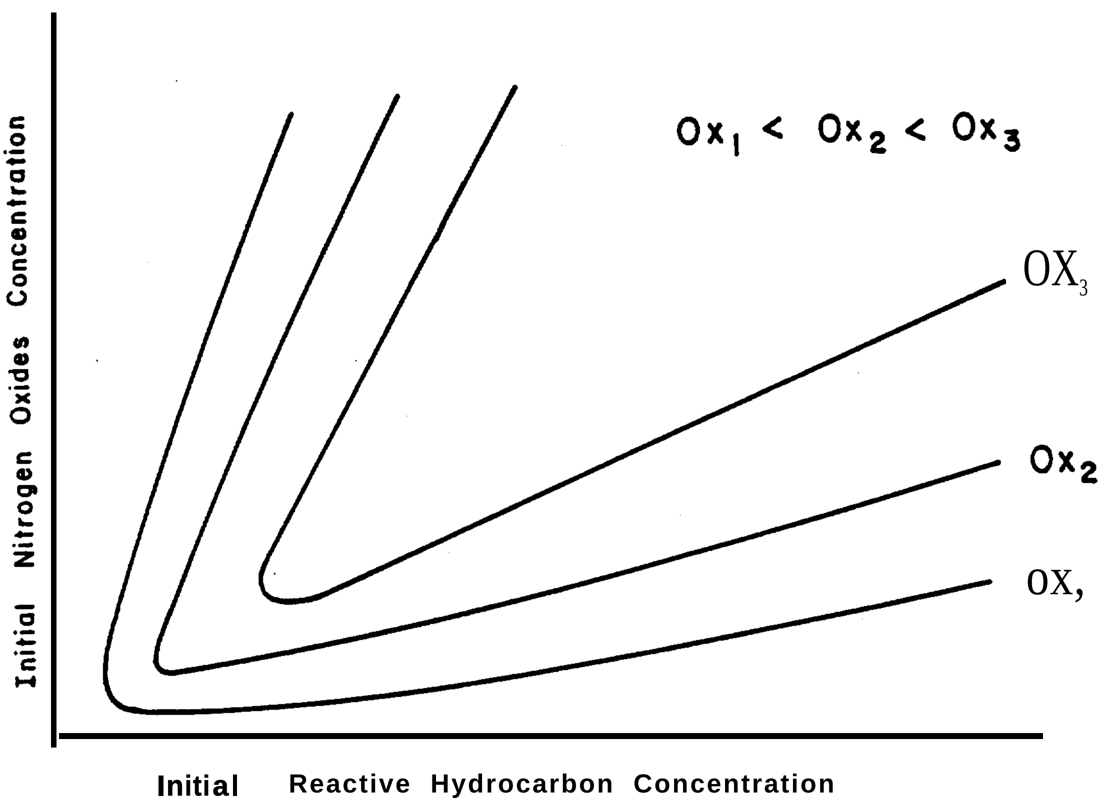
The principal modeling procedure utilized in the Air Quality Management Plan is proportional rollback. This method is based on the assumption that atmospheric concentrations of the contaminant are in direct proportion to emissions. Mathematically, the proportional rollback method can be expressed as:

$$\frac{\text{Baseline Emissions}}{\text{Emissions Objective}} = \frac{\text{Baseline Air Quality}}{\text{Air Quality Objective}}$$

The emissions level consistent with the federal standards (objective) can then be determined with knowledge of the other three components. The procedure was employed to calculate the required reductions of carbon monoxide. A somewhat more sophisticated rollback method was used for total suspended particulate [Southern California Association of Governments and South Coast Air Quality Management District, (1979)]. The rollback method provides an accurate assessment of emissions reductions required in cases where the contaminant is emitted uniformly over the region and there are only limited atmospheric reactions among pollutants. Accuracy is severely curtailed when these conditions are not satisfied. In the South Coast Air Basin, where pollutants are emitted nonuniformly with nonuniform distribution and photochemical oxidants are the primary problem, the linear rollback method is of limited usefulness. Therefore, ozone production was modeled in the AQMP using the Empirical Kinetic Modeling Approach (EKMA).

The EKMA Method is a mathematical model which generates a set of atmospheric ozone concentration isopleths as a function of early morning concentrations of hydrocarbons and nitrogen oxides [Mikolowsky, et al, (1974) and Southern California Association of Governments and South Coast Air Quality Management District, (1979)]. Figure Al illustrates the inherent nature of the ozone isopleths (curves of equal concentration). The curvature of the isopleths indicates that a control strategy which reduced only one of the pollutants -- reactive hydrocarbons or nitrogen oxides -- could conceivably worsen rather than improve the situation. The proper control strategy would, therefore, require that both pollutants be reduced simultaneously.

Figure 5.A1



OZONE ISOPLETHS

REFERENCES

1 Note, for example, that the average daily maximum concentration of NO in "good" air quality communities is .069 ppm where the ambient standard^{2} required an average concentration of .05 ppm.

2 In addition to the difficulty in obtaining accurate cost data on stationary and institutional controls the decision to focus on on-road mobile source control was a function of its relative share of both existing pollution and the future clean-up as envisioned in the Air Quality Management Plan (January, 1979).

3 The area description follows closely the Air Quality Management Plan (January, 1979).

4 A brief discussion of air quality modelling is contained in the appendix to this section.

5 Air Quality Management Plan (January, 1979).

6 The share of the reduction in CO attributable to on-road mobile sources estimated to be in excess of 1.0 indicated an increase in CO emissions from off-road mobile sources and neither an improvement nor deterioration from stationary sources.

7 See Harrison and Rubinfeld (1978) for a detailed description of the methodology.

8 Although the static approach is somewhat unrealistic it was chosen since there was insufficient data on costs and the dynamics of pollution emissions, population, etc. to support analyzing a particular attainment plan.

9 Blowby is the collection of combustion gases that slip past the piston rings from the combustion chamber into the crankcase. These fumes were vented to the atmosphere to prevent contamination and thinning of

crankcase oil [Mills, et al. (1978) and Wakefield (1980)].

10 Personal Communication with Dr. Richard Perrine, UCLA.

11 The 20 miles per gallon assumption corresponds to the CAFE mileage standards for 1980 on a sales weighed basis. Further, these standards are front loaded up to 27.5 MPG in 1985. Thus, using 20 MPG overstates the lifetime fuel cost differential and the mileage penalty.

12 Even though the 1973 federal standard was chosen as the level of uncontrolled emissions, the 1973 levels represent approximately 61%, 55% and 25% control over truely uncontrolled emissions of HC, CO and NO respectively. The 1973 level was chosen to be conservative (overstate) in the cost effectiveness of emission control devices.

13 Personal communication with Dr. Richard Perrine, UCLA.

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CHAPTER 6

EFFECTS OF AIR POLLUTION AND OTHER ENVIRONMENTAL VARIABLES ON OFFERED WAGES

INTRODUCTION

Much of the recent interest in the econometric estimation of labor supply models using individual or micro data has been stimulated by important policy questions such as the role of women in the labor force and the advisability of negative income tax programs. Frequently, these models have consisted of two interrelated equations that explain: (1) how an individual's offered wage rate is determined and (2) how this wage rate together with other factors affects the amount of time an individual chooses to work. Effects on wages and hours in response to changes in exogenous variables including the actual negative income tax rate faced or the number of pre-school children in the home can then be estimated through this framework. This general approach can be easily extended to make parallel estimates of the labor market effects of changes in environmental amenity levels. Such extensions would have obvious policy relevance in that the extent of reduced productivity due, for example, to air pollution could then be assessed.

