January 1990

Valuing Gains and Losses in Visibility and Health with Contingent Valuation

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ABSTRACT

Two different willingness to pay responses are compared - willingness to pay to avoid loss of air quality and willingness to pay to obtain gains in air quality - for visibility and health. Contingent valuation data were used to estimate bid functions for these two types of responses. Comparison of the estimated models indicates that, in addition to magnitude differences, there may be differences in how gains and losses for visibility and health are affected by risk perceptions and other risk-related variables. By comparing empirical results to theory of bid curves, income and health appear to be complements whereas income and visibility may be substitudes.

Thanks to the Jim Sandberg and Paul Brand of the San Francisco Bay Area Air Pollution Control District, Coe Owen of EPA Region 9, and Paul Wilson of the Associated Bay Area Governments for access to data and modelling help. Thanks also to Dan Wolf of SRI who provided the ISODATA program used for census tract clustering. Funding for this research was provided by EPA. The survey and preliminary analysis was carried out at SRI, International as a subcontract to University of Wyoming. Subsequent analysis was performed at Purdue University.

DISCLAIMER

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Introduction

Measuring benefits for environmental goods has been the subject of a large number of studies (Kneese; Cummings, Brookshire, and Schulze give recent reviews). The comparison of compensating and equivalent variation measures has been one topic of concern (Maler) in benefit measurement.

A related issue is the comparative valuation of gains and losses following work by Kahneman and Tversky, who suggested that losses are valued more highly than gains. Studies of willingness to pay and willingness to accept have tested the difference between "buying price" and "selling price" using an experimental market approach (Knetsch and Sinden; Coursey, Hovis, and Schultze). Although utility theory predicts that losses may receive a higher value than gains because of declining marginal utility, the observed value differences in experiments were considered to be larger than might be expected from theory (Knetsch and Sinden). In later work by Coursey, Hovis, and Schultze, initial differences between the payment and compensation measures tended to disappear as the market valuation game was repeated. Initial differences in valuation were attributed to lack of experience by subjects with compensation as compared to payment.

This paper compares the relative values of gains and losses using two willingness to pay measures -- willingness to pay to obtain improvements in air quality (gains) and willingness to pay to avoid worse air quality (losses). By holding the valuation method (payment) fixed, the comparison of gain and loss values is not confounded with the payment/compensation differences.

Rather than using an experimental market approach, observations of willingness to pay were obtained from a contingent valuation study including visibility and health aspects of air quality. In addition to testing magnitude differences between bid values for gains and losses, the availability of cross-sectional data enabled the effects on bids of socioeconomic variables and perceptions to be examined. Although the contingent valuation method has been controversial because of its hypothetical nature and its potential incentive biases, this method is now generally accepted as providing one type of benefit estimate and tests of its possible biases have been formulated (Freeman; Rowe and Chestnut; Brookshire, Thayre, Schulze, and d'Arge).

Below, theoretical properties of the two types of willingness to pay measures are first presented for comparison to empirical results. Then, the study design is described. Finally, empirical models are presented and are applied to bids for gains and losses for visibility and health separately and in combination.

Theory of Willingness to Pay Bid Curves

Microeconomic theory (Freeman) is the basis for benefit measurement for nonmarket goods. Individuals are assumed to have well-defined preferences for market goods and nonmarket goods represented by a utility function. Prices and budget constraints then combine with preferences to determine choices. Choices (here, willingness to pay bids) then reveal underlying preferences. A concave shape for bid curves has been justified by the assumption of declining marginal utility (Bradford).

Below, properties of willingness to pay bid curves for both gains and losses are related to underlying utility function properties. The case when effects of air quality changes are assumed to have certain outcomes is discussed first. Conclusions obtained from the certainty case are:

(i) willingness to pay to avoid losses is not necessarily greater than willingness to pay for gains; it is greater than willingness to pay to obtain gains if income and air quality are complements;

(ii) willingness to pay for a combination of goods (eg. visibility and health) may differ from the sum of willingness to pay for each separately.

Extending the theory to include health risk, the effects of risk perceptions and health status on willingness to pay are considered. A third conclusion from risk theory is that:

(iii) risk perceptions and health status may have different effects on willingness to pay to obtain gains and to avoid losses.

In a later section, these theoretical findings are compared to empirical results for gains and losses in health and visibility.

Willingness to Pay for Gains and Losses with Certain Outcomes

Similar to the definitions given by Brookshire, Randall, and Stoll for public goods, and Bockstael and McConnell for household production, both types of willingness to pay measures - payment to avoid worse air (WTP^e) and payment to obtain better air (WTP^c) - can be defined as expenditure differences. The notation "c" and "e" denotes compensating and equivalent variation measures. The definitions depend on the level of utility achieved (with a gain or a loss) and in both cases "payment" refers to a decrease in income. Below, their derivation from consumer expenditure theory is described.

The indirect utility function represents the level of satisfaction achieved by an individual for a given level of air quality (Y) with optimum choice of private goods subject to a budget constraint:

$$(1) \qquad \overline{U}(M,Y,p) = \max_{x} U(x,Y)$$

$$\text{s.t.} \quad p\,x \leq M$$

where U(.) denotes the utility function, x denotes consumption of market goods at prices p, income is denoted by M, and $\overline{U}(.)$ denotes the indirect utility function in terms of prices, income, and air quality.

Expenditure minimization, the dual of the utility maximization problem, is constrained to achieve a given utility level. The expenditure function expresses the minimum expenditure for private goods given an exogenous level of the nonmarket good and the utility constraint level:

$$(2) \qquad \mu(\overline{U},Y,p) = \min_{x} p\,x$$

$$\text{s.t.} \quad U(x,Y) \geq \overline{U}$$

where $\mu(.)$ denotes the expenditure function.

Willingness to pay for obtaining gains (WTP^c) and for avoiding losses (WTP^e) depend on the utility level achieved (the initial level U° or a new level U^1) for a given air quality change (either an increase or a decrease):

$$(3) \qquad \overline{U}(M - WTP^c, Y^\circ + y, p) = U^\circ = \overline{U}(M, Y^\circ, p)$$

$$(4) \qquad \overline{U}(M - WTP^e, Y^\circ, p) = \overline{U}(M, Y^\circ - y, p) = U^1$$

where $U^1 < U^0$. (Willingness to accept measures may be similarly defined but are not the subject of this study.) By duality, willingess to pay for gains and losses respectively satisfy:

$$(5) \qquad WTP^c = \mu(U^o, Y^\circ, p) = \mu(U^o, Y^\circ + y, p)$$

$$(6) \qquad WTP^e = \mu(U^1, Y^\circ y, p) = \mu(U^1, Y^\circ, p)$$

where Y° is an initial level of air quality (the status quo), y is a given change in air quality, the initial utiity level is $U^\circ = \overline{U}(M, Y^\circ, p)$ and the new utility level is $U^1 = U(M, Y^\circ - y, p)$ which is less than the initial utility U°. These expenditure differences can also be expressed as integrals as in Brookshire et al. and Bockstael and McConnell.

The slope of each type of bid curve is obtained by total differentiation of the indirect utility definition ((3) or (4)) with respect to y:

(7) $$\frac{\partial\ WTP^c}{\partial y} = \bar{U}_y(M - WTP^c,\ Y^o + y,\ p) / \bar{U}_M (M - WTP^c,\ Y^o + y,\ p);$$

(8) $$\frac{\partial\ WTP^e}{\partial y} = \bar{U}_y(M,\ Y^o - y,\ p) / \bar{U}_M (M - WTP^e,\ Y^o,\ p).$$

Since $\bar{U}_y$ and $\bar{U}_M$ are both positive, the marginal bid is positive; i.e. willingness to pay increases with air quality change for both gains and losses.

