VALUING AIR QUALITY IMPROVEMENTS: SIMULATING A HEDONIC EQUATION IN THE CONTEXT OF A CONTINGENT VALUATION SCENARIO

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Abstract

This paper reports on a recently completed pilot study sponsored by the Electric Power Research Institute to develop a methodology for placing economic values on possible air quality improvements and to demonstrate that methodology in Cincinnati.[1] Cincinnati was chosen because its air quality problems are typical of Eastern cities and because of previous air quality work conducted there. In this study we show how a hedonic pricing equation can be simulated in the context of a contingent valuation study to allow for the estimation of the demand for both air quality related health benefits and visibility benefits. This is done by asking respondents how much they are willing to pay for air quality improvement programs which offer various combinations of health and visibility improvements. One can then statistically estimate using a hedonic pricing approach the demand for the two attributes of an air quality improvement. Our approach overcomes key difficulties with respect to both contingent valuation and hedonic pricing. A number of interesting questions are raised by the response behavior observed.

Introduction

One of the key provisions of the Clean Air Act is that it allows for consideration of the economic valuation of changes in visibility in determining where to set the secondary air quality standard, but does not allow for economic considerations (only health) to be used in determining where to set the primary air quality standard.[2] Neither of the two most popular techniques for valuing air quality changes, contingent valuation and hedonic pricing, really address this need to separate health and visibility benefits for the purpose of policy analysis. Typically, a contingent valuation scenario tells a respondent that there are no health effects or to ignore them.[3] Hedonic pricing studies, on the other hand, often do not attempt to provide an estimate of visibility benefits separate from the benefits of the air quality improvement as a whole.[4] When they do, they are used as the only indicator of air quality the visibility gradient or a single air pollutant not thought to be closely tied to health effects.

A potentially major problem with the contingent valuation technique as currently used is its heavy reliance on the assumption that respondents did not include willingness to pay for health improvements when they gave their willingness to pay for visibility improvements.[5] This problem can be cast in psychological terms: if shown pictures of improved visibility, are respondents really likely to believe that there are no improvements in health effects, or if they believe there are health effects, subtract off the part of willingness to pay for air quality improvements that they would assign to health improvements? The problem cast in terms of economic theory has perhaps a deeper and more disturbing implication. If air quality health and visibility improvements are either substitutes or complements and both are changing at the same time then the only way to get a unique value of willingness to pay for visibility improvements is to condition on a particular level of health effects.

There are two key problems with hedonic pricing in the context of valuing visibility benefits. The first is the standard difficulty encountered with hedonic pricing when one tries to separately identify the supply and demand curve. The second is also typical of hedonic pricing but probably even more acute when dealing with air quality, extreme collinearity of the different air quality indicators which makes it difficult, if not impossible, to separate visibility and health benefits.

A Response Surface Approach

The problems of both contingent valuation and hedonic pricing can be overcome by the use of a contingent valuation scenario in which air quality improvement policies consisting of randomly assigned health and visibility levels are valued. Having respondents value programs which explicitly specify the levels of health and visibility improvements avoids having to make assumptions about what level of health improvements they had in mind while valuing a specific visibility improvement. It does of course put one in the position of having to separate the health and visibility benefits and that is where hedonic pricing is useful. A response surface experimental design within the contingent valuation study can be used to set up a "perfect" hedonic pricing equation for estimation. Random assignment of the levels of health and visibility improvements makes the supply of these improvements exogenously determined. Judicious choice of the assignment of the levels can eliminate the usual severe collinearity between the two types of benefits.

Random assignment of health and visibility levels also makes these levels uncorrelated with individual characteristics such as income, age, and residential location. This allows the relationship,

$$WTP_{(ijk)} = f(HDAYS_{(j)}, VDAYS_{(k)} + e_{(ijk)}),$$

where j indexes changes in health days (HDAYS), k indexes changes in visibility days (VDAYS), and i=1,2,...,N indexes randomly sampled agents to be estimated without considering the characteristics of the agents. HDAYS and VDAYS represent the number of health and visibility days being valued. If N is large, $WTP_{(ijk)}$ can be estimated using a non-parametric technique, such as ACE, thus avoiding the functional form restrictions usually necessary with hedonic pricing models.[6] The only restrictions imposed by economic theory are that WTP is monotonically increasing in both i, j and k if health and visibility are normal goods. What results is an estimated response surface with VDAYS and HDAYS as the x and y axes and WTP as the z axis. Figure 1 displays the response surface which was estimated using ACE on the data from our Cincinnati pilot study.