The purpose of this report is to construct some exploratory estimates of the effect of changes in air pollution levels on offered wage rates. Repercussions on the work time choice are not explicitly considered. Specifically, hedonic equations are estimated that allow for an individual's offered wage rate to be determined by his own labor supply characteristics together with measures of amenity levels in the community in which he lives. In this type of analysis, supply characteristic's such as education, work experience, and health status are frequently used exclusively to explain the variation in the offered wage.[1] This specification carries the restrictive implicit assumption that the demand schedule for classes of individuals possessing identical values of these independent variables is infinitely elastic. That is, observed differences in individual wage rates are attributed only to supply characteristics. In order to circumvent this limitation, Nakamura, Nakamura, and Cullen (NNK) (1979), have suggested the inclusion of work environment variables such as the local unemployment rate and a local job opportunities index as additional regressors. These work environment variables, obviously) capture the fact that local labor demand conditions may influence offered wages after adjusting for the effect of individual labor supply characteristics. However, as recognized by other investigators, variables measuring working conditions and job related hazards (Lucas 1977, Hamermesh 1977, Thaler and Rosen 1975, Viscusi 1978, and Brown 1980), social infrastructure (Nordhaus and Tobin 1972, and Meyer and Leone 1977), as well as environmental amenities (Hoch 1977, Rosen 1979, and Cropper 1979) can also play an important role, in explaining the behavior of wage rates. For example, in the case of environmental amenities, ‘if a community is located in an area that is subject to extreme temperatures or unusually high air pollution levels, employers may find it necessary to pay their workers a premium in order to induce them to remain there.

SPECIFICATION AND THE DATA USED IN ESTIMATION

The general form of the offered wage rate equation to be considered here is then

$$\text{WAGE} = f(P,W) \qquad (1)$$

where WAGE denotes the offered wage rate paid, P denotes a vector of personal labor supply characteristics, and W denotes a vector of work environment characteristics. Moreover, the vector P is assumed to contain measures of: (1) whether the individual is a union member (uNON), to an individual working 400 hours or less had that individual have chosen to work, for example, full time. An excellent survey of the sample selection problem as it relates hedonic wage and labor supply estimates is contained in the recent paper by Wales and Woodland (1980).

The exact specification of the wage equation used in the present study is shown in Equation (2).

$$\begin{aligned} \text{Ln(RWGH)} = f(&\text{UNON, HVET, FMSZ, HLTH, EDC2, EDC3, TOJ2, WARM,} \\ &\text{JACR, COLD, HUMD, SOXM, TSPM, NOXM, P**2, SOXM**2,} \\ &\text{N**2, CONSTANT).} \end{aligned} \qquad (2)$$

In Equation (2), the function f is linear in the parameters and RWGH denotes the real wage. Also , note that the squares of the levels of the three pollution variables are included as regressors in order to allow for possible nonlinearities in the way that air pollution affects the real wage. This equation was estimated by ordinary least squares for both the complete sample of 1395 observations and for selected partitions of this sample constructed on the basis of age (AGEH), race (RACE), sex (SEXH), and occupation (OCCP). In particular, there were three age categories (1729, 3049, 5069), two race categories, (white, nonwhite), two sex categories (male, female), and two occupation categories (white collar, blue collar). The total number of possible partitioned regressions was therefore 24(3x2x2x2). However, not all of these possible regressions were actually estimated because for certain partitions the number of available observations was insufficient.[4]

Before turning to a discussion of the results of these regressions, two additional points should be made regarding the pollution variables. First, as previously indicated, observations on these variables were not available for each of the 669 counties of residence for families (2) whether the individual is a veteran (HVET), (3) the size of the individual's family (FMSZ), (4) the individual's health status (HLTH), (5) the individual's prior educational achievement (EDC2,EDC3), and (6) the length of time the individual has spent on his present job (TOJ2)[7]. Next, W contains measures of: (1) mean January and July temperature in the individual's area of residence (COLD, WARM), (2) the job accident rate in the industry where the individual works (JACR), (3) average rainfall in the individual's area of residence, and (4) levels of the air pollutants sulfur dioxide (SOXM), total suspended particulate (TSPM), and nitrogen dioxide (NOXM).

Unfortunately, this formulation may be subject to a specification error of unknown severity resulting from the omission of relevant explanatory variables. While the personal labor supply characteristics are fairly standard for analyses of this type, biased coefficient estimates may result from the exclusion of still other relevant work environment variables. That is, climate, job hazards, and air pollution do not exhaust the list of potential amenities that may affect the offered wage rate. (For good surveys of the role other variables may play, see Brown (1980) and Rosen (1977).) Proximity to recreational opportunities and the amount of local social infrastructure are but two examples of work environment variables that could in principle be measured and included. Also, the more labor market specific variables used by NNK have been excluded from consideration here. Due to budgetary and time constraints, no efforts were made to collect observations on these potentially relevant variables. The variables used to explain variations in the offered wage rate were simply chosen from those that had been collected previously by the Resource and Environmental Economics Laboratory at the University of Wyoming for use on other research projects.

More specifically, the basic data set used to estimate the wage equation consisted of observations drawn from the Panel Study of Income Dynamics (PSID) for the 1971 interview year. In total, there are observations for household heads on variables that can be used to construct a measure of their real wages, together with measures of the variables in the P vector defined previously in Equation (l). The exact definitions of all of these variables as well as their numerical codes used on the PSID tapes are provided in Table

1 entitled Variable Definitions. Table 1 also gives definitions of the variables appearing in the vector W. For the 1971 interview year, the PSID data gives the household's state and county of residence and two digit SIC industry of employment. Consequently, data were collected on COLD, WARM, HUMD, SOXM, NOXM, and TSPM by county and then were matched to the individual observations obtained from the PSID.

. . .

For the variables COLD, WARM, AND HUMD, this matching process was quite simple and requires no further elaboration. However, the matching of the air pollution variables to counties should be explained in greater detail. The matching process was begun by listing each of the 669 counties in the 50 states where PSID families lived during 1970. Outdoor air pollution monitoring data existed for at least one of the three measures SOXM, NOXM, AND TSPM for 247 of these counties. In cases, where data from only one monitoring station in the county were available, those data were automatically assigned to all PSID families residing there. On the other hand, where data were available from multiple monitoring stations in the county, data from the single station that had operated for the greatest portion of the nine year period 19671975 were selected. The monitoring stations selected using this rule tended to be at central city locations. Finally, since no pollution data were available for 422 counties (699247), values were assigned to the air quality variables for these counties using one of two procedures for handling missing observations that will be described momentarily.

For the purpose of estimating the hedonic wage equation, the data set was reduced from the roughly 3300 possible observations to 1395 observations after excluding all housholds where: (1) any family member received transfer income, (2) the head's annual hours of working for money was less than 400 hours. The first of these exclusions was made in order to reduce the statistical problem created by families that may be facing nonconvex budget constraints while the second was made in order to eliminate casual workers, who may be out of equilibrium because their asking wage may exceed offered wage, from the sample. Curiously, after making these two exclusions, there were <u>no</u> families remaining in the sample where the head: (1) received income from overtime, bonuses or commissions, or (2) was self employed.

The restricted sample used here is quite similar to that used by Wales and Woodland (1976, 1977, 1978) in their numerous papers on the empirical determinants of labor supply using PSID data. However, by excluding household heads who worked less than 400 hours, the estimates reported in the next section are subject to sample selection bias, a problem dicussed at length by Heckman (1976, 1979). Essentially, Heckman contends that the estimates resulting from such a sample do not apply to the general population. Instead, they apply only to those in the population having the same characteristics of those in the sample. In short, the estimates say little about the wage rate

DISPLAY 1
VARIABLE DEFINITIONS*

A. PECUNIARY VARIABLES

HOURS = (1839) (head's annual hours working for money)
AWGH = (1897) (head's money income from labor)
WAGH = O if HOURS = O, otherwise WAGH = AWGH/HOURS
BDAL = Index of comparative living costs for a four person family for various areas as published by Bureau of Labor Statistics in the Spring 1967 issue of Three Standards of Living for an Urban Family of Four Persons. The lowest living standard was used. This index is published for the 39 largest SMSAS and by region for other SMSAS.
RWGH = WAGH/BDAL

B. SUPPLY CHARACTERISTIC VARIABLES

HLTH = 1 if (2121) = 1 or 3 or if (2122) = 1 or 3 or both.
= O otherwise (If HLTH = 1, there are limitations on amount or kind of work that the head can do)
UNON = 1 if (2145) = 1, zero otherwise (Head belongs to a labor union if UNON = 1)
EDC1 = 1 if (2197) = 0, 2, 3, or 9 zero otherwise (If EDC1 = 1, head" has completed grades 08 or has trouble reading.)
EDC2 = 1 if (2197) = 3, 4, or 5 zero otherwise (If EDC2 = 1, head has completed grades 912 + possible nonacademic training.)
EDC3 = 1 if (2197) = 6, 7, or 8 zero otherwise (If EDC3 = 1, head has completed at least some college.)
HVET = 1 if (2199) = 1 zero otherwise (If HVET = 1, head is a veteran.)
FMSZ = (1868) (Family size in 1971)
TOJI = 1 if (1987) = 1, 2, or 3 zero otherwise (head's length of time on present job is 3 years or less if TOJI = 1)
TOJ2 = 1 if (1987) = 4, 5, or 6 zero otherwise (head's length of time on present job is longer than 3 years if TOJ2 = 1)

Variable Definitions (Continued)

C. WORK ENVIRONMENT VARIABLES

WARM = Mean annual July temperature in the county of residence in 1970 in F° x 10.0. These data are from the U.S. Bureau of Census, County and City Data Book, 1971.