The shapes of the two bid curves are obtained by differentiating (7) and (8) with respect to y. If there is diminishing marginal utility in both M and Y and $\bar{U}$ is quasiconcave in M and Y, then WTP^c is concave (as in Bradford):

(9) $$\frac{\partial^2\ WTP^c}{\partial y} = [\bar{U}_M^2\ \bar{U}_{yy} + \bar{U}_{MM}\ \bar{U}_y^2 - 2\ \bar{U}_{My}\ \bar{U}_y\ \bar{U}_M)] / \bar{U}_M^3.$$

By differentiating (8), WTP^e has a shape determined by

(10) $$\frac{\partial^2\ WTP^e}{\partial y} = \frac{-\ \bar{U}_{yy}\ \bar{U}_M^2 + \bar{U}_y^2\ \bar{U}_{MM}}{U_M^3}.$$

The WTP^e bid curve can be either concave or convex depending on the relative sizes of $\bar{U}_{yy}$ and $\bar{U}_{MM}$.

<u>Relative Size of Willingness to Pay Measures</u>. Considering both WTP^e and WTP^c to be functions of y for given Y°, M, p, conditions when WTP^e exceeds WTP^c can be identified by comparing the Taylor series for each for a change y. Both types of bids are zero at y = 0. Therefore, the Taylor series about y = 0 are:

$$WTP^c(y;\ Y^o,\ M,\ P) = \frac{\partial WTP^c}{\partial y}\bigg|_{y=0} y + \frac{1}{2}\ \frac{\partial^2 WTP^c}{\partial y^2}\bigg|_{y=0} y^2 + \text{Remainder}$$

$$WTP^e(y;\ Y^o,\ M,\ P) = \frac{\partial WTP^e}{\partial y}\bigg|_{y=0} y + \frac{1}{2}\ \frac{\partial^2 WTP^e}{\partial y^2}\bigg|_{y=0} y^2 + \text{Remainder}.$$

(7) and (8) are equal at y = 0. (10) is greater than (9) if $\bar{U}_{yy} < 0$ and air quality and income are complements ($\bar{U}_{My} \geq 0$); that is, as air quality (y) increases, the marginal utility of income also increases. Thus, for small changes in y, if complementarity of income and air quality ($\bar{U}_{MY} \geq 0$) holds, then WTP^e will exceed WTP^c. Conversely, for WTP^c to exceed WTP^e for small changes in y, then $U_{MY} < 0$ (air quality and income are substitutes) must hold.

Willingness to Pay for Multiple Goods. To extend the expenditure model to value a combination of goods, such as visibility and health, the bid curves are similarly described in terms of differences in the expenditure function, However, willingness to pay for multiple goods will not necessarily be the sum of willingness to pay for each good separately.

For two goods Y_1, Y_2:

(11) $$WTP^c = \mu(U^o, Y_1^o, Y_2^o, p) = \mu(U^o, Y_1^o + y_1, Y_2^o + y_2, p)$$

(12) $$WTP^e = \mu(U^1, Y_1^o - y_1, Y_2^o - y_2, p) = \mu(U^1, Y_1^o, Y_2^o, p)$$

where $U^\circ = \bar{U}(M, Y_1^o, Y_2^o, p)$ and $U^1 = \bar{U}(M, Y_1^o - y_1, Y_2^o - y_2, p)$. In both cases, these measures can again be defined as an integral expression

(13) $$WTP = \int_P [- \frac{\partial\mu}{\partial y_1} dy_1 - \frac{\partial\mu}{\partial y_2} dy_2]$$

over a path P between (Y_1^o, Y_2^o) and $(Y_1^o + y_1, Y_2^o + y_2)$. If μ is continuously differentiable, these measures are well-defined (or "path independent") by Green's theorem but are not necessarily equal to a sum over each good considered separately.

For example, suppose $\bar{U}$ is of the translog form:

(14) $$\bar{U}(M, Y_1, Y_2, p) = M + \alpha_1 \ln Y_1 + \alpha_2 \ln Y_2 + \gamma \ln Y_1 \ln Y_2 = \sigma \ln p$$

where γ represents the interaction effect of Y_1 and Y_2 on utility. The assumption that increasing health should not decrease the marginal utility of increased visibility is expressed by the condition $\gamma \geq 0$. The corresponding expenditure function is

(15) $$\mu = \bar{U} - \alpha_1 \ln Y_1 - \alpha_2 \ln Y_2 - \gamma \ln Y_1 \ln Y_2 + \sigma \ln p.$$

From the definitions (11) and (12),

(16) $WTP^c = \alpha_1 \ln(Y_1'/Y_1^o) + \alpha_2 \ln(Y_2'/Y_2^o) + \gamma [\ln Y_1' \ln Y_2' - \ln Y_1^o \ln Y_2^o]$

(17) $WTP^e = \alpha_1 \ln(Y_1^o/Y_1'') + \alpha_2 \ln(Y_2^o/Y_2'') + \gamma [\ln Y_1^o \ln Y_2^o - \ln Y_1'' \ln Y_2'']$

where $Y_i' = Y_i^o + y$ and $Y_i'' = Y_i^o - y$. If there is interaction between goods in the utility function because $\gamma \neq 0$, then the WTP bid functions are not additive in willingness to pay for each good separately.

Willingness to Pay for Gains and Losses when Risk is Affected by Air Quality

Air quality may affect the probability of illness as well as the subsequent level of indirect utility. Below WTP^e and WTP^c bid curves are described for this situation. We also show that WTP^e and WTP^c may be affected differently by risk-related variables, here represented by initial health risk and initial health status of a person.

Willingness to pay when there is health risk is defined below based on the concept of option price with state-dependent utility (Smith; Graham). Willingness to pay is an option price which must be paid ex ante before the state of nature is known; hence it does not depend on the realized state of nature. Consumption choices, made after the state of nature is known, determine the resulting indirect utility which depends on whether illness or health occurs. Willingness to pay is defined in terms of expected value of the state-dependent indirect utility.

The probability of illness (ρ_i) is related to existing air quality and initial good health (H) of a person:

$$\rho_i = \rho_i(H, Y).$$

We assume

$$\frac{\partial \rho_i}{\partial Y} \leq 0 \text{ and } \partial \rho_i / \partial H \leq 0;$$

that is, improving air quality decreases probability of illness and improved initial health also reduces the probability of illness. Below, ρ_i^o denotes the ex ante probability of illness for the initial air quality and health:

$$\rho_i^o = \rho_i(H^o, Y^o).$$

Let $\bar{U}_i(M,Y,p)$ denote the level of indirect utility if illness occurs and $\bar{U}_h(M,Y,p)$ denote the level of indirect utility if no illness occurs. Ex ante, the expected value of indirect utility measures the welfare of the individual for any level of air quality Y:

(18) $$E\bar{U} = \rho_i\, \bar{U}_i(M,Y,p) + (1 - \rho_i)\bar{U}_h(M,Y,p).$$

With base air quality conditions, denote initial expected utility by:

$$E\bar{U}^o = \rho_i^o\, \bar{U}_i(M,Y^o,p) + (1-\rho_i^o)\, \bar{U}_h(M,Y^o,p).$$

These probability measures are not required to be objective; that is decisions may be based on subjective or perceived probabilities.

The WTP^c measure equates expected utility with initial air quality to expected utility with both air quality and income changes. Let $\rho_i' = \rho_i(H,Y^o+y)$ denote probability of illness after air quality improves ($\rho_i' < \rho_i^o$). WTP^c is defined from

(19) $$\rho_i'\bar{U}_i(M-WTP^c,\ Y^o+y,p) + (1-\rho_i')\bar{U}_h(M-WTP^c,Y^o+y,p) = E\bar{U}^o.$$

Differentiating (19) with respect to y, the effect of changing air quality on WTP^c is

(20) $$\frac{\partial WTP^c}{\partial y} = \frac{\rho_i' \frac{\partial \bar{U}_i}{\partial y} + (1 - \rho_i')\frac{\partial \bar{U}_h}{\partial y} + \frac{\partial \rho_i'}{\partial y}(\bar{U}_i'-\bar{U}_h')}{\rho_i' \frac{\partial \bar{U}_i'}{\partial M} + (1 + \rho_i')\frac{\partial \bar{U}_h'}{\partial M}}$$

$$= \frac{E(\frac{\partial \bar{U}}{\partial y})}{E(\frac{\partial \bar{U}}{\partial M})} + \frac{\partial \rho_i'}{\partial y}\frac{(\bar{U}_i'-\bar{U}_h')}{E(\frac{\partial \bar{U}}{\partial M})}$$

where $\bar{U}_h'$, $\bar{U}_i'$ denote the utility levels after a compensated change in air quality. Comparing (20) to the certainty case (7), the marginal bid with risk is the ratio of the <u>expected</u> values of marginal utility of air quality and income plus a term for the value of the effect of air quality on health risk, with health held constant. The marginal bid (20) is positive with the assumption that utility when no illness occurs exceeds utility with illness

$(\bar{U}'_h - \bar{U}'_i \geq 0)$. Because of the risk effect value, this willingness to pay measure is then larger than that for the case when health risk is not affected by air quality.

