Using Stated-Preference Questions to Investigate Variation in Willingness to Pay for Preserving Marble Monuments: Classical Heterogeneity and Random Parameters

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Abstract

The thousands of trips to Washington D.C. each year to visit its monuments reveal significant use value for these cultural resources. Focus-group and survey responses indicate passive use value is also significant and likely more important to many people than use value. The goal of this paper is three-fold: to estimate mean willingness to pay (WTP) for the preservation of these cultural resources, to determine the extent to which individual WTP varies, and to try to explain WTP variation as a function of individual characteristics such as age, income, gender, and ethnicity. The data are responses to hypothetical pair-wise choices. Each sampled individual was asked to choose between two monument preservation programs. The question was repeated ten times with varying costs and preservation levels across the alternatives. Some of these pairs included the status quo as one of the alternatives. Comparing choice pairs with referendum CVM, referendum CVM can be viewed as a single choice pair where one of the alternatives is the status quo. Asking each individual multiple choice questions facilitates the investigation of preference heterogeneity. Preference heterogeneity is incorporated into a discrete-choice random utility model by interacting characteristics of the preservation program with characteristics of the individual and by including random parameters. The results indicate significant WTP for the preservation of these monuments and significant variation in WTP. A significant part of the variation is explained by age, income category, gender, and ethnicity.

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1. Introduction

Stated-choice questions are used to investigate preference heterogeneity in willingness to pay for the preservation of 100 significant marble monuments in Washington, D.C. The results extend a study (Morey et al., 1997 and 2002) undertaken to determine the benefits society would receive from a reduction in the rate of injury to these monuments. Marble monuments are injured by exposure to air pollutants such as sulfur dioxide (SO_2), which is being reduced by Title IV of the 1990 Clean Air Act Amendments. The issues are how society values this reduction in the rate of injury and how these values vary across individuals.

Simply put, a stated-choice question presents an individual with a number of alternatives, each described in terms of the levels of their common set of characteristics. The individual is asked to state his preferred alternative. Stated-choice techniques are used in marketing, transportation, and economic research to value products, environmental resources, and changes in transportation modes as a function of their characteristics.[1] In this application, each respondent is presented ten choice sets where each set consists of a pair of preservation programs. Each of the alternatives is described in terms of two characteristics: the level of preservation and a price. For example,

Preservation Option B for $7	or	Preservation Option C for $25

The study is limited in that it only investigates the benefits of reducing the injuries to the approximately 100 marble monuments in Washington, D.C., and only estimates those benefits for the residents of two northeast cities: Boston and Philadelphia. The analysis was limited to these monuments for the following reasons: they have national significance; a majority of the monuments in Washington are made of marble;, these monuments generate significant use values (approximately 75% of our sample reported visits to these monuments); focus groups and pretesting indicated significant nonuse values; most of the reductions in SO_2 emissions as a result of Title IV will occur in the eastern United States; and there was a limited budget for the study. These monuments include the U.S. Capitol, the Lincoln Memorial, the Jefferson Memorial, the Washington Monument, the Supreme Court Building, many statues, and cemeteries.

The goal was to get a sense of regional values for these resources in a cost-effective manner. Given our decision to do in-person surveys in a cost-effective manner, we decided to survey in only two major metropolitan areas in the northeast. Washington D.C. and New York City were excluded as being unrepresentative. Both Boston and Philadelphia have many historic sites, so it was presumed that respondents would have some familiarity with the issues. In summary, the population of interest is residents of Boston and Philadelphia. No claim is made that these estimated values apply to other populations. Since we are one of the first to use choice experiments to value cultural resources, we thought it best to limit the scope of the task. Issues of the degree to which the population is represented by in-person surveys are discussed, so is our decision to do in-person surveys.

The study of the demand for and benefits from cultural sites is a growing area of research. The *Journal of Cultural Economics* has published a number of cultural valuation studies (e.g., Hansen, 1997, and Santagata and Signorello, 2000). See also Willis (1992), Mossetto (1993), Grosclaude and Soguel (1994), and Narvud and Ready (2002); the latter is a collection of empirical studies. For a general discussion of the issues associated with valuing cultural resources see Morey (2001).