COLD = Mean annual January temperature in the county of residence in 1970 in F° x 10.0. These data are from U.S. Bureau of Census, County and City Data Book, 1971.

JACR = Number of disabling work injuries in 1970 for each million employee hours worked by 2 and 3 digit SIC code. The data were obtained from Table 163 of Bureau of Labor Statistics, Handbook of Labor Statistics, 1973, Bulletin 1735, U.S. Department of Labor, Washington, DC., USGPO, 1972.

SOXM = Annual 24 hour geometric mean sulfur dioxide micrograms per cubic meter as measured by the Gas Bubbler Pararosaniline Sulfuric Acid Method. These data were obtained from the annual USEPA publication, Air Quality Data Annual Statistics, and refer to a monitoring station in the county of residence for 1970.

HUMD = Mean annual precipitation in inches x 100.0. These data are taken from the U.S. Bureau of Census, County and City Data Book, 1971.

NOXM = Annual 24 hour geometric mean nitrogen dioxide in micrograms per cubic meter as measured by the Salzman Method. These data were obtained from the annual USEPA publication, Air Quality Data Annual Statistics and refer to a monitoring station in the county for residence for 1975.

TSPM = Annual 24 hour geometric mean total suspended particulate in micrograms per cubic meter as measured by the HiVol Gravimetric Method. These data were obtained from the annual USEPA publication, Air Quality Data Annual Statistics and refer to a monitoring station in the county for residence for 1975.

SOXM** = SOXM2
P**2 = TSPM2
N**2 = NOXM2

D. PARTITIONING VARIABLES

AGE = (1972) (head's age in years)
OCCP = 1 if (1984) = 1, 2, 4, or 5 otherwise = 0 (head is a white collar worker if OCCP = 1 and, a blue collar worker if OCCP = 0)
SEX = 1 if (1943) = 1 otherwise = 0 (head is male if SEX = 1)
RACE = 1 if (2202) = 1 zero otherwise (If RACE = 1, head is white.)

Variable Definitions (Continued)

E. AUXILIARY VARIABLES

REG1 = 1 if (2284) = 1 otherwise = O (head lives in a northeastern state if REG1 = 1)
REG2 = 1 if (.2284) = 2 otherwise = O (head lives in a northcentral state if REG2 = 1)
REG3 = 1 if (2284) = 3 otherwise = O (head lives in a southern state if REG3 = 1)
REG4 = 1 if (2284) = 4 otherwise = 0 (head lives in a western state if REG4 = 1)
PRX1 = 1 if (2210) = 1 zero otherwise (If PRX1 = 1, head's dwelling unit is within 5 miles of center of city of 50,000 or more.)
PRX2 = 1 if (2210) = 2 zero otherwise (If PRX2 = 1, head's dwelling unit is between 514.9 miles of city center.)
PRX3 = 1 if (2210) = 3 zero otherwise (If PRX3 = 1, head's dwelling unit is between 1529.9 miles of city center.)
PRX4 = 1 if (2210) = 4 zero otherwise (If PRX4 = 1, head's dwelling unit is between 3049.9 miles from city center.)
PRX5 = 1 if (2210) = 5 zero otherwise (If PRX5 = 1, head's dwelling is greater than 50 miles from city center.)
AVGT = Average annual temperature for counties in degrees centigrade for 1970.

*Variable numbers from the PSID tape code book are given for the data collected from the PSID interviews. For the remaining data, no variable numbers are given.

that would be paid in. the PSID data set. In these cases, the missing observations were either replaced by the means of the observed values for the pollutants or estimated using a technique suggested by Dagenais (1973). A brief discussion of the replacement with means method is outlined in Maddala (1977). The Dagenais procedure involves running a regression of each pollution variable on: (1) all remaining (nonpollution) explanatory variables in Equation (2), and (2) relevant auxiliary variables that may be selected and then predicting the values of the missing observations from these regressions.[5] Predicting equations for each of the three pollutants are shown in Tables 21, 22, and 23. As shown in these tables, the auxiliary variables used are dummies relating to the distance of a family's residence from a city center (PRX1, PRX2, PRX3, PRX4, PRX5), the region of the country where the family lives (REG1, REG2, REG3, REG4) and a measure of the average temperature in the family's county of residence (AVGT). Unfortunately, the R^2's for these regressions ranged from .33 for NOXM to .37 for TSPM to .54 for SOXM indicating that their forecasting power may not be particularly high. An alternative to either the replacement with means or the Dagenais' procedures would be to restrict the sample to only those observations where actual measurements were available on all variables, including the pollutants. Even though this restriction reduces the available data set to 112 observations, it was employed in the estimation of one equation for illustrative purposes.[6]

A further problem with the SOXM data is that they were obtained using the Gas Bubbler Pararosaniline Sulfuric Acid Method. This method has been shown to result in estimates of SO_2 levels that are biased downward. Mathtech, however, has supplied a conversion equation that corrects for the bias in the original data. That conversion equation is given below.

$$CSOX = 10.625 + 1.97269(SOXM) - 0.10891[SOXM \cdot AVGT] \qquad (3)$$

where CSOX is the converted sulfur dioxide measure. In estimating Equation (2), CSOX was substituted in place of SOXM, and its square, $CSOX^2$ = S**2 was used in place of SOXM**2.

EMPIRICAL RESULTS

As previously indicated, three basic versions of Equation (2) were estimated where: (1) the restricted sample of 112 observations was employed, (2) the Dagenais procedure was used to construct the pollutants, and (3) the replacement with means procedure was used. All regressions were estimated by OLS.

Table 2 reports the results from estimation with the restricted data set. In this equation, all of the supply characteristic variables are significant at the 1 percent level except HLTH and TOJ2. However, the work environment variables are all insignificant at conventional levels. In fact, the t-statistics on the pollution variables in no case exceed 1.1 in absolute value. Using the replacement with means procedure, the quality of the estimated coefficients improves considerably. These results are shown in Table 3. With the increase in the number of observations employed from 112 to 1395, all of the supply characteristic variables turn out to be significant at the 1 percent level and have the correct sign. Differences in data sets and in equation specifications make it difficult to directly compare these results to those obtained in previous studies. Nevertheless, their general pattern of the estimates presented in Table 3 corresponds closely to those obtained by other investigators.

The estimates of the coefficients on the work environment variables also tend to be more highly significant and are more plausibly signed than in the case where the restricted sample of 112 observations is used. Also, they are generally consistent with the findings of other investigators. As indicated in Table 3, the variables WARM and COLD enter with a significant negative sign. In the case of WARM, the negative sign indicates that the individuals in the sample are willing to accept a lower wage in order to live in an area with hot summers. That same qualitative result has been obtained by Rosen (1979) using individual data from the Current Population Survey together with SMSA specific attributes and by Hoch (1977) and Cropper (1979) using aggregate SMSA data exclusively. On the other hand, the negative sign on COLD suggests that individuals must be paid a premium to live in areas where mean January temperatures are low and winter weather is probably severe. Of the three studies just mentioned, only the one by Hoch employs a similar variable. The coefficient on "winter temperature" is positive in his regressions on Samples I and II and negative in his regression on Sample III (see Hoch's Table 5, p. 39).