The effect of ex ante health status on willingness to pay can be obtained from the model. By taking the derivative with respect to p^o_i in (19), assuming that health factors (H) affecting $\rho_i{}^o$ also affect ρ'_i, the effect of initial health risk is given by

$$(21) \qquad \frac{\partial WTP^c}{\partial \rho^o_i} = \frac{[\bar{U}^o_h - \bar{U}^o_i] - \frac{\partial \rho'_i}{\partial \rho^o_i}[\bar{U}'_h - \bar{U}'_i]}{\rho'_i \frac{\partial \bar{U}'_i}{\partial M} + (1 - \rho'_i)\frac{\partial \bar{U}'_h}{\partial M}} .$$

Since

$$\frac{\partial WTP^c}{\partial H^o} = \frac{\partial WTP^c}{\partial \rho^o_i} \frac{\partial \rho^o_i}{\partial H^o} ,$$

willingness to pay will decrease with improved initial health if (21) is positive (higher risk implies greater willingness to pay). This occurs if the difference in utility between the two states declines after the compensated change:

$$\bar{U}'_h - \bar{U}'_i \leq \bar{U}^o_h - \bar{U}^o_i,$$

and if $\frac{\partial \rho'_i}{\partial \rho^o} \leq 1$; i.e. subsequent changes in probability of illness decline:

$$\frac{\partial \rho'_i}{\partial H^o} \leq \frac{\partial \rho^o_i}{\partial H^o} .$$

Properties of willingness to pay to avoid loss (WTP^e) are obtained similarly to the above procedures. WTP^e equates expected utility for income decreases to expected utility for pollution increases:

$$(22 \qquad \rho^o_i \bar{U}_i(M\text{-}WTP^e,Y^o,p) + (1\text{-}\rho^o_i) \bar{U}_h(M\text{-}WTP^e,Y^o,p)$$
$$= \rho''_i \bar{U}_i(M,Y^o\text{-}y,p) + (1\text{-}\rho''_i)\bar{U}_h(M,Y^o\text{-}y,p).$$

where the increased probability of illness is $\rho''_i = \rho_i(H,Y^o\text{-}y) > \rho^o_i$. The effect of air quality change on this willingness to pay measure is given by

$$(23) \qquad \frac{\partial WTP^e}{\partial y} = \frac{\rho_i'' \frac{\partial \bar{U}_i'''}{\partial y} + (1-\rho_i'') \frac{\partial \bar{U}_h'''}{\partial y} + \frac{\partial \rho_i''}{\partial y} (\bar{U}_h''' - \bar{U}_i''')}{\rho_i^o \frac{\partial \bar{U}_i''}{\partial M} + (1-\rho_i^o) \frac{\partial \bar{U}_h''}{\partial M}}$$

where $\bar{U}_i''$, $\bar{U}_h''$ denote utility with the money payment and $\bar{U}_i'''$, $\bar{U}_h'''$ denote utility with the air quality decline. Since making initial air quality worse increases health risk, the marginal bid (23) is positive if $U_h''' > U_i'''$. Again, comparing (23) to (7), the marginal bid with risk is the ratio of the expected marginal utilities of air quality and income plus a term for the value of illness probability change.

The effect of ex ante health status on WTP^e is obtained from differentiating (22):

$$(24) \qquad \frac{\partial WTP^e}{\partial \rho_i^o} = \frac{[\bar{U}_i'' - \bar{U}_h''] - \frac{\partial \rho_i''}{\partial \rho_i^o} [\bar{U}_i''' - \bar{U}_h''']}{\rho_i^o \frac{\partial \bar{U}_i''}{\partial M} + (1-\rho_i^o) \frac{\partial \bar{U}_h''}{\partial M}} .$$

Because (24) and (21) have different forms, it is possible that initial health status (H°) and perceived initial health risk (ρ_i^o) may have differing effects for WTP^c and WTP^e! Below, the effects of risk perceptions and health status on bids are tested.

Study Design

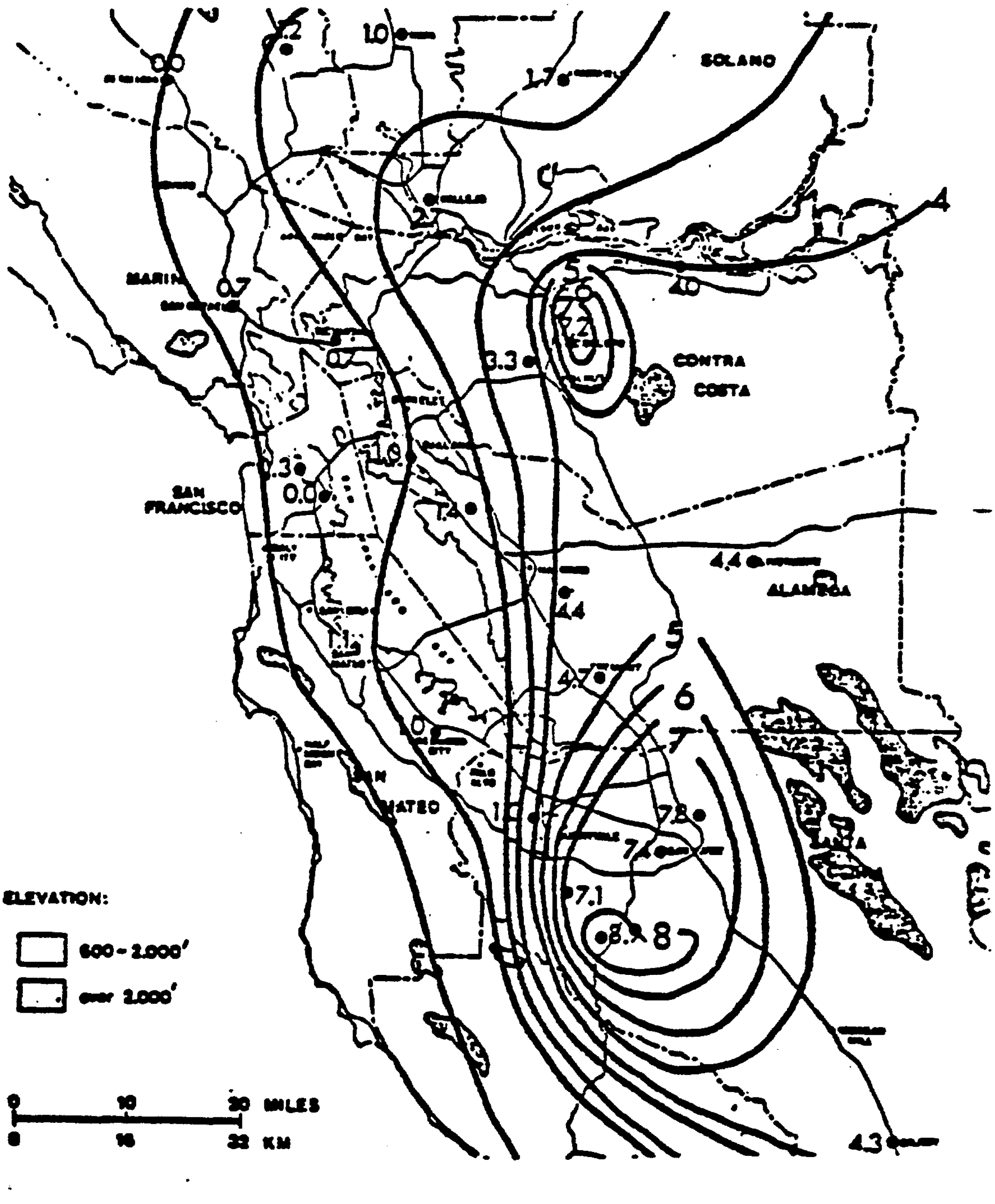
To provide willingness to pay data related to potential changes in air quality, a contingent valuation study was undertaken in the spring of 1980 in the San Francisco Bay area. Figure 1 illustrates the variation in air quality in this area in terms of the EPA ozone standard (number of days per year exceeding .12 ppm).