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[1] Wittink and Cattin (1989) survey the commercial use of choice questions; use is widespread. For survey articles see Louviere (1988 and 1992), Green and Srinivasan (1990) and Batsell and Louviere (1991). Hensher (1994) provides an overview of choice questions as they have been applied in transportation. Louviere (1994) does the same for marketing. Choice questions are increasingly used to estimate the value of public and environmental goods. See, Adamowicz et al. (1994, 1996, 1997), Breffle et al. (2002), Layton and Brown (2000), Magat et al. (1988), Morey et al. (1997, 2002a and b), Ruby et al. (1998), Swait et al. (1998), Viscusi et al. (1991), and Mathews et al. (1997).

The rest of the paper is organized as follows: Section 2 discusses our reasons for choosing choice questions as the preference solicitation method; Section 3 explains the preservation programs; Section 4 covers experimental design and survey administration; Section 5 discusses the sample; Section 6 our approach to modeling preference heterogeneity; Section 7 presents the discrete-choice random utility model; Section 8 discusses estimation and presents the empirical results in general terms; Section 9 presents estimates of WTP; Section 10 considers heterogeneity in WTP in more detail; and Section 11 summarizes.

2. Choice Questions: A Stated-Preference Approach

In focus groups and pretests, participants were asked to rate several reasons why monuments are important. We found that, on average, participants rate passive values more highly than those values related to direct use.[2] This finding is consistent with Narvud et al. (1992), who found that nonuse motivations tended to be more important than concerns about the quality of a person's own visits. Consistently we found that although respondents commented on moving personal experiences when visiting certain monuments, the primary reason they gave for being willing to pay to preserve and maintain these monuments was so that they would be available for others now and in the future. They stressed the historic and inspirational message the monuments convey and the importance of conveying this message to future generations.

These initial findings lead us to choose a stated-preference approach (SP), an approach which can be designed to estimate all benefits, use and passive. Revealed-preference (RP) approaches, such as travel-cost, would capture only direct use values. Furthermore, such approaches would be difficult to implement because visits to monuments are often part of a multi-purpose trip.

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[2] Passive use benefits are benefits one can receive without being at or near the site. For example, an individual might benefit from knowing that salmon are prospering in the Columbia River basin even though he has no intention of of viewing, catching, or eating them. Passive use damages are the loss of such passive use benefits.

While many economists tend to have more faith in RP than SP data, SP data has some distinct advantages. Morikawa et al. (1990) states, "since SP data are collected in a fully controlled "experimental" environment, such data has the following advantages in contrast with RP data that are generated in natural experiments: 1) they can elicit preferences for non-existing alternatives; 2) the choice set is pre-specified; 3) collinearity among attributes can be avoided; and 4) range of attribute values can be extended." Researchers estimating the value of cultural resources are often valuing commodities or conditions that do not currently exist. In addition, because SP data allow the researcher to control more variables and because there are more unknowns influencing the decisions in RP data, the SP data often contains less noise and measurement error (Louviere, 1996).

Like all data on preferences - including actual choices (RP data) - the responses to choice questions may contain biases or random errors with respect to preferences. The random errors are a component of the statistical model. Choosing can be difficult if the individual is almost indifferent between two alternatives. If each respondent is asked to answer a number of choice questions there can be both learning and fatigue. Respondents can become frustrated if they dislike all of the available alternatives, and they may have little incentive for sufficient introspection to determine their preferred alternative. In addition there can be a bias towards the status quo, the respondent might ignore his constraints, and the respondent might behave strategically. It is our view that these pitfalls can be avoided in a well-designed study.