Next, the coefficient on JACR is positive and significant supporting Viscusi's (1978) result that employers must pay a premium in order to induce workers to accept jobs where the probability of accidents is higher. Also, this result is consistent with the findings of other investigators who measured other dimensions of working conditions. For example, Lucas (1977), Hammermesh (1977), and Thaler and Rosen (1975) consider the effect of wages of variables including: (1) a generalized measure of poor working conditions, (2) the presence of hazardous materials and/or equipment, and (3) deaths per 1,000 man years of work. All three of these variables have been found to be positively and significantly related to similar dependent variables to the one used in the present study.

With respect to the HUMD variable, Table 3 shows that its coefficient is negative but 'statistically insignificant at the 5 percent level. Although this negative sign is intuitively implausible, that same result was obtained in Hoch's regressions on each of his three samples. Rosen, however, obtains the more appealing result that increases in precipitation are positively associated with real wages. The precipitation variable that Rosen uses, which is defined as number of rainy days, was always positive and usually statistically significant in each of 29 different equation specifications (see Rosen's Table 3.3, p. 94).

The pollution variables do not perform quite as well as the other variables in the equation. Both the linear and quadratic terms for CSOX and for NOXM are statistically insignificant at the 5 percent level. The result for CSOX conflicts with those of Cropper (1979). In her regression for all earners and in four of her eight occupation specific regressions, a measure of SO_2 turned out to be positively and significantly related to median earnings of males who were employed full time. However, in the Cropper study SO_2 was the only pollution measure used and, therefore, this variable could also be proxying the effects of other pollutants. Rosen's results show that this conjecture is a real possibility. His SO_2 measure occasionally has the right sign, but is more frequently negative and significant. Particulate, on the other hand, exhibit superior performance in Rosen's equation. This variable was positive in each of the 32 cases where it was used and had a tstatistic exceeding 2 in 27 cases (again, see Rosen's Table 3.3, p.94). The results on the TSPM variable used in the present study compares favorably with the findings of Rosen. As Table 3 shows, the linear TSPM term has a positive and statistically significant coefficient and the quadratic TSPM term has a smaller negative but significant coefficient.

The elasticity of the real wage with respect to a change in TSPM can be computed from the estimates presented in Table 3 according to

$$e_{TSPM} = \frac{\partial RWGH}{\partial TSPM} \frac{TSPM}{RWGH} = \alpha'' TSPM + 2\beta'' TSPM^2 \qquad (4)$$

where e_{TSPM} denotes the elasticity, a denotes the estimated coefficient on the linear term and β denotes the coefficient on the quadratic term. Evaluated at the mean of the observed values for TSPM, e_{TSPM} = 0.0367, evaluated at the national primary standard, e_{TSPM} = .1322, and evaluated at the national secondary standard, e_{TSPM} = .2005. The mean of the actually observed values of TSPM = 96.56 and the national primary and secondary standards for TSPM are shown in Table 24. The comparatively high value for the mean of TSPM can be attributed to a relatively small number of counties in the data set where total suspended particulate was considerably in excess of 100. In any case, these results suggest that in the neighborhood of the national air quality standards benefits from reducing TSP concentrations are likely to exist.

Illustrative calculations of benefits of national pollution abatement programs are presented for two SMSAs, Denver and Cleveland. These calculations are derived from the pooled regression estimates in Table

In particular:

(i) SMSA specific means for the variables EDC2, EDC3, HVET, and FMSZ were obtained from the 1970 U.S. Census 1 in 100 public use sample tapes and substituted into the equation reported.

(ii) SMSA specific averages for the variables WARM, COLD, and HUMD were obtained from other sources and substituted into the equation reported.

(iii) For the remaining nonpollution variables, UNON, HLTH, TOJ2, and JACR, the sample means reported in Table 22 were substituted into the equation reported. This procedure was used because of the difficulties in obtaining meaningful SMSA specific means for these variables.

These means, which are reported in Table 26, were then multiplied by their respective coefficients in order to obtain a predicted wage exclusive of pollution effects.

For the pollution variables, it was assumed that neither community would have air pollution levels higher than the primary standards for SO , NO_2 and TSP by 1985 and that the secondary standards for all three pollutants would be met by 1987. In cases where current (1978) pollution concentrations are lower than the secondary standards, those current concentrations were assumed to prevail throughout the forseeable future. As previously indicated, Table 27 reports the national primary and secondary standards legislated to take effect in 1985 and Table 28 reports 1978 pollution concentrations for Denver and Cleveland.

In Denver, for example, the change in the predicted RWGH associated with a reduction in total suspended particulate concentrations was obtained holding constant the values of the other pollution and nonpollution variables. The values for the remaining pollution variables were held constant because Denver is already meeting the national secondary standards for them. Also, the values of the nonpollution variables were assumed to remain unchanged over time. Projected benefits were then obtained by multiplying the change in the hourly real wage by annual hours of full time work and then multiplying this result by an estimate of the number of affected household heads in each SMSA.

Annual hours of full time work were assumed to be 2000 and the 1 in 100 Census Bureau public use sample indicated that there were approximately 382,700 household heads in Cleveland and 218,100 household heads in Denver with the hours of work and employment characteristics required for inclusion in the sample used to make the pooled regression estimates.

Annual benefit estimates from pollution abatement in the two cities are positive according to the calculations made here. 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 <u>household head</u> in the two cities are $426.35 for Denver and $212.60 for Cleveland. Simple calculations using the estimates in Table 3 and the mean values in Table 26 show that reductions in TSP levels would be responsible for all of these estimated benefits. The larger value for benefits for all of these estimated benefits per person in Denver arises because greater reductions must be achieved as compared with Cleveland, in order to achieve the national secondary standards.

Finally, the results from estimating Equation (2) using the Dagenais procedure to construct the missing observations on the pollution variables are reported in Tables 4 through 20.[7] Tables 4 through 19 contain various partitions of Equation (2) based upon age, race, and sex and Table 20 contains the pooled sample regression. The coefficients on the supply characteristic variables reported in Table 20 are very similar to those reported in Table 3. However, both the linear and quadratic terms for all three pollutants enter the pooled regression insignificantly at the 5 percent level using a twotailed test. In the partitioned regression equations, the[8] air pollution variables are seldom significantly different from zero either. More specifically, there are five of these regressions where one of the pollution variables entered significantly. These are: (1) the Male, White, White Collar Worker, Age 5069 partition (TSPM), (2) the Male, White, Blue Collar Worker, Age 3049 partition (TSPM) , (3) the Male, White, Blue Collar Worker, Age 1769 partition (CSOX) , (4) the Male, NonWhite, Blue Collar Worker, Age 3049 partition (CSOX), (5) the Female, White, White Collar Worker, Age 1769 partition (TSPM). Neither the linear nor the quadratic term on NOXM was ever significantly different from zero at the 5 percent level. In the five cases where a pollution variable was significant, the elasticity of the real wage with respect to a change in the pollution was computed using the method shown in Equation (4). All of these elasticities were evaluated at the grand mean (computed over all 1395 observations) of the pollution variables. These means, together with the means and standard deviations of all variables used in this analysis are shown in Table 25. Finally, the results of the elasticity calculations are presented beneath the coefficient estimates for the equations to which they pertain. As indicated there, three of the calculated elasticities are positive while two are negative.

The relatively weaker performance of the pollution variables in the equations estimated using the Dagenais procedure can perhaps be attributed to several factors. First, although Dagenais shows that his method produces consistent prediction of the missing observations, this asymptotic property may say little about the finite sample properties of such a procedure, particularly when a large fraction of the observations are missing. Table 29 shows how this missing observations problem relates to each of the 16 partitional equations estimated. In particular, this table presents the number of observations for each partition for which actual pollution data were available. As can be seen, four of these partitions had no observations where data on all three pollutants were available. Second, the consistency of Dagenais' method depends upon the use of a generalized least squares procedure to estimate the hedonic wage relation that requires the solution of a set of simultaneous, nonlinear equations. Because of computational difficulties, OLS was used instead. In this setting, it is not clear what statistical properties can be claimed for the Dagenais approach. Two other reasons for weak performance, which are common to the replacement with means procedure can also be offered: (1) observations that do exist on the air pollutants may be measured with so much error that they provide a great deal of misinformation, (2) after adjusting for the other factors included in each regression, air pollution, even if measured perfectly, may not be an important determinant of wages paid.