Survey Instrument Design

The survey instrument used in this study was developed after an extensive period of pre-testing involving several focus groups and in-depth test interviews conducted with respondents recruited by the Behavioral Sciences Laboratory at the University of Cincinnati. In common with other contingent valuation visibility studies the final instrument uses photographs to help convey the nature of the visibility amenity. Respondents were shown three 5 x 6 Cibachorome photographs for each of the three scenarios. The photographs portrayed visibility ranges of 1-6, 7-14, and 15+ miles as measured at the Greater Cincinnati airport by Charles Gruber, a former Cincinnati air pollution control official.

Unlike most previous contingent valuation visibility studies, the visibility changes were described as changes in distributions of days instead of changes in mean visibility. Another unique feature was the large number of changes valued by each respondent (ten) made it possible to study in a new way the kinds of decision rules used by respondents in the contingent valuation setting.

We developed a program card visual aid to communicate the visibility changes. Each program card showed the number of days in an average year that would fall into the three visibility categories--0-6, 7-14, and 15+ miles--and the changes in this distribution from the present to a hypothetical future. The present distribution, which was calculated from past visibility records at the airport weather station, served as a baseline. Ten future distributions were offered within a range whose upper bound was defined as the most improvement that could credibly occur given a maximum control effort directed at cars, factories, and other sources of air pollution.

In order to test the assumed health benefit hypothesis, two versions of the questionnaire were administered to equivalent sub-samples: version A used programs that changed the distribution of days from a baseline (described as the current situation in Cincinnati) on both health and visibility dimensions which were described using the type of program card shown in Figure 2. Version B was identical in every respect but the following: (1) the programs included only visibility changes, which were the same visibility changes used in Version A, and (2) at three places in the interview they were informed that despite the changes in visibility there would be no change in health effects and that they should only value the visibility changes. Respondents in both versions were told that visibility and health effects could be independent of each other; an explanation not included in earlier contingent valuation visibility studies.

Other features of the instrument include having the respondents rank the ten programs in their order of preference without regard to cost; having the respondents reveal which programs, if any, are worth at least a small amount to them if they were to vote in an air pollution referendum; and having them place a dollar value on each of the valued programs using an open ended elicitation format.

As the primary purpose of the pilot study was not to draw inferences for policy purposes, but rather to test version A against version B and to develop a working survey instrument, a non-random sample was used to reduce costs. The sample used was based on a previous sample drawn by the University of Cincinnati Survey Research Center, which we hoped was representative of the area's population so we could determine how well the instrument would work with people with different economic, racial, and educational characteristics. The in-person surveys were conducted by The Information Center, a Cincinnati marketing research firm, under the close supervision of Robert Mitchell. After two days of training, the interviewers administered versions A and B in alternating fashion to ensure randomization. A total of 151 interviews were completed in the Fall of 1988; 76 using version A and 75 using version B. Examination of the demographic characteristics of the people in the two versions showed them to be statistically similar. The overall sample itself, while it appears to mirror the Cincinnati population, is undoubtedly biased toward those who enjoy participating in surveys. The mean interview time for version A was 53 minutes, twelve and a half minutes shorter than the mean time for version B.

Results

One of the primary objectives of this pilot study was to examine whether a contingent valuation study of visibility benefits should ask respondents to value health and visibility changes simultaneously or to value visibility changes alone. As mentioned earlier, the study utilizes a split sample design (versions A and B) to allow for a test of whether respondents valued a program containing j VDAYS and k HDAYS differently than a program containing only j VDAYS and 0 HDAYS. We found that the respondents valued the programs with both visibility and health improvements higher than the programs with visibility improvements only however that does not guarantee that visibility is always being correctly valued by itself.

The problem can be seen in the presence of a significant interaction term between visibility and health in a simple regression equation suggesting at least a violation of the separability condition necessary for independent valuation to be valid. It can also be seen in the differences in predictions for only visibility changes from equations estimated using two different versions.

We believe the best way to see the problem is to look at the cumulative distribution functions (CDF's) from two different paired comparisons. Figure 3 shows a comparison between Program A with three visibility day improvements and three health day improvements and Program B with only three visibility day improvements. Comparing the CDF's for the two different treatments shows large differences. Contrast this with Figure 4 which shows Program A, 29 visibility days and 12 health day improvements, and Program B, 29 visibility day improvements and 0 health day improvements, where the two CDF's lie almost on top of each other. If health and visibility day improvements were being valued independently then the two CDF's in Figure 4 should look much more like those in Figure 3 and indeed, if anything, be farther apart. Our preliminary interpretation is that while respondents were willing to believe that there did not have to be any health day improvements associated with small visibility improvements, they were unwilling or incapable of making this separation for larger visibility improvements.