We chose to collect SP data with repeated pair-wise choices rather than use the contingent valuation method (CVM).[3] Both methods were investigated in pretests. Reasons for choosing choice pairs include:

1. The scenario to be valued (the reduction in the rate of injury to these monuments caused by Title IV) was unknown at the time of the study. The materials experts felt that they could bound the rate of reduction as being between a 25% and 100% decrease, but could not be more exact until

[3] Referendum CVM can be viewed as a single choice pair where one of the alternatives is the status quo.

more information became available. We therefore needed a flexible tool that was capable of estimating WTP for different reductions in the rate of injury. CVM values one scenario.

2. The participants in the pretests found pair-wise choices and referendum CVM easier than payment cards or ranking over more than two alternatives.
3. Pair-wise choice experiments easily accommodate multiple valuation questions per respondent and so make data collection more cost effective, particularly with in-person surveys.
4. In the pretests with referendum CVM, some respondents had a tendency to *cost calculate*; that is, reject the stated cost even though it was less than their WTP reasoning, correctly, that if all households paid this cost, program funding would be excessive. This was less of an issue with repeated pair-wise choices. The variation in costs in the pair-wise choices (as well as instructions to focus on what the program would be "worth" to them) tended to focus respondents on the tradeoff between cost and effectiveness. This variation in cost and effectiveness also makes it more difficult for respondents to behave strategically.
5. Choice questions encourage respondents to focus on attribute trade-offs. This can be cognitively challenging depending on the familiarity of the goods (and, thus, attributes and attribute levels), number of attributes, size of choice set, number of choices, and complexity of choices. Several studies have examined the advantages and difficulties associated with respondent cognition and the choice question format, for example Morikawa *et al.* (1990) and Adamowicz *et al.* (1998). Our choice tasks are relatively simple: each alternative is described in terms of only two characteristics.[4]

Choice-based methods are explicitly identified (as conjoint methods) in the NOAA NRDA regulations for use in valuing and scaling injuries and restoration (15 CFR part 990, preamble Appendix B, part G). In addition to estimating damages or benefits, stated-choice questions are a promising technique for making the determination of in-kind compensation and restoration, because in addition to monetizing damages, choice questions investigate how individuals make resource-to-resource tradeoffs. For this reason, stated-choice questions can be attractive to those who have no desire to estimate benefits or damages in monetary terms.

3. Valuing One of the Minor Impacts of Reducing Acid Deposition

To estimate the benefit of reducing air pollution injuries to cultural resources, we concluded that it was necessary to construct a hypothetical mechanism which achieves the reduction in injury but that is not a reduction in acid deposition. There are many benefits to reducing acid deposition in addition to its effects on marble monuments; in addition, the benefits from reducing the injuries to marble monuments in Washington D.C. are likely to be only a small proportion of the total benefits. To avoid potential embedding and the difficulty of separating out the effect on marble monuments in just Washington D.C., we created hypothetical treatment programs that would, decrease the rate at which the monuments would deteriorate. During the scoping phase, we tested a number of preservation programs. Focus groups participants found a chemical treatment program for marble to be credible (even though no such method existed at the time of the survey). We needed to specify that the monument would be cleaned before the coating was applied. Such a cleaning would be detrimental to the marble, but many focus group participants did not like the idea of applying a protective coating to something that was "dirty".

Three different "treatment" (preservation) programs, A, B, and C, were created. They varied in effectiveness. The different effectiveness levels were achieved using different coating and application techniques. The three options were distinguished by how they affected the injury time line. Option A increased by 25% the amount of time it would take for a given level of injury to occur, B by 50%, and C by 100%. Respondents were first shown photos of what a number of monuments look like now and how

[4] For example, Opaluch *et al*. (1993) describe seven attributes associated with noxious facilities; Adamowicz *et al*. (1997) use six attributes to describe recreational hunting sites; and Morey *et al*. (2002a) use six attributes to describe

they would look in 75 and 150 years if nothing was done to reduce the rate of deterioration.[5] Preservation options were presented as shifts in this time line.

With some trepidation, the payment vehicle was left intentionally vague. Respondents were told, "For each alternative, you should imagine that the price is a one-time payment that your household would make if that preservation program were undertaken." And that "the exact payment mechanism is undecided" This wording was tested in the focus groups.