Illustrative benefit calculations were also made for Denver and Cleveland using the estimtaes presented in Table 20. The procedure for making these calculations was the same as that described previously. For Denver, meeting the national secondary standards for TSP results in a reduction in the offered wage from $4.3545/hour to $4.0490/hour implying that annual benefits per household head are $611 and total benefits are $133,198,000. For Cleveland, on the other hand, meeting the national secondary air quality standards causes the real wage to fall from $3.3251/hour to $3.2336/hour so that annual benefits per household head are $183 and total benefits are $70,034,100.

Table 2

Restricted Sample Regression

Estimates

VAR	B	T
UNON	.313	2.920
HVET	.265	2.991
FMSZ	.0302	2.074
HLTH	-.202	-1.324
EDC2	.205	2.136
EDC3	.495	4.477
TOJ 2	.0801	.957
WARM	.942	1.050
JACR	.0000594	.0433
COLD	-.291	-1.357
HUMD	.0102	1.388
Csox	.532	.895
TSPM	-.832	-1.060
NOXM	.0394	.117
P**2	.00000334	1.066
S**2	-.00000305	- .538
N**2	.000000526	.198
CONSTANT	-30.473	- .818

R^2 = .59 DF = 94

Table 3

Pooled Sample Regression--

Replacement with means

VAR	B	T
UNON	.127	4.576
HVET	.187	7.179
FMSZ	.0218	3.969
HLTH	-.107	-2.873
EDC2	.0726	2.153
EDC3	.491	12.747
TOJ2	.133	4.929
WARM	-.00977	-2.865
JACR	.00145	3.561
COLD	-.00807	-3.148
HUMD	-.00192	-1.589
Csox	-.00298	- .609
TSPM	.00945	2.045
NOXM	.00206	.268
P**2	-.0000509	-2.203
S**2	-.00000548	- .0805
N**2	-.0000252	- .294
CONSTANT	1.505	3.237

R^2 = .30 DF = 1377

Table 4

Male, White, White Collar Worker,
Househo d Heads Aged 7-29

VAR	B	T
X10-UNON	.17476	1.4327
X12-HVET	-.66795D-01	-.60872
X19-FMSZ	.11798	2.7474
X26-HLTH	- 18627D-01	-.27860
X28-EDC2	-.35504	-.97654
X29-EDC3	-.32479D-01	-.89856D-01
X40-TOJ2	-.47591	-.81308
X43-WARM	.34974D-02	.36132
X44-JACR	31325D-02	1.9076
X45-COLD	./1370D-02	-1.0911
X46-HUMD	.21394D-02	.40559
X41-CSOX	.33653D-04	.25623D-02
X47-TSPM	-.40187D-02	-.31493
X49-NOXM	-.90972D-02	-1.2980
X 1-P**2	.19683D-04	.33616
X 2-S**2	.31803D-04	.11465
X 3-N**2	.85521D-04	1.7349
CONSTANT	1.3185	1.0201

R-SQUARE= 0.2104
SSR= 21.60 DF= 95

Table 5

Male, White, White Collar Worker,

Household Heads Aged 30-49

VAR	B	T
X10-UNON	.26432D-01	.50824
X12-HVET	.10866	2.3615
X19-FMSZ	-.15115D-01	-1.3827
X26-HLTH	-.21725	-3.5129
X28-EDC2	.16370	2.3367
X29-EDC3	.46052	6.1510
X40-TOJ2	.11154	2.4769
X43-WARM	-.99376D-02	-1.6578
X44-JACR	.83032D-03	1.0669
X45-COLD	.42689D-04	.11088D-01
X46-HUMD	.30551D-02	1.2979
X41-CSOX	-.26112D-02	-.39982
X47-TSPM	.16092D-01	1.4245
X49-NOXM	.26707D-02	.69860
X 1-P**2	-.55353D-04	-.91941
X 2-S**2	-.10503D-03	-.81162
X 3-N**2	-.16092D-04	-.56085
CONSTANT	.96252	1.4981

R-SQUARE= 0.2632

SSR= 53.12 DF= 346

Table 6

Ma e, White, White Collar Worker,

Househo d Head= Aged 5o-69

VAR	B	T
X10-UNON	.75762D-01	.85593
X12-HVET	-.90192D-01	-1.1334
X19-FMSZ	-.95895D-02	-.44268
X26-HLTH	-.68573D-01	-.81402
X28-EDC2	.27338	2.5788
X29-EDC3	.51817	4.8639
X40-TOJ2	-.32128D-01	-.43872
X43-WARM	-.16985D-01	-1.9505
X44-JACR	-.14722D-02	-1.2219
X45-COLD	.38514D-02	.56162
X46-HUMD	.50936D-03	.11387
X41-C8OX	.67178D-02	.53131
X47-TSPM	.10101	3.3604
X49-NOXM	-.66079D-02	-1.0324
X 1-P**2	-.52137D-03	-3.1102
X 2-S**2	-.50256D-04	-.20280
X 3-N**2	.31952D-04	.72943
CONSTANT	-1.9436	-1.5904

R-SQUARE= 0.3777
SSR= 14.07 DF= 108

$e_{TSPM} = 4.884$

Tab e 7

Ma e. White, ≥ ue Co ar Worker,

Household Heads Aged 17-29

VAR	B	T
X10-UNON	.22126	1.5232
X12-HVET	.11507	.77295
X1? FMSZ	.67060D-01	1.0862
X26-HLTH	-.11194D-01	-.29284D-01
X2S EDC2	.50214	1.4339
??? EDC3	.37717	1.0469
X40-TOJ2	-.85560D-01	-.13650
X43-WARM	.26415D-01	1.3533
X44-JACR	.14590D-02	.65186
X45-COLD	-.21866D-01	-2.0895
X46-HUMD	-.12347D-01	-1.3453
X?1-CSOX	-.26390D-01	-1.7609
?47-SPM	-.54343D-01	-1.7497
X ?9-NOXM	.59654D-02	-.56895
X 1-P**2	.30447D-03	1.8053
2-S**2	.55753D-03	1.8201
X 3-N**2	.57881 ·04	.79457
ONSTANT	2.1767	1.1070

-QUARE= 0.3239
SK= 9.739 DF= 45

Table 8

Male, White, Blue Collar Worker,

Household Heads Aged 30-49

VAR	B	T
X10-UNON	.14275	1.3955
X12-HVET	.11510	1.4074
X19-FMSZ	-.11188D-01	-.48891
X26-HLTH	-.21963D-02	-.18383D-01
X28-EDC2	-.64656D-01	-.66772
X29-EDC3	.66018D-01	.40793
X40-TOJ2	.28272	3.2842
X43-WARM	-.73856D-02	-.49400
X44-JACR	.17985D-02	1.1995
X45-COLD	.50207D-02	.58515
X46-HUMD	-.43683D-03	-.77757D-01
X41-CSOX	-.13004D-01	-1.0804
X47-TSPM	.25542D-01	2.1776
X49-NOXM	.48542D-02	.79327
X 1-P**2	-.11023D-03	-1.9741
X 2-S**2	.17094D-03	.75189
X 3-N**2	-.48756D-04	-1.3613
CONSTANT	.19701	.13496

R-SQUARE= 0.4280

SR= 4.471 DF= 56

e_{TSPM} = 1.4204

Table 9

Male, White, Blue Collar Worker,

Household Heads Aged 17-69

VAR	B	T
X10-UNON	.16463	2.3087
X12-HVET	.13518	2.1021
X19-FMSZ	.19745D-01	1.0386
X26-HLTH	-.18033D-01	-.18505
X28-EDC2	.69451D-02	.83603D-01
X29-EDC3	.26313D-01	.25971
X40-TOJ2	.35908	5.1153
X43-WARM	-.12433D-01	-1.6865
X44-JACR	.29094D-03	.28674
X45-COLD	-.89463D-02	-1.7421
X46-HUMD	-.99736D-03	-.27515
X41-CSOX	-.24192D-01	-2.8544
X47-TSPM	.85630D-02	.83961
X49-NOXM	.18851D-02	.35982
X 1-P**2	-.29044D-04	-.55213
X 2-S**2	.46754D-03	2.7702
X 3-N**2	-.24129D-04	-.69613
CONSTANT	1.9040	2.4022