The study area encompassed an extensive geographical area containing 946 census tracts and 73 cities. To develop a sampling scheme for the contingent valuation study, census tracts in this area were first classified according to land use characteristics (density of census tracts), characteristics of residents (age, income), and city characteristics (urban, suburban). Using cluster analysis, eleven distinct types of census tracts were identified. To limit the sample size for the study, all tracts used in the final analysis had population density associated with predominantly single family owner occupancy. Included were tracts with two age categories ("younger" and "older" residents) and three levels of income (high, medium, and low income residents). The area was further subdivided into five air quality regions described below. The combined socio-economic/geographic/air quality classification system yielded forty-two distinct types of tracts. (Not all possible combinations of age, income, air quality, and location were present.) Using stratified sampling with selection probabilities proportional to population, one tract of each type was randomly chosen for a total of forty-two tracts. Ten respondents were then chosen randomly from each selected tract; 412 usable survey responses resulted. Appendix Table 1 shows income and population characteristics for respondents compared to the entire study area divided by air quality and location.

Five air quality areas (labelled A, B, C, D, E in Figure 2) were obtained by classifying visibility and health characteristics of air quality in the Bay Area. The visibility classification was based on data from nearby airports (shown in Appendix Table 2). Cities in areas A and C had more than ninety percent of days with greater than 10 miles visibility; cities in areas B, D, and E had 80% or less days of this type. Visibility in areas A and C corresponds to Travis Airport and areas B, D, and E are assigned to the nearest other airport sites.

The PSI index developed by EPA was used to classify areas according to health characteristics (see Appendix Table 3 for definitions). According to ambient air pollution data from the Bay Area Air Pollution Control District, areas A and B had no more than one "unhealthful" day and no "very unhealthful" days. Areas C and D had two to five "unhealthful" days and no more than one "very unhealthful" day. Area E, the worst area, had more than twelve "unhealthful" days and two to seven "very unhealthful" days.

Figure 1
Study Area



1978 Expected Annual Exceedances of Federal Ozone Standard, in days -r year with a high hourly average exceeding .12 ppm, based on running 3-year average (1976-78).

Source: BAAPCD

Figure 2

AIR QUALITY TYPES DEFINED IN TERMS OF VISIBILITY AND HEALTH

	VISIBILITY DAYS	
HEALTH DAYS	(FAIRFIELD READING)	(SF-OAK-SJ READING)
<100 MODERATE 0-1 UNHEALTHY 0 V. UNHEALTHY	A	B
>100 MODERATE 2-5 UNHEALTHY 0-1 V. UNHEALTHY	C	D
>130 MODERATE >12 UNHEALTHY 2-7 V. UNHEALTHY		E

Numerical measures of air quality used in this study, defined in terms of visibility and health separately, are shown in Appendix Table 4 for each air quality area. Visibility (PCTVIS) is the percent of moderate or poor days. Health (PSI2) is the PSI value times the percent of non-good health days. Values of these air quality measures are consistent with the classification that areas A and C have better visibility and that good health ratings increase going from area E to A.

Information (Table 1) concerning visibility and health characteristics for each area was presented to respondents in the contingent valuation study. Visibility was described in terms of number of days with visibility at three levels: non-polluted, moderate, poor. These levels correspond to visibility greater than 10 miles, 6 to 10 miles, and below 6 miles when relative humidity is less than 70%. Photographs were used to define these visibility levels pictorially for three typical scenes in the Bay Area. Health-related air quality was described in terms of the number of good days, moderate days, unhealthful days, very unhealthful days, and hazardous days. The PSI index was the basis for describing health effects. Respondents were told what types of health symptoms might be expected to occur for each type of day and the corresponding limitations for persons with different health conditions (see Appendix A).

Respondents were then asked to compare air quality areas pairwise, comparing their own area to each of the other air quality areas. Table 1 shows the information given for each area. A fictitious area F, with air quality much worse than other areas, was also included. Respondents were asked to state their maximum willingness to pay per month, either to avoid the situation in a worse air quality area, or to obtain the situation in a better air quality area. Respondents could bid any dollar amount per month but were given a list of possible amounts ranging from $0 to "more than $100" as suggested amounts. It was stated that the money would go to the Bay Area Air Pollution Control District to be used to improve air quality in all areas. (Appendix B gives the form of the willingness to pay questions.)

Table 1. Characteristics for Air Quality Areas in the Contingent Valuation Study.

	Area A	B	C	D	E	F*
VISIBILITY						
Non-Polluted Days	330	265	330	265	265	205
Moderate Days	20	70	20	70	70	100
Poor Days	15	30	15	30	30	60
HEALTH						
Good Days	294	294	232	232	191	161
Moderate Days	70	70	130	130	150	140
Unhealthful Days	1	1	3	3	20	50
Very Unhealthful Days	0	0	0	0	4	12
Hazardous Days	'0	0	0	0	0	2

* Fictitious Area

The study also asked respondents questions about their visibility perceptions, their current health status, and their beliefs about personal risk; these factors, in addition to the magnitudes of air quality changes, were used to explain willingness to pay responses. Responses to these questions are described below.

Visibility, Perceptions, Health Status, and Risk Perceptions of Bay Area Residents

Willingness to pay obtained through contingent valuation can be validly linked to air quality levels only if respondents can actually perceive distinctions among air quality levels. Several questions on the contingent value survey were designed to test this linkage by comparing perceptions of air quality to measures of air quality. Three questions were:

-Is air quality in your city generally poor, fair, good, or excellent?

-Does air quality in your area need improvement?

-How many days per month is the visibility like that in the photograph ("clear", "moderate", or "poor") in a typical month during winter (fall, spring, summer)?

Responses to these questions (shown in Appendix Tables 6-9) indicate that judgements are generally consistent with objective air quality measures (shown in Appendix Tables 2 and 3). In terms of overall quality, area B was rated between areas A and C for the average response and E was judged to be worst. Consistent with the visibility classification system, areas A and C were judged to have about the same air quality; B and D were judged to be worse than A and C and E was judged to be significantly worse. However, respondents generally believed the number of good days to be fewer, and bad days to be greater, than objective information indicates.

Generally, respondents in the East Bay and in urban locations (San Francisco, Berkeley, Oakland) believed air quality to be worse than their counterparts in West Bay and suburban locations.

Within each geographic area, visibility perceptions varied, i.e. some people believed air quality to be better than others. A variable measuring such differences was defined by comparing an individual's judgement of the number of clear days with the average clear rating for his/her air quality area.

Health Status

An index of initial health status was defined to combine information from questions dealing with type, severity, and frequency of symptoms which might be associated with air pollution. The greater the severity, seriousness, or frequency of symptoms, the greater this index; that is, higher values of the index imply worse health.