The intent of the survey precluded a fee based on use. A tax payment mechanism caused some focus-group respondents to reject payment amounts for reasons not related to household WTP, e.g., the total amount collected by the tax would far exceed the cost of the program, and poor households would not be able to easily pay the amount.

4. Experimental Design and Administration

The design is simple: there are only two attributes, quality and price; quality can take only one of four levels, and price only one of nine levels. Twenty versions of the survey were developed such that all plausible combinations appeared on at least one version. Plausible combinations excluded pairs where one of the alternatives was both cheaper and more effective than the other.[6] Each of the twenty versions had five pairs where one of the alternatives was the status quo. Whether, and how often, one should include

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mountain bike sites.

[5] Actual photos were digitally altered with the help of materials experts to show what the monuments would look like in the future with different amounts of deterioration.

[6] There is a potential problem with excluding such pairs because they give the respondent the opportunity to reveal that they don't like the monuments (prefer less preservation and are willingness to pay for less preservation).

the status quo as one of the alternatives in choice experiments is an ongoing topic of contention.[7] Note also that that all of the questions are forced choices; that is, the respondent is not given the opportunity to choose “none of the above”.

To help the respondents to understand the process, the section on pair-wise choices began with two example pairs that were presented by the survey administrator: Option C at $25 or the No Preservation Option, then Option B at $10 or Option C at $15.

The surveys were administered in person in groups. Group size varied from 7 to 31. The sessions lasted approximately 1.5 hours and respondents were paid $50 to participate. During the first part of the survey, respondents alternated being listening to the administrator present information, reviewing the information in their response booklets, and providing written answers to survey questions. Respondents could not discuss items with the other participants and questions were answered individually. During the second half of the survey, respondents worked at their own pace, reading survey questions, and providing answers. The choice questions were a large component of the second half.[8] This group format was the most cost-effective way of presenting in a consistent manner a substantial amount of written, verbal and photographic information.[9]

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[7] One reason to exclude the status quo is its exclusion reduces the potential for status-quo bias. For a discussion of the debate and the underlying theory see Morey (2001). For this data set, when the scale parameter in the extreme value distribution was allowed to differ as a function of whether the choice pair included the status quo, the model estimated that there was more noise in the choice question that included the status quo than those that did not. We also found that the spread/scope on the WTP estimates for the three treatment programs is much less when a model is estimated using only the data from the status-quo pairs. Forcing the individual to directly compare two alternatives, both different from the status quo, seems to cause a greater perception of differences in non-status-quo alternatives than does letting them vary from pair to pair. Including the data from the status-quo pairs significantly reduces the magnitude of WTP for the most effective program. Numerous interpretations are possible. One interpretation is that status-quo bias increases in significance as a function of the extent the non-status-quo alternative differs from the status quo.

[8] A copy of the survey can be found at www.colorado.edu/Economics/morey

[9] Presenting such detailed information is not possible in a phone survey. The cost of producing many high quality photos would make a mail survey very expensive. An internet survey is a possibility, one could even keep track of how much time, if any, respondents spent with the different study materials.

5. The Sample

With in-person surveys, there is always the issue of how well the sample represents the population. Two areas were chosen in each city as representative of residents of that city. Randomly selected households were contacted and an adult in the household was asked to participate in a survey about a national policy issue. This recruitment was conducted by phone by a survey research firm. Those surveyed were told that the survey was being conducted by researchers from the University of Colorado, that the survey would take approximately two hours and that they would be paid $50 to participate. The surveying was conducted in hotel conference room in the respondents' area

3100 households were randomly selected. Of these, 908 completed the telephone screener and 45% agreed to attend a survey group. Of the remaining 2200 only 274 refused to complete the screener, the remaining could not be contacted in 6 calls, could not participate because of language or hung upat the beginning of the call. Surveys were completed by 259 individuals (66% of those who agreed to participate).