R-SQUARE= 0.3457

SSR= 23.65 DF= 160

$e_{CSOX} = -.3125$

Table 10

Male, Non-White, White Collar Worker,

Household Heads Aged 30-49

VAR	B	T
X10-UNON	.23558	2.3992
X12-HVET	.10339	.96532
X19-FMSZ	.93703D-02	.43587
X26-HLTH	.15968	.89901
X28-EDC2	-.19323D-02	-.13398D-01
X29-EDC3	.33745	1.9824
X40-TOJ2	-.84307D-01	-.88253
X43-WARM	.39743D-02	.29485
X44-JACR	-.25733D-02	-1.7306
X45-COLD	.88710D-03	.15121
X46-HUMD	.12822D-02	.21563
X41-CSOX	.14184D-01	.69880
X47-TSPM	.43585D-01	1.5422
X49-NOXM	-.43509D-03	-.52820D-01
X 1-P**2	-.20806D-03	-1.3906
X 2-S**2	.57166D-04	.18097
X 3-N**2	.21693D-04	.34107
CONSTANT	-1.6930	-1.1465

R-SQUARE= 0.3789

SSR= 11.87 DF= 78

Table 11

Male, Non-White, White Collar Worker,

Household Heads Aged 17-69

VAR	B	T
X10-UNON	.18604	2.5040
X12-HVET	.10293	1.4498
X19-FMSZ	-.30211D-02	-.22040
X26-HLTH	.75768D-01	.49945
X28-EDC2	.77325D-01	.80932
X29-EDC3	.26636	2.2519
X40-TOJ2	.66240D-01	.93804
X43-WARM	-.41372D-02	-.34556
X44-JACR	-.13921D-02	-1.2404
X45-COLD	.25076D-02	.47568
X46-HUMD	.17020D-02	.33027
X41-CSOX	.13801D-01	.88935
X47-TSPM	.44063D-01	1.8041
X49-NOXM	-.86660D-02	-1.3842
X 1-P**2	-.19905D-03	-1.5454
X 2-S**2	-.20679D-03	-.92285
X 3-N**2	.64510D-04	1.2350
CONSTANT	-.96187	-.76367

R-SQUARE= 0.2669
SSR= 18.95 DF= 130

Table 12

Male, Non-White, Blue Collar Worker,

Household Heads Aged 17-29

VAR	B	T
X10-UNCN	.24384	1.4211
X12-HVET	.18665	1.2896
X19-FMSZ	.32341D-01	1.4866
X23-HLTH	.20659D-01	.54668D-01
X28-EDC3	1.1371	2.0847
X28-EDC2	1.0858	2.1051
X43-WARM	.95153D-01	1.7411
X44-JACR	.38772D-02	1.3118
X45-COLD	.24412D-01	1.0801
X46-HUMD	-.55684D-02	-.24360
X41-CSOX	.11290	1.7170
X47-TSPM	-.32204D-01	-.76046
X49-NOXM	-.18104D-01	-.89487
X 1-P**2	.14400D-03	.80510
X 2-S**2	-.12088D-02	-1.4287
X 3-H**2	.23047D-03	1.1785
CONSTANT	-7.3120	-1.5632

R-SQUARE= 0.4325

SSR= 8.369 DF= 41

Table W

Male, Non-White, Blue Collar Worker, Household Head, Aged 30-49

VAR	B	T
X10-UNON	.34653	5.5150
X12-HVET	-.59878D-01	-.93846
X19-FMSZ	.25630D-01	2.3752
X26-HLTH	-.20026	-2.1214
X28 EDC2	-.49395D-01	-.77176
X29-EDC3	-.32436D-01	-.28477
X40-TOJ2	.62105D-02	.95739D-01
X43-WARM	-.79103D-02	-.96984
X44-JACR	.22691D-02	2.3888
X45-COLD	.89463D-02	1.9652
X46-HUMD	.68790D-02	2.2345
X41 CSCI	.19598D-01	1.9061
X47-TSPM	.10988D-01	1.1272
X49-NOXM	-.19917D-04	-.46344D-02
X 1-P**2	-.28270D-04	-.56956
X 2-S**2	-.31317D-03	-2.1435
X 3-N**2	.74386D-05	.20174
CONSTANT	-.40612	-.44776

R-SQUARE= 0.5342
SSR= 9.055 DF= 109

$e_{CS \cdot x} = .2959$

Tab e 4

Male, Non-White, Blue Collar Worker,

Househo d Head≤ Aged 50-69

VAR	B	T
X10-UNON	.15722	1.7283
X12-HVET	-.35557D-01	-.38795
X19-FMSZ	-.56542D-02	-.28441
X26-HLTH	-.47119	-2.9557
X28-EDC2	.71372D-01	.87034
X29-EDC3	-.21025	-.70450
X40-TOJ2	-.13163D-01	-.12876
X43-WARM	-.24253D-02	-.91059D-01
X44-JACR	-.37103D-03	-.29262
X45-COLD	-.11073D-02	-.10988
X46-HUMD	-.15479D-01	-1.7323
X41-CSOX	.76148D-02	.43807
X47-TSPM	.12786D-01	.35004
X49-NOXM	-.22636D-02	-.21454
X 1-P**2	-.11832D-03	-.52261
X 2-S**2	.19079D-03	.95534
X 3-N**2	.48949D-04	.43614
CONSTANT	1.5146	.63855

R-SQUARE= 0.5976
SSR= 2.774 DF= 42

Table 15

Male, Non-White, Blue Collar Worker,

Household Heads Aged 17-69

VAR	B	T
X10-UNON	.29899	5.7490
X12-HVET	.18808D-01	.37703
X19-FMSZ	.25626D-01	2.8439
X26-HLTH	-.25763	-3.2402
X28-EDC2	-.25874D-01	-.50980
X29-EDC3	.10841	1.2425
X40-TOJ2	-.70438D-01	-1.3048
X43-WARM	-.28275D-03	-.35284D-01
X44-JACR	.20377D-02	2.9009
X45-COLD	.32852D-02	.87020
X46-HUMD	.31924D-02	1.0831
X41-CSOX	.12347D-01	1.4095
X47-TSPM	.29400D-02	.40219
X49-NOXM	.27822D-03	.71365D-01
X 1-P**2	.70330D-05	.19892
X 2-S**2	-.18161D-03	-1.4782
X 3-N**2	.18663D-04	.52094
CONSTANT	-.16171	-.19144

R-SQUARE= 0.3625

SSR= 26.29 DF= 227

Table 16

Female, Non-White, White Collar Worker,

Household Heads Aged 17-69

VAR	B	T
X10-UNEM	.28245D-01	.10561
X19-FMSZ	.15621D-03	.38146D-02
X26-HLTH	-.34959	-.50487
X28-EDC2	-.38257D-01	-.28711
X29-EDC3	.27585	1.0881
X40-TOLZ	.55338D-01	.29232
X43-WARM	-.72220D-01	-1.5014
X44-JACR	-.38060D-03	-.15408
X45-COLD	-.20614D-01	-1.8159
X46-HUMD	.18623D-01	1.5558
X41-CSOX	-.33666D-01	-1.4806
X47-TSPM	.25308D-01	.31477
X48-NOXM	-.12947D-01	-.18447
X 1-P**2	-.78438D-04	-.20411
X 2-S**2	.14024D-03	.51054
X 3-N**2	.17071D-03	.22538
CONSTANT	5.8250	1.4665

R-SQUARE= 0.5182

SSR= 1.432 DF= 20

Table 17

Female, White, White Collar Worker, Household Heads Aged 17-69

VAR	B	T
X10-LNCN	.14377	1.1279
X18-FMSZ	-.54193D-02	-.17481
X23-HLTH	-.15652	-1.0157
X28-EDC2	.13746	.77183
X29-EDC3	.29233	1.8481
X40-TOJ2	-.10249D-01	-.12433
X43-WARM	.55008D-02	.45504
X44-JACR	-.10702D-03	-.55780D-01
X45-COLD	-.11855D-01	-1.3461
X46-HUMD	-.70804D-03	-.13108
X41-CSOX	.23805D-02	.17803
X47-TSPM	-.51187D-01	-2.7307
X48-NOXM	-.15298D-01	-1.7358
X 1-P**2	.30097D-03	2.3582
X 2-S**2	-.27158D-03	-1.0810
X 3-M**2	.71703D-04	1.2853
CONSTANT	3.7946	3.0396