The index (H.S.) was constructed somewhat arbitrarily as follows:

$$H.S. = \sum_i (SI_i \times SV_i \times FI_i)$$

where i denotes a symptom. SI_i is an index for each symptom taking on the following values: 0 if the symptom does not occur, 1.5 for nose/throat/eye irritation, coughing, sneezing; 2 for nausea or headache; 4 for chest pain or shortness of breath. SV_i is a severity index for each symptom with the following values: .5 for mild, 1 for moderate, 2 for severe. FI_i is a frequency index for each symptom taking on the following values: 10 for seldom, 50 for now and then, and 200 for frequent. The possible range of this health status index was from 0 to over 11,000. According to this index (Appendix Table 10), Area E exhibited a much higher average health index (less healthy) than areas in the suburban West Bay with better air quality. East Bay residents were also generally less healthy than West Bay residents.

Risk Beliefs

Theory above showed that risk perceptions should influence willingness to pay. A risk belef index (Appendix Table 11) was designed to indicate whether a respondent believed himself or herself to be at risk on days defined as being of reduced health quality according to the PSI index. The risk belief index was constructed so that greater belief in the PSI index implied a greater index.

A person may personally believe the PSI index information. Then, he or she would believe that a mild restriction would be experienced on moderate days, a moderate restriction would occur on very unhealthy days, and a severe restriction would occur on hazardous days. Or, if a person believes that only mild restriction would occur on even the worst air quality days, then the risk belief index should have a lower value.

The risk belief index (R.B.) was constructed, again somewhat arbitrarily, as follows:

R.B. = .5 (Mild Restriction Index)
+ 1 (Moderate Restriction Index)
+ 2 (Severe Restriction Index)

where restriction indices (mild, moderate, or severe) are computed based on whether a person believes that a health restriction will occur on a given type of day. The following type of table was used to calculate the restriction indices by assigning a zero (no occurrence) or one (occurrence) to each row and column intersection and adding the numbers across each row. For example, for a person believing the PSI information, the resulting restriction indices are shown below:

	Occurrence by Type of Day			
Type of Restriction	Unhealthy	Very Unhealthy	Hazardous	Restriction Index
mild	1	1	1	3
moderate	0	1	1	2
severe	0	0	1	1

An index value of 5.5 = .5 (3) + 1 (2) + 2 (1) would then be obtained for such a person.

For a person who believes that only mild restriction of activities would be experienced on unhealthy days, moderate restricted activity would occur on hazardous days, and severe restriction would never be experienced, a risk index of R.B. = 2.5 = .5 (3) + 1 (1) is obtained. Thus, a risk index value much lower than 5.5 would indicate that a person does not associate much personal health risk with the PSI index while a value greater than 5.5 indicates that a person believes himself or herself to be at greater risk than the PSI index describes.

In general, the risk belief index was much lower than 5.5 for each area. Only about 30% of the persons sampled had an index of 5.5 or greater, indicating that people generally do not believe they will experience the health effects associated with the PSI index description. No difference in beliefs by geographic area was indicated.

Average Willingness to Pay Responses

Averages for willingness to pay responses for each air quality comparison were obtained to provide a preliminary examination of responses. Table 2 shows the average willingness to pay by area for all paired comparisons: A to B, A to C, A to D, A to E, A to F; B to A, B to C, B to D, B to E; etc. A fictitious area F, with air quality much worse than other areas, was also included. Above the diagonal in Table 2 average willingness to pay to avoid worse air quality (WTP^e) is shown while values below the diagonal are average willingness to pay (WTP^c) to obtain gains. The coefficients of variation for responses and median responses are also given in Table 2 in a similar format.

No responses were omitted in Table 2 - i.e. "zero" and other protest bids, as well as responses with inconsistencies and other ranking problems, were included in Table 2. Inclusion or exclusion of such responses made little difference in averages or in regression results given below. The proportion of such responses were small.

Averages for WTP^e for a given region form a scale; that is, average willingness to pay to avoid worse air quality increases as the air quality change is increased in a row of Table 2. The average WTP^c values in a row also form a scale. Persons in lower income areas would pay less for similar air quality changes (area A changing to area B compared to area C changing to D).

Table 2a shows that average bids for obtaining gains are generally less than average bids for avoiding losses, e.g. $12.50 for going from A to B but only $5.80 for going from B to A; $13.75 for going from A to C and $10.78 for going from C to A. However, this difference in the two bids nearly disappears for some comparisons (B changing to D and D changing to B), perhaps partly due to socioeconomic differences in the areas. Residents in area A would pay about $13 to avoid a 20% decrease in either health (area A changing to area B) or visibility (area A changing to area C), and more than $13 to avoid changes in both visibility and health (area A changing to area D). However, less than the sum for each separately would be paid for the combined change.

The coefficient of variation (CV) for bid responses shown in Table 2b can be used to compare reliability of the average bids. That is, a smaller CV indicates a less variable response about the average bid for an area. For WTP^c, the coefficient of variation decreases as the air quality change increases. The WTP^e responses do not indicate as clear a pattern. In general, the coefficient of variation for a WTP^c response is larger than for the corresponding WTP^e response (e.g. B to A as compared to A to B). These results indicate that the average bid is less reliable as a measure of individual response for willingness to pay for gains than for avoiding losses.

Median responses shown in Table 2c are amounts such that 50% of the respondents would be willing to pay more than this amount to obtain the indicated change. The median can be used to identify taxation levels which would pass if a majority rule election were held over tax levels used to make the air quality change (Loehman and De). The median payment for avoiding

Table 2a. Average Monthly Willingness to Pay For Changes.

From	A		C			
A	--	$ 5 0	13.75	22.11	38.33	60.00
B	5.80	--	6.13	7.70	12.23	16.63
C	10.78	6.36	--	7.98	14.18	24.39
D	10.08	7.70	5.96	--	9.48	16.46
E	9.35	6.44	3.79	3.00	--	13.00

Table 2b. Coefficient of Variation For Willingness *to* Pay Responses.

From	A		C	D	E	F
A	--	Ifi	1.3	.9	.8	.6
B	1.9	--	1.5	1.4	1.4	1.2
C	1.5	1.7	--	1.6	1.1	1.0
D	1.4	1.6	2.1	--	1.3	1.3
E	1.7	1.5	1.7	1.8	--	1.6

Table 2c. Median Monthly Willingness to Pay For Changes.

			Change To			
From	A	B	C	D	E	F
A	--	5	5	20	50	50
					10	10
B	5	1-	5 --	5	10	20
D	5		1	--	5	10
E	5		1	0	--	10

*Ficticious area

worse quality is $5 per month for air quality changes of at least 20% in either visibility or health separately or in both combined. Thus, a tax of $5a month to avoid a 20% deterioration in both visibility and health would pass a majority vote. For improving air quality, median values are lower - $1 a month would receive a majority vote for changes above 20% in both visibility and health.

To test whether willingness to pay responses were predictive of actual preferences, respondents were also asked whether they would be in favor of a vehicle maintenance inspection plan which would involve a cost for automobile repair of at most $61 per year (about $5 per month) and would be expected to give a reduction of about 15% in automobile emissions if all complied. Responses (Appendix Table 12) regarding inspection were consistent with the median values shown in Table 2c: a majority (in all areas except E) of respondents would be in favor of this plan. This plan was in fact later passed by majority vote.

To compare average bids in Table 2 for obtaining gains and for avoiding losses requires comparing responses from areas with differing socioeconomic characteristics. A better type of analysis would make adjustments for socioeconomic and other differences. Such an analysis is given below.

Bid Curve Estimation

Regression analysis was used to measure the relation between willingness to pay and changes in visibility and health and to determine the effects of income and other socioeconomic characteristics on bids. Separate models were estimated for willingness to pay for obtaining gains and for avoiding losses. The same functional form was used for both WTP^c and WTP^e so that the resulting coefficients could be compared. The regression model used in each case is a translog function, similar to (16) and (17):

(25) $WTP = \alpha_1 \ln (1+y_1) + \alpha_2 \ln (1+y_2) + \gamma \ln (1+y_1) \ln (1+y_2)$;

y_1 denotes a percent change in health and y_2 denotes a percent change in visibility. The terms al and α_2 denote marginal bids, i.e. each represents the marginal effect on willingness to pay of a small percent change, in visibility or health taken separately. The term γ tests for the effect of an interaction between visibility and health on willingness to pay; if $\gamma = 0$, then there is no interaction effect. The model does not include a constant term since WTP should be zero when the percent changes in visibility and health are zero.