Recommendations

Based on the analysis of the pilot study results, we recommend that a contingent valuation survey should question respondents about simultaneous health and visibility changes. Our rationale for the recommendation is as follows. From a theoretical vantage point, joint valuation is the correct strategy if air quality changes incorporate both health and visibility changes alone. Two conditions would argue for valuing visibility improvements alone. The first is if respondents encountered substantial difficulties in providing dollar values for the more complex good comprised of both health and visibility improvements. The second is if values for visibility improvements are independent of values for health improvements. Neither of these conditions appears to be true based on the pilot study results.

The bids of the respondents have several striking features that are important for inferring the values of air visibility and health changes. Of these features, the one that will concern us most is the persistence with which a sizeable fraction of the respondents gave equal values to alternatives which they had previously ranked uniquely. Despite their apparent comfort with ranking the alternatives without ties, the respondents frequently reverted to ties when they assigned monetary values to the alternatives. These respondents rarely assigned small differences in monetary values between groups of equally valued programs but rather tended to separate them with substantial dollar differences. A retrospective look at previous contingent valuation surveys of a similar kind shows that such responses are actually prevalent but less obvious due to a smaller number of programs valued in most studies and the larger differences between the physical changes valued.

Our interpretation of this phenomenon is that respondents used equal bids to communicate the uncertainty they hold for their actual values. Because they regarded greater precision as artificial, the respondents gave rough values which indicate that some alternatives are worth approximately the same amount. If several alternatives were assigned the same value, this should not be interpreted as stating that the respondent was indifferent between the alternatives. Instead, such equal valuations indicate that within the precision that the respondent is comfortable, the bid is representative of the values of the specified alternatives.

The significance of uncertainty in respondents is that there is an uncertainty in visibility values that surveys will not be able to remove. Traditionally survey researchers have applied statistical methods with the view that large enough sample sizes can reduce measurement error as close to zero as one desires. If the respondents are incapable of providing that exact value of air visibility and health changes however, then this tradition is dubious and the goal of precise measurement of values is illusory. Instead, our survey and statistical analysis must provide measures of both values and their uncertainty. One of the major findings of this interim report is that the survey instrument developed in the pilot study is a useful tool for this task.

We also note two other features of the responses. First, there is strong evidence that the respondents are not homogeneous in their values for air visibility and health. Among the seventy respondents to version A, approximately 33 percent rank ordered programs on health improvements only and 31 percent on visibility improvements only. Thus, the responses fall into three roughly equal sized groups according to ranking behavior. One group strongly prefers visibility over health improvements, a second group prefers health to visibility, and a third group makes tradeoffs between them. Second, there appears to be a pronounced threshold effect, or nonlinearities, in the willingness to pay function for visibility and health improvements. A large majority of the sample were unwilling to pay for programs improving only a few visibility days. This phenomena is not evident in Figure 1 which traces out mean willingness to pay.

Combined with the finding that health and visibility values must be solicited simultaneously, these three features of the responses suggest to us that our survey instrument has unanticipated advantages. We believe equal valuation grouping by respondents may be desirable; while one could force respondents to give distinct values, such an instrument would yield artificial responses. Rather than suggesting the need for major modifications to the survey instrument, we believe that there are ways to refine the pilot version to exploit these advantages more fully.

Concluding Remark

We are currently working on improving the basic contingent valuation scenario, the issue of visibility perception, the use of computer generated photographs tied to an air quality model, utility models which are consistent with observed response patterns, and the development of statistical techniques to better exploit the features of our particular experimental design and type of data generated by our survey instrument. This work should be of interest to those conducting contingent valuation visibility studies for policy purposes.

References

1. R.C. Mitchell, R.T. Carson, and P.A. Ruud, *Cincinnati Visibility Valuation*

Study: Pilot Study Findings, Report prepared for the Electric Power Research Institute, Palo Alto, CA, 1989.
2. R.D. Rowe and L.G. Chestnut, ***The Value of Visibility: Economic Theory and Applications for Air Pollution Control***, Abt Books, Cambridge, MA, 1982.
3. R.C. Mitchell and R.T. Carson, "Using Surveys to Value Public Goods: The Contingent Valuation Method," ***Resources for the Future***, Johns Hopkins University Press, Washington, D.C., 1989.
4. D. Harrison and D.L. Rubenfeld, "Hedonic Housing Measures and the Demand for Clean Air," ***Journal of Environmental Economics and Management***, *5*, 81, 1978.
5. G. Tolley and R. Fabian, Editors, ***The Economic Value of Visibility***, Blackstone Books, Mount Pleasant, MI, 1986.
6. L. Breiman and J.H. Friedman, "Estimating Optimal Transformations or Multiple Regressions and Correlations," ***Journal of the American Statistical Association***, ***80***, 580, 1985.