Those who completed the survey were representative of all those recruited in terms of race and gender but not as representative in terms of age. Young and old people were more likely to be no shows. The demographics of the group completing the survey were also compared to the demographic data for the census tracts in the surveyed areas. The sample has about a 10% higher proportion of whites than does the population. The sample also over-represents those in the 35 – 64 age group. This caused income and education levels to be slightly higher in the sample than in the population. The population statistics can be used to adjust for differences between sample and population WTP.

6. Modeling Preference Heterogeneity

A standard approach to modeling the answers to stated-choice questions is a discrete-choice random-utility model: multinomial logit (MNL), nested-logit or probit. Here we adopt the general MNL framework. Utility, conditional on the choice of a state of nature, is a function of the cost and characterists of that state, which the researcher can observe, and an additive term that is known to the individual, but a random variable from the researcher's perspective. The MNL specification is obtained by assuming the additive component has an Extreme Value distribution. Note that individual is being asked to choose which program he prefers, not what he would do if an alternative was in place.

Heterogeneity of preferences is incorporated into this MNL framework model by allowing variation in the preference parameters (β) across individuals. The "classic" method of doing this allows for variation across individuals by estimating β as a function of observable characteristics of the individuals, for example gender and age; that is, alternative-specific characteristics are interacted with individual characteristics.[10] As a result, it is possible to identify how preferences and willingness-to-pay (WTP) vary by individual characteristics. However, it is unlikely that all heterogeneity in preferences is this systematic. Furthermore, the interaction terms must be determined a priori and the appropriate individual-specific data must be available.

To consider additional heterogeneity, the multinomial logit (MNL) can be generalized to random parameters logit (RPL) allowing the preference parameters on observed variables to vary randomly over individuals (Ben-Akiva and Lerman, 1985) Techniques to simulate probabilities have made it feasible to estimate such models.[11] Applications include Train (1998), Layton and Brown (2000), Revelt and Train (1998), and Brownstone and Train (1999).

The inclusion of random parameters may significantly improve the explanatory power of the model. However, while RPL provides information about the extent of the heterogeneity, it provides no information regarding how preferences vary by individual characteristics. For this reason, the interaction terms can be an important complement to the RPL model. This study demonstrates that, with the data

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[10] Modeling heterogeneity via interaction terms allows preferences to vary across types of individuals, assuming preferences to be constant within types. This can also be achieved through other specifications of preferences, for example, estimating type-specific logit scale parameters, estimating the logit scale parameter as a function of individual characteristics, and estimating type-specific preference parameters.

used here, combining interaction terms with random parameters is superior to either method, random parameters or interaction terms, alone.

7. A Discrete-Choice Random Utility Logit Model with Random Parameters and Interactions Terms

Random parameter logit is a generalization of the standard MNL model. Rather than the parameters being estimated as though they are constant across individuals with the same characteristics, as in MNL, RPL allows parameters to vary across individuals of the same type. Individual *i*'s vector of preference parameters, $\boldsymbol{\beta}_i$, is assumed an independent draw from $N(\boldsymbol{\mu}, \boldsymbol{\Omega})$; that is, $\boldsymbol{\beta}_i$, while deterministic from the individual's perspective, is a vector of random variable from the researcher's perspective.[12] Parameter k for individual i, β_{ik}, can be expressed as the sum of the population mean, μ_k, and an individual deviation, η_{ik}. Thus, the utility associated with alternative j for individual i on choice occasion c is:

$$U_{ijc} = \beta_i' \boldsymbol{x}_{ijc} + \varepsilon_{ijc} = \boldsymbol{\mu}' \boldsymbol{x}_{ijc} + \boldsymbol{\eta}_i' \boldsymbol{x}_{ijc} + \varepsilon_{ijc} \qquad i = 1,2\ldots\mathrm{I} \text{ and } j = 1, 2 \tag{1}$$

where $\mathbf{x}_{ijc}$ is a vector of alternative specific characteristics, some of which may be interacted with individual specific characteristics, ε_{ijc} is assumed a random draw from an extreme value distribution, and $\boldsymbol{\eta} \sim N(\boldsymbol{\mu}, \Omega)$. It is assumed that ε_{ijc} and η_i are independent. For individual i, correlation is induced across choice occasions by the common influence of $\boldsymbol{\eta}_i$.[13]

Conditional on $\boldsymbol{\beta}_i$, the probability of observing the individual i's sequence of pair-wise choices is:

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[11] For example, see McFadden and Ruud (1994). For a discussion of estimation that does not require simulation see Breffle, Morey and Waldman (2001).