Both initial air quality and air quality change are combined in the percent change measure. Since there was correlation between the initial air quality in an area and the subsequent changes given on the questionnaire for example, area A had the best initial air quality and was also associated with the largest changes, as in going from A to E, therefore, separate effects of initial air quality and air quality change could not be identified.

Socioeconomic characteristics are assumed to affect the marginal bids α_i. Marginal bids α_i in (25) were specified to be linear functions of socioeconomic characteristics:

(26)
$$\alpha_1 = \sum_j \alpha_{1j} s_{1j}$$
$$\alpha_2 = \sum_j \alpha_{2j} s_{2j}$$

where s_{1j} and s_{2j} denote socioeconomic characteristics relevant for visibiity and health. Combining (25 and (26), the regression model contains multiplicative terms with respect to air quality changes and socioeconomic factors. Each coefficient α_{ij} expresses the effect of a single socioeconomic factor (j) on the marginal bid for health or visibility.

Income is hypothesized to affect the marginal bids for both visibility and health. The marginal value of visibility is also hypothesized to be affected by an individual's visibility perceptions relative to others in the same geographic area. Systematic differences in values by geographic region (urban/suburban and East or West Bay market area) are accounted for by urban and market dummy variables in (26). Other variables hypothesized to affect the marginal bids for health are the health status index, amount of cigarette smoking, and the risk belief index.

Since air quality information given to subjects (Table 1) exhibited less variation than actual conditions, the effect of inaccuracies in air quality information were included by using separate correction terms for visibility and health.

Estimation Results

Tables 3 and 4 summarize estimation results for WTP^e and WTP^c. In Table 3, the percent change in air quality in (25) was completed assuming that a person judges air quality in terms of the percent of "good" days (WTP_{Good}). Since it is also possible that a person make judgements in terms of the number of days which are "not good", the bid curve WTP_{Bad} was also estimated with air quality measured in terms of percent changes in "not good" days. In each table, listed under "visibility" or "health" are the socioeconomic factors which shift the marginal bids for visibility and health. Results for the two types of air quality measures shown in Tables 3 and 4 are consistent in terms of sign and significance of coefficients; coefficient magnitudes differ because the two types of air quality measures differ in magnitude.

The coefficient for the health-visibility interaction term is positive and significant at the 97% or 99.5% level for the "loss" models. It is negative and significant at the 99% level for the "gains" models. Thus, respondents would pay more than the separate bid values for visibility and

Table 3. Monthly Willingness to Pay.[a]
(y_1 = %A good visibility days; y_2 = %A good health days)

Variable	Obtain Gains WTP^c_{Good}	Avoid Losses WTP^e_{Good}
VISIBILITY (α_1):		
PERCEPTIONS	-10.81 (-2.02)	-8.45 (-1.19)[a]
INCOME	.00074 (3.54)	.00097 (3.42)
URBAN	-9.45 (-.91)	-12.39 (-.65)
MARKET	29.85 (3.65)	-6.34 (-.53)
HEALTH (α_2):		
HEALTH STATUS	.0050 (1.25)	.0095 (2.64)
SMOKING	.0259 (1.71)	.065 (3.93)
RISK BELIEF	1.34 (1.64)	1.6888 (1.85)
INCOME	.00066 (4.33)	.00052 (2.69)
URBAN	--	-30.01 (-3.15)
MARKET	8.89 (1.48)	36.42 (4.55)
CORRECTION (Visibility)	14.57 (3.39)	14.09 (2.77)
CORRECTION (Health)	12.03 (4.23)	23.64 (6.28)
INTERACTION: VISIBILITY & HEALTH (7)	-67.61 (-2.48)	66.57 (1.97)
Adj R^2	.0601	.1649
Sample Size[b]	571	800

[a] Values in parentheses are t values.
[b] Sample size refers to the number of responses, not respondents.

Table 4. Monthly Willingness to Pay.
(y_1 = %Δ Moderate or poor visibility days; y_2 = %Δ PSI2)

Variable	Obtain Gains	Avoid Losses
	WTP^c_{Bad}	WTP^e_{Bad}
VISIBILITY (a):		
PERCEPTION&	-4.67	-2.66
	(-2.05)	(-1.33)[a]
INCOME	.00032	.00023
	(3.55)	(3.84)
URBAN	-2.67	-8.38
	(-.60)	(-1.03)
MARKET	11.80	3.79
	(3.43)	(1.24)
HEALTH (α_2):		
HEALTH STATUS	.0041	.0024
	(1.71)	(2.88)
SMOKING	.0120	.01843
	(1.36)	(4.57)
RISK BELIEF	.7687	.5567
	(1.61)	(2.50)
INCOME	.00038	.00014
	(4.28)	(3.69)
URBAN	--	-3.27
		(-1.38)
MARKET	7.44	4.80
	(2.03)	(2.74)
CORRECTION (Visibility)	13.97	4.15
	(3.27)	(.83)
CORRECTION (Health)	10.51	13.99
	(3.74)	(2.96)
INTERACTION:		
VISIBILITY & HEALTH (7)	-17.16)	5.52
	(-2.35)	(2.67)
Adj R^2	.0756	.1580
Sample Size[b]	571	800

[a] Values in parentheses are t values.
[b] Sample size refers to the number of responses, not respondents.

DEFINITION OF REGRESSION VARIABLES

PERCEPTIONS	- The ratio of the respondent's perception of the number of good visibility days to the average number of good days perceived for the air quality area in which the respondent lived; a value less than one indicates the respondent perceives the air to be worse than others in the area.
INCOME	- Annual income ($1980) of the respondent from a categorical variable.
URBAN	- A dummy variable indicating whether the respondent lives in an urban or suburban area (1 = urban).
MARKET	- A dummy variable respondent indicating whether the respondent lives in the East or West Bay (1 = West).
HEALTH STATUS	- Health status index; higher values indicate worse health.
SMOKING	- An index of smoking; high values indicate more smoking,
RISK BELIEF	- An index of belief in health effects occurring on polluted days; increasing values indicate increasing belief.
CORRECTION	- Corrections needed since air quality measures defined on the survey were sometimes not the actual values for the area in which the respondent lives; zero when no correction is needed.
PSI2	- The average PSI for an area times the percent of non-healthy (moderate, unhealthful, and very unhealthful) days.
PCTVIS	- Percent of polluted visibility days (days with below ten miles of visibility and humidity less than 70 percent).

health combined to "avoid losses" and <u>less</u> than the separate values to "obtain gains". Therefore, the hypothesis above is supported -- that willingness to pay for health and visibility combined is not the linear combination of willingness to pay for each separately.

The hypothesis is also confirmed that risk perceptions may have different effects on willingness to pay for obtaining gains than for avoiding losses. For health related factors, the coefficients of the health status index, smoking index, and risk belief index were positive and significant at the 99% level for avoiding losses. That is, willingness to pay increases with worse health, more smoking, and more risk belief. The health status index was less significant (95%) and smoking and the risk belief index were also less significant (90%) for obtaining gains. Thus, health-related factors were more significant for avoiding losses than for obtaining gains.

The coefficient of the visibility perception variable is negative (less would be paid by those who believe air to be better) and significant (97% level) for obtaining gains. Market location effects on visibility bids similarly exhibit significance for the "gains" case but are not significant for the "losses" case. However it is less signficant (less than 90%) for avoiding losses. Thus, opposite to the health case, perceptions about visibility were more significant for "gains" than for "losses".

In terms of R^2, air quality change measured in terms of "not good" days gave a somewhat better fitting model for willingness to pay to obtain gains while air quality change measured in terms of "good days" provided a better fit for willingness to pay to avoid losses. Thus, it is possible that responses for obtaining gains and avoiding losses may have different frames of reference.