R-SQUARE= 0.3800
SSR= 6.044 DF= 50

$e_{TSPM} = -2.58$

Table 18

Female, White, Blue Collar Worker,

Household Heads Aged 17-69

VAR	B	T
X10-UNON	.26862	.75532
X12-HVET	.10974	.25750
X19-FMSZ	.26944D-01	.19444
X26-HLTH	.39030D-01	.82491D-01
X28-EDC2	.41989	.92274
X29-EDC3	.89085D-01	.13941
X40-TOJ2	.21485	.55869
X43-WARM	.62321D-02	.87444D-01
X44-JACR	.80756D-02	.97336
X45-COLD	.10648D-01	.27562
X46-HUMD	-.78924D-02	-.21904
X41-CSOX	.14246D-01	.22577
X47-TSPM	.12046	1.6627
X49-NOXM	.20425D-01	.82539
X 1-P**2	-.66602D-03	-1.7580
X 2-S**2	-.12062D-03	-.94019D-01
X 3-N**2	-.10477D-03	-.81019
CONSTANT	-6.8873	-.84302

R-SQUARE= 0.6809
SSR= 1.513 DF= 8

Table 19

Female, Non-White, Blue Collar Worker,

Household Heads Aged 17-69

VAR	B	
X10-UNON	.17380	1.4829
X18-FMSZ	.57971D-01	2.6227
X23-HLTH	-.13370	-1.0388
X26-EDC2	-.882350-01	-.88551
X29-EDC3	-.21011	-.54462
X40-TDJ2	.38029D-01	.90084
X43-WARM	-.10153D-02	-.46757D-01
X44-JACR	.41026D-02	2.0654
X45-COLD	-.40113D-02	-.46224
X46-HUMD	-.88367D-02	-1.3888
X41-CSOX	.87514D-02	.34591
X47-TSPM	-.78813D-02	-.48790
X48-NOXM	-.38782D-02	-.45343
X 1-P**2	.16793D-04	.22902
X 2-S**2	.30708D-04	.10881
X 3-N**2	.21237D-04	.34388
CONSTANT	1.4636	.95992

R-SQUARE= 0.4077
SSR= 6.881 DF= 74

Table 20

Pooled Sample Regression

VAR	B	T
X10-UNON	.12826	4.5299
X12-HVET	.18686	7.1260
X19-FMSZ	.22907D-01	4.1336
X26-HLTH	-.99943D-01	-2.6863
X28-EDC2	.74755D-01	2.2167
X29-EDC3	.49221	12.708
X40-TOJ2	.12811	4.7644
X43-WARM	-.77862D-02	-2.4942
X44-JACR	.14097D-02	3.4679
X45-COLD	-.73928D-02	-4.1044
X46-HUMD	-.78358D-04	- .56596D-01
X41-CSOX	.18462D-02	.55284
X47-TSPM	.82340D-02	1.8694
X49-NOXM	.16475D-02	.84763
X 1-P**2	-.37398D-04	-1.6590
X 2-S**2	-.97076D-04	-1.5851
X 3-N**2	-.40s460-05	- .28572
CONSTANT	1.1411	3.5403

R-SQUARE = 0.3065
SSR = 281.1 DF = 1377

Table 21

Regression to Construct SOXM

VAR	B	T
X1O-UNON	3.0550	3.5062
X12-HVET	-2.5744	-3.0967
X19-FMSZ	.27915	1.7229
X26-HLTH	- .69527	- .57786
X28-EDC2	.35916	.35429
X29-EDC3	-1.3497	-1.1199
X4O-TOJ2	-1.6145	-1.9672
X42-AVGT	-2.2513	-3.3839
X43-WARM	- .96528D-01	- .52877
X44-JACR	- .32979D-01	-2.6856
X45-COLD	.46237	1.9103
X46-HUMD	- .39650	-5.1329
X35-REG1	30.051	10.556
X36-REG2	9.0446	3.3579
X37-REG3	21.416	6.9766
X30-PRX1	-3.644o	-1.0700
X31-PRX2	-4.0488	-1.2150
X32-PRX3	-2.9865	- .86171
X33-PRX4	-6.1270	-1.3064
CONSTANT	40.391	2.9248

R-SQUARE = 0.5420
SSR = .3229D + 05 DF = 482

Table 22

Regression to Construct TSPM

VAR	B	T
X10-UNON	- .27108	- .17266
X12-HVET	.13148	.885050-01
X19-FMSZ	.20762	.65983
X26-HLTH	.11578	.57456D-01
X28-EDC2	-1.2855	- .65959
X29-EDC3	-5.3022	-2.3759
X40-TOJ2	- .62307	- .41121
X42-AVGT	-4.2312	-7.9669
X43-WARM	.786o1	2.9667
X44-JACR	- .96968D-02	- .41621
X45-COLD	1.5041	8.9149
X46-HUMD	-1.1924	-10.784
X35-REG1	39.444	8.8559
X36-REG2	32.932	7.7270
X37-REG3	29.224	5.8749
X30-PRX1	14.834	3.6951
X31-PRX2	17.663	4.4771
X32-PRX3	13.110	3.0617
X33-PRX4	-2.0068	- .36068
CONSTANT	41.964	2.2201

R-SQUARE = 0.3727
SSR = .22410 + 06 DF = 691

Table 23

Regression to Construct NOXM

VAR	B	T
X10-UNON	4.0234	1.8520
X12-HVET	-3.1084	-1.6117
X19-FMSZ	- .65904	-1.8977
X26-HLTH	-5.6057	-1.9463
X28-EDC2	-2.8367	-1.2861
X29-EDC3	- .42449	- .16104
X40-TOJ2	.58784	.31671
X42-AVGT	10.479	4.5831
X43-WARM	-3.5136	-3.2760
X44-JACR	.61724D-02	.22688
X45-COLD	-1.6996	-2.6106
X46-HUMD	- .29514	- .74684
X35-REG1	7.1282	.67026
X36-REG2	8.1533	1.0176
X37-REG3	-15.842	-1.3853
X30-PRX1	-3.4347	- .59532
X31-PRX2	- .47142	- .83510D-01
X32-PRX3	-7.1744	-1.2183
X33-PRX4	-31.613	-2.8677
CONSTANT	271.03	3.6656