[12] Assuming the random parameters are normally distributed is the most common assumption in RPL, but, in principle, one can adopt any distributional assumption. The normal belongs to the class of distributions with positive density between minus and plus infinity, which implies that the sign of the realized parameter can vary across individuals. Whether this is realistic or not depends on the application.

$$P(\boldsymbol{\beta}_i, \mathbf{x}_i) = \prod_{c=1}^{C} \left(\frac{e^{\boldsymbol{\beta}_i' \mathbf{x}_{ikc}}}{e^{\boldsymbol{\beta}_i' \mathbf{x}_{ikc}} + e^{\boldsymbol{\beta}_i' \mathbf{x}_{i(3-k)c}}} \right) \tag{2}$$

where k represents the chosen alternative from the pair of alternatives 1 and 2. Thus, the probability of observing the individuals sequence of pair-wise choices is:

$$P_i = \int_{-\infty}^{+\infty} \cdots \int_{-\infty}^{+\infty} P(\boldsymbol{\beta}, \mathbf{x}_i) N(\boldsymbol{\beta} | \mu, \boldsymbol{\Omega}) d\boldsymbol{\beta} \tag{3}$$

Exact maximum likelihood estimation is not possible since this integral cannot be calculated analytically. P_i is simulated by summing over R random draws from $N(\boldsymbol{\beta}|\boldsymbol{\mu}, \boldsymbol{\Omega})$ using a pseudo-random number generator. The simulated probability is:

$$\mathrm{SP}_i = \frac{1}{\mathrm{R}} \sum_{r=1}^{R} \mathrm{P}(\boldsymbol{\beta}_i^r, \mathbf{x}_i) \tag{4}$$

where $\boldsymbol{\beta}_i^r$ is the $\boldsymbol{\beta}$ from the r$^{\text{th}}$ random draw from $N(\boldsymbol{\beta}|\boldsymbol{\mu}, \boldsymbol{\Omega})$ for individual i. Thus, the simulated log-likelihood function for the RPL is:

$$\mathrm{SL} = \sum_{i=1}^{N} \ln \left[\frac{1}{\mathrm{R}} \sum_{r=1}^{R} \mathrm{P}(\boldsymbol{\beta}_i^r, \mathbf{x}_i) \right]. \tag{5}$$

By construction, SP_i is an unbiased estimate of P_i for any R; its variance decreases as R increases (Lee, 1992; Hajivassiliou and Ruud, 1994; and Brownstone and Train, 1999). For estimation, it is critical that R is sufficiently large to eliminate simulation noise.

Train (1998), and Breffle and Morey (2000) both estimate RPL models of the demand for fishing, both using repeated RP data. Revelt and Train (1998), Layton and Brown (2000), and Brownstone and Train (1999) use RPL models with SP data. Except for Layton and Brown (2000), all of these studies

[13] With RPL, the inclusion of or change to a third alternative affects the ratio of probabilities of choosing two alternatives. This has been interpreted as relaxing IIA. RPL does not, however, relax the more fundamental interpretation of IIA: the assumption that any *ranking* of two alternatives is independent of a third alternative. See Breffle and Morey (2000) for a discussion of this issue.

estimate use values. Our focus group and attitudinal data indicate significant non-use value for monument preservation in Washington, D.C.