R^2 values are not very high for any model. Consistent with the coefficient of variation results in Table 2, the regression fit was better for the "avoid losses" models than for the "obtain gains" models. Since bids from the same respondents were used for both types of questions, this suggests that people may be more certain about willingness to pay responses for avoiding losses than for obtaining gains.

Evaluation of Bid Curves

The bid curves in Tables 3 and 4 were evaluated to compare the relative sizes of willingness to pay bids for gains and losses for visibility and health separately and combined. Socioeconomic characteristics for area B were used for this bid evaluation because it is the predominant population area in the region. The magnitude of α_i in (25) did not vary greatly due to differences in socioeconomic characteristics such as income (Appendix Table 13 compares α_i values for area B with an area having different socio economic characteristics).

Each α_i approximates the monthly willingness to pay value for a small change in each air quality characteristic separately (visibility or health). For example for WTP^e_{Good}, α_1 = 63.38 for area B so to avoid a 1% loss in good health days in area B (about 3 days), the monthly WTP^e_{Good} is \$63.38 1n(1.01) ≈ \$.63; in comparison, to obtain a 1% gain in good health days, for WTP^c_{Good}, α_1 = \$33.96 so the bid is about \$.33. Thus, for a 1% change in health quality, willingness to pay to avoid health losses is about twice willingness to pay to obtain gains.

In contrast, for visibility, gains are valued higher than losses. For a 1% change (about 3-4 days), a 1% gain (WTP^c_{Good}) has a value of 40.05 1n (1.01) ≈ \$.40 whereas a 1% loss (WTP^e_{Good}) is valued at 13.34 1n (1.01) ≈ .13.

To show relative magnitudes of combined and separate bids for visibility and health, willingness to pay bids are shown in Table 5 for 1, 7, and 30 day changes predicted from the models shown in Tables 3 and 4. The effect of the interaction term, when changes in both visibility and health occur, is to change the sum of the separate bids for visibility and health by about ten percent, with an increase for WTP^e and a decrease for WTP^c.

Comparing WTP^e_{Good} and WTP^c_{Good}, the separate bid value for avoiding health losses for all indicated health day changes is roughly twice the value for obtaining health gains. For visibility separately, WTP^c exceeds WTP^e using either the "Good" or "Bad" frame of reference.

For health and visibility combined and the "Good" frame, the value of avoiding losses exceeds the value of obtaining gains but, because of the offsetting visibility effect and the interaction term, there is less difference in magnitude of WTP^e_{Good} and WTP^c_{Good} for the combined bid than for the health bid alone. For WTP^e, both "Bad" and "Good" frames gave results of similar magnitude. For WTP^c, quite different results for health were obtained from "Bad" and "Good" models. Since the predicted health bid WTP^c_{Bad} for thirty days ($13.23) is large relative to the average of actual responses for a larger number of days in Table 2a, the estimated WTP^c_{Bad} model does not predict well. The WTP^c_{Good} model predicted a combined bid for thirty days ($6.93) consistent with the magnitude of the average responses.

Table 5. Predicted Monthly Bid Values for Willingness to Pay (Area B, West Bay Suburban).

	Change in Number of Days								
	Visibility			Health			Combined		
	1	7	30	1	7	30	1	7	30
WTP^{e}_{Good}	.05	.34	1.43	.21	1.50	6.15	.26	1.88	8.27
WTP^{e}_{Bad}	.07	.53	2.05	.22	1.49	7.06	.30	2.06	9.76
WTP^{c}_{Good}	.15	1.04	4.34	.11	.80	3.30	.26	1.81	6.93
WTP^{c}_{Bad}	.16	1.11	4.30	.39	2.55	10.69	-55	3.53	13.23

WTP^{e}_{Good} = Avoid loss of good health and good visibility days.

WTP^{c}_{Good} = Obtain increase in good health and good visibility days.

WTP^{e}_{Bad} = Avoid increase in polluted days; visibility measured as moderate or poor days, health as moderate days.

WTP^{c}_{Bad} = Obtain reduction in polluted days; visibility measured as moderate or poor days, health as moderate days.

Conclusions

The purpose of this research was to test for differences between willingness to pay to obtain gains (WTP^c) and willingness to pay to avoid losses (WTP^e) for visibility and health using a contingent valuation approach. Comparing average bids and combining health and visibility changes, willingness to pay to avoid losses was generally higher than to obtain gains.

To separate the effects of health and visibility changes, and their interaction with socioeconomic factors, bids for both types of willingness to pay were similarly estimated as functions of air quality, perceptions and risk beliefs, health status, and socioeconomic characteristics. For health separately, willingness to pay to avoid losses was approximately twice as large as willingness to pay to obtain gains. The combined bid for health and visibility showed a smaller difference: for a change of thirty days of good air quality, the difference between bid values for gains and losses was only about 16%. This smaller difference for the combined bid is explained by the finding of an interaction effect between visibility and health and the finding that WTP^e did not exceed WTP^c for visibility separately.

Finding valuation differences for health and visibility does not contradict the theory of bid functions that was presented here. Theory showed that the size relationship between willingness to pay to avoid losses and willingness to pay to obtain gains is determined by whether a nonmarket good is a complement or a substitute for income. Therefore, from empirical results, visibility and income are substitute goods whereas health and income are complementary goods.

Perceptions related to health and visibility did not affect gain and loss models with the same significance. Visibility perceptions were significant for gains models but were not significant for loss models. Health risk beliefs were more significant for loss models than for gains models; health status showed a similar pattern. These results are consistent with our theory of bid functions with risk included. This theory also explains why improved health status would reduce willingness to pay, as was observed here.

Another indication that responses differ for gains and losses is based on variability of response: R^2 was greater and coefficient of variation was lower for willingness to pay for avoiding losses compared to obtaining gains. Also, framing may be different for the two types of measures. R^2 values indicate that willingness to pay for avoiding losses may be framed in terms of the perceived number of good days of air quality whereas willingness to pay for obtaining gains may be framed in terms of the perceived number of bad days.

While our results for health and visibility combined are consistent with the conjecture by Kahneman and Tversky and others that losses are valued more highly than gains, our results go beyond testing this conjecture. The findings that the processes for valuing gains and losses are different, and that there are differences in the treatment of visibility and health as economic goods, are perhaps more interesting than finding size differences. Identification of these effects was made possible by the use of contingent valuation cross-sectional data. Since testing these effects requires combining concepts of economics and psychology, there is a clear need for more cooperation between economists and psychologists to test such effects more fully.

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Appendix A

Definitions Given to Respondents: Health Effects Related to Air Quality

PSI Level of Air Quality	Health Effects	Likelihood of Effects and Limitations
Good	No health effects	None
Moderate	Eye irritation	Affects few persons
Unhealthful	Eye irritation Breathing problems	Affects some persons Persons with lung or heart disease should reduce physical activity
Very Unhealthful	Eye irritation Breathing problems Coughing Headaches Reduced alertness	Affects most persons Children, elderly, and persons with lung or heart disease should stay indoors and reduce physical activity
Hazardous	Eye irritation Breathing problems Coughing Headaches Reduced alertness Nausea Possible premature death for ill	Affects almost everyone Children, elderly, and persons with lung or heart disease should stay indoors and avoid physical activity. General population should avoid outdoor activity.

Appendix B: Form of WTP Questions

Air quality in the Bay Area could become better or worse depending on whether we undertake certain actions. Suppose we could improve air quality but it would cost money. We might pay a monthly bill to the Bay Area Air Quality management District to improve air quality in all areas. What would you be willing to pay per month to keep the area here - as it is shown on card "AREA _____" from becoming like that in area E (which is the worse air quality in the Bay Region). Card G here gives you some ideas of amounts, but you can choose any dollar amount you wish. (PUT RESPONDENT'S AREA CARD AND CARD X SIDE BY SIDE AND POINT OUT SIMILARITIES AND DIFFERENCES.)