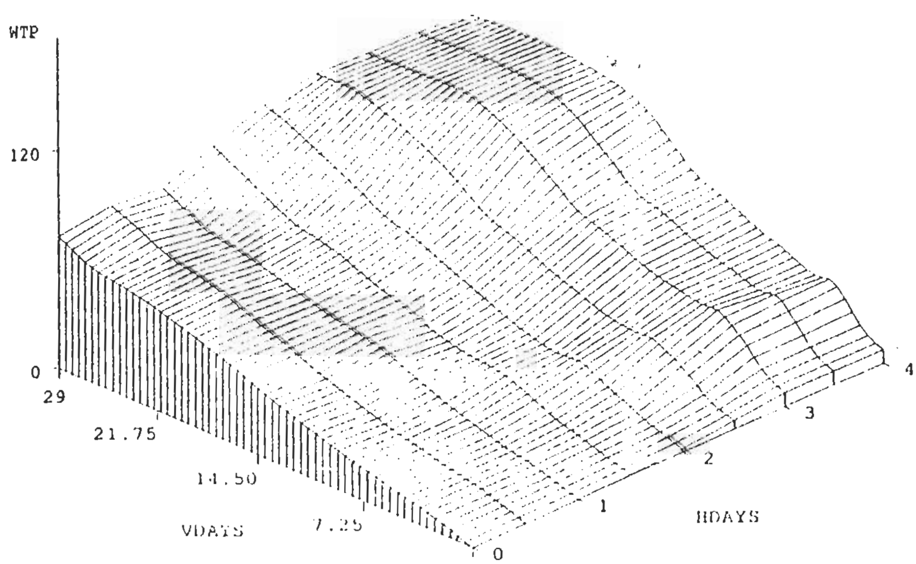

Figure 1. Response surface estimate of value of air quality improvements

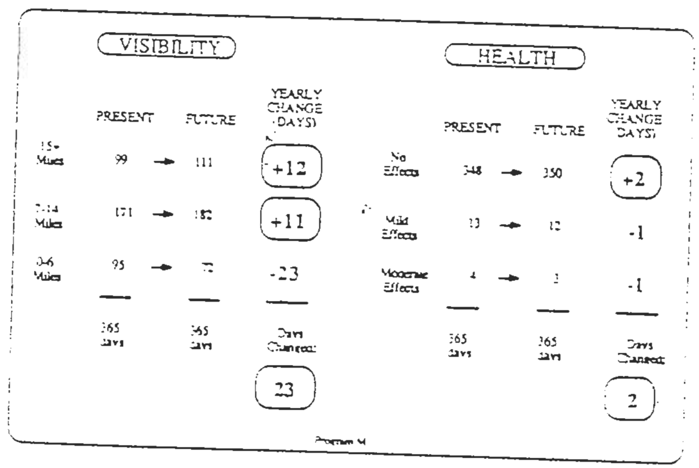

Figure 2. Program card

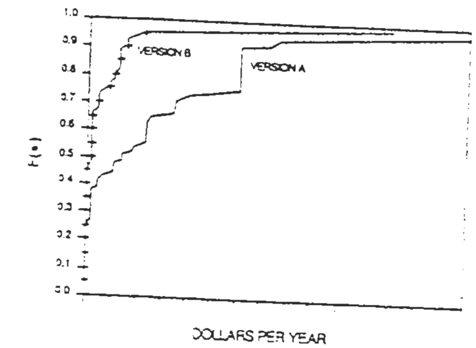

Figure 3. Empirical distribution function of bids
version A: 3 visibility days and 3 health days
version B: 3 visibility days and 0 health days

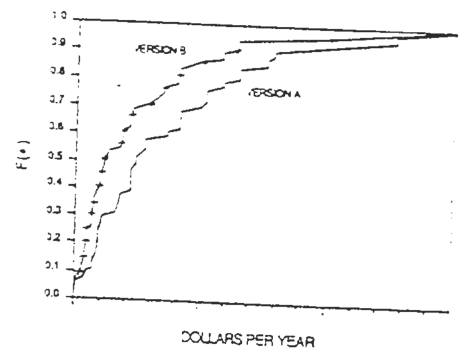

Figure 4. Empirical distribution function of bids
version A: 29 visibility days and 12 health days
version B: 29 visibility days and 0 health days