8. Model Estimation and Results

8.1. Estimation

Choice data are available for N = 259 individuals, and choices of preservation alternatives for up to ten choice occasions per individual, C_i, yielding a total of 2,568 choices. Conditional indirect utility is a function of the two alternative-specific attributes characterizing alternative *j*: the level of preservation of alternative *j*, ($Preservation_j$), and the amount of money the individual has left to spend on all other goods after choosing preservation alternative *j*, ($Income_i$ - $Price_j$). Classic heterogeneity is introduced by interacting these two site characteristics with *Gender*, *Age*, *Ethnicity* and a dummy variable for *LowIncome*, so includes an income effect.[14] Specifically,

$$\begin{aligned} V_{ijc} = &(\beta_1 + \beta_2\, Gender_i + \beta_3\, LowIncome_i)\,(Income_i - Price_{jc}) \\ &+ (\beta_4 + \beta_5\, Age_i + \beta_6\, Ethnicity_i)\, Preservation_{jc} \\ &+ (\beta_7 + \beta_8\, Age_i + \beta_9\, Ethinicity_i)\, Preservation_{jc}^{\frac{1}{2}} \end{aligned} \tag{6}$$

Note that in this model with only classic heterogeneity, the beta parameters are not random parameters, and so do not vary across individuals. We refer to this model as the *Classic* Model. $Preservation_j$ can take on one of four values: 0 for the status quo, 0.25 for Option A, 0.50 for Option B, and 1.00 for Option C. $Price_j$, the dollar amount associated with preservation alternative *j*, can take on one of nine values: $p = \{0, 0.25, 1.00, 3, 7, 10, 15, 25, 50\}$.[15] The variables $Gender_i$ (1 for female), $LowIncome_i$ (1 if annual household income is less than \$12,000), and $Ethnicity_i$ (1 for non-Caucasian) are binary variables.

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[14] No other individual characteristics were found to be significant.

[15] These amounts were chosen based on pretest findings.

Preferences among individuals of the same type (that is, with the same individual characteristics) may not, however, be identical. Estimating one or more of the parameters as random allows for variation in preferences beyond the systematic differences specified in the Classic Model.

The non-interaction parameters β_4 and β_7 are natural candidates to be random parameters. Estimating β_4 and β_7 as random allows for differences in preferences within age and ethnic groups. Furthermore, it is reasonable to expect that β_4 and β_7 are correlated and thus the correlation between them should be estimated. For the model that combines interaction terms and random parameters, hereafter called the *Combined Model*, it is assumed that β_4 and β_7 are distributed bivariate normal, which admits the possibility that for some individuals increasing preservation levels can decrease utility; that is, preservation is not restricted to be a good. While the attitudinal data from the survey suggest that most people prefer more preservation to less, the data indicate that this may not be the case for all individuals, in particular it may not hold for lower income, non-Caucasians.

For the purposes of generating pseudo random numbers, note that $\boldsymbol{\eta}_i = \mathbf{L}\boldsymbol{\chi}_i$ where $\mathbf{L}$ is a lower-triangle Choleski factor of $\boldsymbol{\Omega}$, such that $\mathbf{LL}' = \Omega$ and $\boldsymbol{\chi}_i$ is a vector of independent standard normal deviates. Assuming that only β_4 and β_7 are random (i.e. all other parameters are fixed) and that they are correlated, all elements of $\mathbf{L}$ are zero except σ_4, σ_7 and $\sigma_{4,7}$.[16]

RPL models to date include few, if any, classic heterogeneity interaction terms. For example, Train (1998) and Layton and Brown (2000) estimate RPL models without any individual characteristics interacted with alternative attributes. and Train (1998) include interaction terms only on the price variable. Brownstone and Train (1999) interact an education dummy and commute distance with two alternative specific variables; and Breffle and Morey (2000) interact age, experience, and club

[16] It should be noted that the zeros in the covariance matrix are not additional restrictions imposed by the RPL specification. The standard logit model assumes implicitly a degenerate distribution for the β's which means that all elements of $\boldsymbol{\Omega}$ are zero (Layton and Brown, 2000).

participation with fishing catch rates. Our inclusion of correlated random parameters on the linear and non-linear specification of *Preservation* allows for differences in the curvature of marginal utility (and, thus, welfare) with respect to *Preservation*.