I'd like you to make 3 assumptions when you do this. First, assume that you could not avoid the issue by moving away from here. Second, assume that everyone in the Bay Area would contribute to achieving air quality improvements. Third, assume that improvements would occur in all areas of the Bay Region.

(FOR AREA A:) Here is an area that has better air quality than here. (POINT OUT SIMILARITIES AND DIFFERENCES) What would you pay per month to improve the air from what it is now to what is shown on this card? (REPEAT FOR AREAS D, B, AND C ASKING HOW MUCH YOU PAY TO IMPROVE, LIKE BETTER CARD, OR KEEP FROM BEING LIKE WORSE CARD, AS APPROPRIATE).

Area	$ Payment per Month
A	_____
B	_____
C	_____
D	_____
E	_____

We would like to know what you would pay to prevent the air quality from becoming worse than it is in any area in the Bay Area today. Here is another card (HAND RESPONDENT CARD F) which shows you the air quality for an area outside the Bay Area. Please tell me how much you would pay to keep your city from becoming like Area F.

CARD G

HOW MUCH YOU WOULD PAY PER MONTH:

01	$0	06	$30	11	$80
02	$1	07	$40	12	$90
03	$5	08	$50	13	$100
04	$10	09	$60	14	More than $100
05	$20	10	$70		

Appendix Table 1. Socioeconomic Characteristics by Area.

Number of Respondents by Area

	A	B	C	D	E	
West Bay						
Suburban	10	40	21	50	60	
Urban		30				
East Bay						
Suburban		60	50	51		
Urban		40				
All Areas	10	170	71	101	60	412
Proportion						
in Sample	.02	.41	.17	.25	.15	
in Population	.02	.46	.11	.23	.18	

Average Income by Area from Survey Responses ($1,000)

	A	B	C	D	E
West Bay					
Suburban	34	29	35	26	27
Urban		25			
East Bay					
Suburban		23	29	25	
Urban		18			
Average	34	24	31	25	27

Appendix Table 2. **Visibility By** Airport Visibility Site and **Category.**[a,b]

Airport Visibility Site	% Non-Polluted Visibility Days		% Moderate Visibility Days		% Poor Visibility Days	
	1977	1978	1977	1978	1977	1978
Travis A.F.B., Fairfield	90.6	89.9	5.0	6.0	4.4	4.1
Oakland Airport, Oakland	80.8	76.8	14.7	16.4	4.5	6.8
San Francisco Airport, Millbrae	77.4	74.5	18.5	18.2	4.1	7.2
Moffet Field, Sunnyvale	37.0	51.2	48.4	37.5	14.6	11.3

[a]**Non-Polluted** Days — Days with visibility greater than 10 miles when the relative humidity was less than 70 percent.

Moderate Days — Days with visibility greater than or equal to 6 miles, but less than or equal to 10 miles when the relative humidity was less than 70 percent.

Poor Days — Days with visibility less than 6 miles when the relative humidity was less than 70 percent.

[b]Total of moderate and poor visibility days correspond to days exceeding the state visibility standard.

Appendix Table 3. Health Definitions.[a]

PSI Designation	Ozone (O_3)(ppm) 1 Hour Max.	Carbon Monoxide (CO) (ppm) 8 Hour Max.	Total Suspended Particulate (TSP) ($\mu g/m^3$) 24 Hour Max.
Good Day	.00-.06	0.0-4.5	00-75
Moderate Day	.07-.12	4.6-9.0	76-259
Unhealthful Day	.13-.19	9.1-14.8	260-374
Very Unhealthful Day	.20-.40	14.9-29.6	375-624
Hazardous Day	greater than .40	greater than 29.6	greater than 624

[a]Based on Pollutants Standard Index (PSI) as defined by the E.P.A.

Appendix Table 4. Average[a] Air Quality by Area.

	A	B	C	D	E
West Bay					
Suburban					
PSI2[b]	6.4	9.2	11.3	15.7	33.27
PCTVIS[c]	9.7	24.0	9.7	34.4	34.4
Urban					
PSI2		6.6			
PCTVIS		24.0			
East Bay					
Suburban					
PSI2		7.8	16.8	19.4	
PCTVIS		21.2	9.7	21.2	
Urban					
PSI2		5.9			
PCTVIS		21.2			

[a] Average is computed from city values weighted by population.
[b] PSI index weighted by percent of nongood days.
[c] Percent of moderate or poor visibility days.

Appendix Table 5. Percent Changes in Air Quality Corresponding to Willingness to Pay Questions.

From	Change To A	B	C	D	E	F
A	.	-20[a]	0	-20	-20	-38
	.	0[b]	-21	-21	-35	-45
B	+25	.	+25	0	0	-23
	0	.	-21	-21	-35	-45
C	0	-20	.	-20	-20	-38
	+27	+27	.	0	-18	-31
D	+25	0	+25	.	0	-23
	+27	+27	0	.	-18	-31
E	+25	0	+25	0	.	-23
	+54	+54	+21	+21	.	-16

[a] Percent change in visually "non-polluted days; "+" denotes change to a better air quality and "-" denotes change to a worse air quality.
[b] Percent change in health "good days"; "+" denotes a change to a better air quality and "-" a worse air quality.

Appendix Table 6. Percent Rating Air Quality Generally Good or Excellent, by Area.

	A	B	C	D	E	
West Bay						
Suburban	90	82	90	62	22	
Urban		70				
East Bay						
Suburban		66	42	49		
Urban		50				
Average	90	67	56	55	22	56

Appendix Table 7. Percent Rating Air Quality As Needing Improvement, by Area.

	A	B	C	D	E	
West Bay						
Suburban	50	35	52	58	85	
Urban		40				
East Bay						
Suburban		53	68	61		
Urban		77				
Average	50	52	63	59	85	61

Appendix Table 8. Average Number of Days Per Year Rated Not Visually Polluted, by Area.

	A	B	C	D	E	
West Bay						
Suburban	268	225	247	149	122	
Urban		163				
East Bay						
Suburban		168	193	154		
Urban		163				
Average	268	179	209	152	122	171

Appendix Table 9. Average Number of Days Per Year Rated As Poor Visibility, by Area.

	A	B	C	D	E	
West Bay						
Suburban	25	35	23	69	90	
Urban		77				
East Bay						
Suburban		38	46	68		
Urban		72				
Average	25	52	39	69	90	59

Appendix Table 10. Average Illness Index By Area.

	A	B	C	D	E	
West Bay						
Suburban	212	219	217	318	508	
Urban		251				
East Bay						
Suburban		315	452	385		
Urban		547				
Average	212	336	382	352	508	370

Appendix Table 11. Average Risk Belief Index By Area

	A	B	C	D	E	
West Bay						
Suburban	2.4	1.4	2.4	2.7	2.9	
Urban		3.1				
East Bay						
Suburban		2.1	4.4	3.0		
Urban		3.0				
Average	2.4	2.4	3.8	2.9	2.9	2.8

Appendix Table 12 Percent In Favor of Vehicle Maintenance/Inspection Plan

	A	B	C	D	E	
West Bay						
Suburban	90	50	71	70	47	
Urban		67				
East Bay						
Suburban		62	76	49		
Urban		72				
Average	90	62	75	59	47	62

Appendix Table 13. Comparison of Model Coefficients for Two Geographic Areas

Coefficient	Area B	Area E
Visibility		
$\alpha^{e}_{1,Good}$	13.34	11.40
$\alpha^{c}_{1,Good}$	40.50	39.02
$\alpha^{e}_{1,Bad}$	7.80	7.37
$\alpha^{c}_{1,Bad}$	16.41	15.77
Health		
$\alpha^{e}_{2,Good}$	63.38	64.30
$\alpha^{c}_{2,Good}$	33.96	34.78
$\alpha^{e}_{2,Bad}$	12.29	12.58
$\alpha^{c}_{2,Bad}$	21.82	22.77

α_1 - value in cents of 1% change in visibility alone

α_2 - value in cents of 1% change in health alone

"e", "c" denote equivalent and compensating variation bid measures

"G", "B" denote "good" and "not good" air quality measures.