R-SQUARE = 0.3337

SSR = .4039D + 05 DF = 236

Table 24

Correlation Matrix

	1 P**2	2 S**2	3 N**2	10 UNCN	12 HVET	19 FMSZ	22 OCCP	25 RHWG	26 HLTH	28 EDC2	29 EDC3	40 TOJ2	41 CSOX	43 WARM	44 JACR	45 COLD	46 HUMD	47 TSPM	49 NOXM
1P**2	1.00	0.26	0.08	-0.05	0.14	0.06	0.08	-0.09	-0.04	0.05	0.05	-0.03	-0.03	0.02	0.02	-0.02	-0.03	-0.05	-0.04
2S**2	0.26	1.00	-0.00	-0.02	0.30	0.08	0.44	0.85	-0.05	-0.17	0.40	0.13	-0.00	-0.22	0.02	-0.23	-0.15	0.05	0.02
3N**2	0.08	-0.00	1.00	0.04	0.16	-0.07	0.01	0.00	-0.03	0.26	-0.22	-0.01	0.02	-0.06	0.04	-0.06	-0.05	0.01	-0.04
10UNCN	-0.05	-0.02	0.04	1.00	0.07	0.08	-0.13	0.11	-0.02	0.14	-0.21	0.12	0.08	-0.06	0.27	-0.11	-0.06	0.07	0.08
12HVET	0.14	0.30	0.16	0.07	1.00	0.12	0.16	0.28	-0.01	0.09	0.07	0.12	-0.02	-0.16	0.11	-0.08	-0.12	0.02	-0.01
19FMSZ	0.06	0.08	-0.07	0.08	0.12	1.00	-0.01	0.09	-0.01	-0.02	-0.11	0.14	-0.02	0.08	0.14	0.02	0.09	0.02	-0.10
22OCCP	0.08	0.44	0.01	-0.13	0.16	-0.01	1.00	0.46	0.01	-0.14	0.32	0.06	-0.05	-0.13	-0.07	-0.15	-0.11	-0.00	0.00
25RHWG	-0.09	0.85	0.00	0.11	0.28	0.09	0.46	1.00	-0.05	-0.16	0.36	0.17	0.03	-0.22	0.05	-0.25	-0.15	0.07	0.02
26HLTH	-0.04	-0.05	-0.03	-0.02	-0.01	-0.01	0.01	-0.05	1.00	-0.05	-0.02	0.08	-0.00	-0.12	-0.03	-0.07	-0.08	0.04	-0.05
28EDC2	0.05	-0.17	0.26	0.14	0.09	-0.02	-0.14	-0.16	-0.05	1.00	-0.65	-0.01	0.08	0.01	0.07	-0.05	-0.02	0.08	-0.06
29EDC3	0.05	0.40	-0.22	-0.21	0.07	-0.11	0.32	0.36	-0.02	-0.65	1.00	-0.04	-0.04	-0.13	-0.20	-0.06	-0.14	-0.04	0.07
40TOJ2	-0.03	0.13	-0.01	0.12	0.12	0.14	0.06	0.17	0.08	-0.01	-0.04	1.00	0.03	-0.06	0.05	-0.10	-0.00	0.02	-0.02
41CSOX	-0.03	-0.00	0.02	0.08	-0.02	-0.02	-0.05	0.03	-0.00	0.08	-0.04	0.03	1.00	-0.10	-0.08	-0.23	0.06	0.28	-0.07
43WARM	0.02	-0.22	-0.06	-0.06	-0.16	0.08	-0.13	-0.22	-0.12	0.01	-0.13	-0.06	-0.10	1.00	0.03	0.36	0.42	-0.12	-0.18
44JACR	0.02	0.02	0.04	0.27	0.11	0.14	-0.07	0.05	-0.03	0.07	-0.20	0.05	-0.08	0.03	1.00	-0.03	0.07	-0.03	-0.04
45COLD	-0.02	-0.23	-0.06	-0.11	-0.08	0.02	-0.15	-0.25	-0.07	-0.05	-0.06	-0.10	-0.23	0.36	-0.03	1.00	0.15	-0.25	0.37
46HUMD	-0.03	-0.15	-0.05	-0.06	-0.12	0.09	-0.11	-0.15	-0.08	-0.02	-0.14	-0.00	0.06	0.42	0.07	0.15	1.00	-0.42	-0.26
47TSPM	-0.05	0.05	0.01	0.07	0.02	0.02	-0.00	0.07	0.04	0.08	-0.04	0.02	0.28	-0.12	-0.03	-0.25	-0.42	1.00	-0.08
49NOXM	-0.04	0.02	-0.04	0.08	-0.01	-0.10	0.00	0.02	-0.05	-0.06	0.07	-0.02	-0.07	-0.18	-0.04	0.37	-0.26	-0.08	1.00

STOP
TIME 13.8 SECS

Table 25

Means and Standard Deviations

of Variables

VAR	MEAN	SD
X 1-P**2	9261.2	3391.5
X 2-S**2	423.37	430.09
X 3-N**2	3546.6	2470.7
X 4-OTBC	0.	0.
X 5-TINC	0.	0.
X 6-AGEH	41.107	5.5200
X 7-SEXH	1.0000	0.
X 8-HLT1	4.4780	1.3287
X 9-HLT2	4.7582	.94289
X10-UNON	.30769	.46217
X11-EDUC	4.9588	1.9641
X12-HVET	.63462	.48220
X13-RACE	1.0000	0.
X14-CITY	.72253	.44837
X15-PROX	2.3984	1.1538
X16-REG	2.2445	1.0950
X17-SELF	1.0000	0.
X18-SIZE	.80495	.39679
X19-FMSZ	4.7335	2.0049
X20-LTOJ	3.9588	1.3385
X21-INDX	1.0091	.39053D-01
X22-OCCP	1.0000	0.
X23-CIDC	24090.	12428.
X24-AHWG	5.8680	2.7355
X25-RHWG	1.6620	.44564
X26-HLTH	.14835	.35594
X27-EDC1	.13462	.34178
X28-EDC2	.43407	.49632
X29-EDC3	.43132	.49594
X30-PRX1	.22527	.41834
X31-PRX2	.38736	.48782
X32-PRX3	.23352	.42365
X33-PRX4	.71429D-01	.25789
X34-PRX5	.82418D-01	.27538
X35-REG1	.32143	.46767
X36-REG2	.29670	.45743
X37-REG3	.19780	.39889
X38-REG4	.18407	.38807
X39-TOJ1	.60989	.48845
X40-TOJ2	.39011	.48845
X41-CSOX	25.456	11.258
X42-AVGT	11.431	3.9808
X43-WARM	74.316	4.8543
X44-JACR	58.464	30.979
X45-COLD	31.723	11.083
X46-HUMD	35.935	11.221
X47-TSPM	94.513	18.148
X48-SOXM	17.771	10.386
X49-NOXM	56.763	18.040

Table 26

MEANS OF NON-POLLUTION VARIABLES

USED IN BENEFIT CALCULATIONS

VARIABLE	MEAN	
	Denver	Cleveland
UNON	.307	.307
HVET	.402	.556
FMSZ	3.40	3.46
HLTH	.148	.148
EDC2	.456	.567
EDC3	.449	.298
TOJ2	.390	.390
WARM	72.00	71.90
JACR	58.46	58.46
COLD	30.60	18.90
HUMD	13.73	33.66
CONSTANT	1.00	1.00

Table 27

NATIONAL AIR POLLUTION STANDARDS

(In Micrograms Per Cubic Meter)

	PRIMARY STANDARD	SECONDARY STANDARD
SO_2	75	60
NO_2	100	100
TSP	75	60

Table 28

1978 POLLUTION CONCENTRATIONS

IN DENVER AND CLEVELAND

(In Micrograms Per Cubic Meter)

	DENVER	CLEVELAND
SO_2	16.9	61.49
NO_2	100	65.0
TSP	86	72.2

Table 29

Cross-Tabulation of Incidence of

Actual Pollution Data By Partition

Table Number	TSPM	SOXM	NOXM	TSPM,SOXM	TSPM,NOXM	SOXM,NOXM	TSPM,NOXM,SOXM
4	58	30	17	26	5	5	4
5	164	94	48	87	25	18	15
6	59	49	22	42	10	14	10
7	28	19	2	16	1	2	1
8	28	17	5	11	0	1	0
9	22	15	10	12	6	5	4
10	59	39	19	33	13	17	13
11	78	60	36	46	22	29	19
12	40	36	23	30	13	17	11
13	80	61	32	50	17	24	14
14	25	23	11	19	9	10	8
15	145	120	66	99	39	51	23
16	24	18	6	18	6	6	6
17	32	22	7	19	3	4	2
18	16	6	5	6	0	0	0
19	57	52	32	43	21	27	18

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1. See, for example, papers by Hall (1973), Heckman (1976), Rosen (1976), and Wales and Woodland (1980).

2. The variables contained in P and W will be defined more explicitly momentarily.

3. The procedure used to assign air pollution measures to the individual observations is similar to that used by Crocker, Schulze, et al. (1979).

4. Regressions for partitions containing less than 50 observations were not estimated. For these cases, the observations from two or more partitions were pooled and one regression was run on the combined data sheet.

5. Dagenais also suggests using a generalized least squares approach to estimate the hedonic wage equation. However, the approach recommended required that a system of k simultaneous nonlinear equations be solved in order to obtain estimates of the slope coefficients where k denotes the number of regressors. Because of the computational burden involved in using the procedure, it was abandoned in favor of the simpler OLS approach.

6. Additionally, even if the NOXM variable was eliminated from consideration, there would still have been only 432 families for whom data on both SOXM and TSPM could have been matched.

7. Note that in some of these partitioned regressions, variables such as UNON and HVET are excluded because all observations on them are equal to zero. For example, HVET has been excluded for this reason in Table 17.

8. The regressions used to construct the missing values for the pollution variables are shown in Tables 21, 22, and 23.

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