We estimate the distribution parameters of the random elements of $\boldsymbol{\beta}$ (μ_4, μ_7, σ_4, σ_7, and $\sigma_{4,7}$) and calculate standard errors for elements of $\mathbf{L}$ with the derivative rule (Revelt and Train, 1998). To estimate the model, we used a simulator for RPL in the Gauss programming language that was developed by Train, Revelt and Ruud.[17]

For each parameter vector, SP_i is calculated by taking *R* draws of $\boldsymbol{\beta}_i$, $\boldsymbol{\beta}_i^1,...,\boldsymbol{\beta}_i^r,...\boldsymbol{\beta}_i^R$, calculating SP_i^r for each draw, and then averaging them. The variance of SP_i is non-zero not only because it is a function of random variables, but also because of simulation noise. One approach to gauging the degree of accuracy of the simulator is to test the sensitivity of the WTP estimates to different levels of *R*. The method used here is to estimate the model several times using the same R and starting values, but to vary the seed value used by the pseudo random number generator. With this approach and data set, only when $R = 5{,}000$ do the changes in estimated mean WTP vary by less than 5%. For comparison, at $R = 100$, estimated mean WTP varies by as much as 40%, and at $R = 2{,}500$, estimated mean WTP varies by as much as 11%. The number of draws necessary to achieve an acceptable level of accuracy depends on the data. The sensitivity test used here is similar to a test conducted by Breffle and Morey (2000), who found that estimated mean WTP changed by less than 1% at *R* of 2,500.[18] Aside from Breffle and Morey (2000), none of the other RPL studies referenced in this paper test the sensitivity of estimated parameter values or

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[17] A RPL simulator is available on Train's WWW site: www.elsa.berkeley.edu/~train/. The version on the web page restrict the covariance between the random parameters to be zero. We thank Ken for making their more general code available to us. Rather than using the Gauss add-on MaxLik, their optimization algorithm includes a procedure for calculating the gradients analytically.

[18] Breffle and Morey (2000) used the same seed value and starting values but continually increased R, comparing expected WTP at each increment in R.

estimated mean WTP to *R*, though two others do report the number of draws used: Brownstone and Train (1999) use $R = 250$, and Layton and Brown (2000) use $R = 1000$.[19]

8.2. Goodness of fit

Based on likelihood ratio tests (LRTs), the Combined Model predicts the respondents' stated-choices significantly better than the Classic Model (with no random parameters). The Classic Model predicts significantly better than a model with homogenous preferences, and that model predicts significantly better than a random allocation. Both the interaction terms and random parameters add to the explanatory power of the Combined Model. The pseudo R^2 for the combined model is .51.

Figure 2 provides an illustration of the accuracy of the estimated choice probabilities. Consider first the right-most bar in Figure 2. In 1696, or 66%, of the observed choices, the estimated probability of choosing alternative B is 90% or greater. For 83% of these, the respondent indeed chose alternative B. Now consider the left-most bar in Figure 2. The estimated probability of choosing alternative B was 10% or less (that is, the estimated probability of choosing alternative A was 90% or greater) for only 132, or 5%, of the choices. In 30% of these, alternative B was chosen. Recall that there are 2568 observed choices in the data set. Summing these two bars, in 71% of the observed choices, the model estimated that the probability associated with one of the two alternatives is 90% or greater; that is, for 71% of the observed choices the model is making a strong prediction as to which alternative the individual will choose. For 79% of these, the predicted alternative is the chosen alternative. In contrast, for the 182 choices where the model makes only a weak prediction (neither alternative has a predicted probability greater than 60%), the actual choices split much more evenly: 44% for B and 56% for A.

[19] Brownstone and Train (1999) compare the simulation variance of a GHK probit simulator and a mixed logit simulator. Within this comparison, they test the sensitivity of the log-likelihood function at the estimated parameters with $R = 50$ for the mixed logit simulator, though they do not test the sensitivity of the estimated parameter values nor the welfare estimates to *R*.

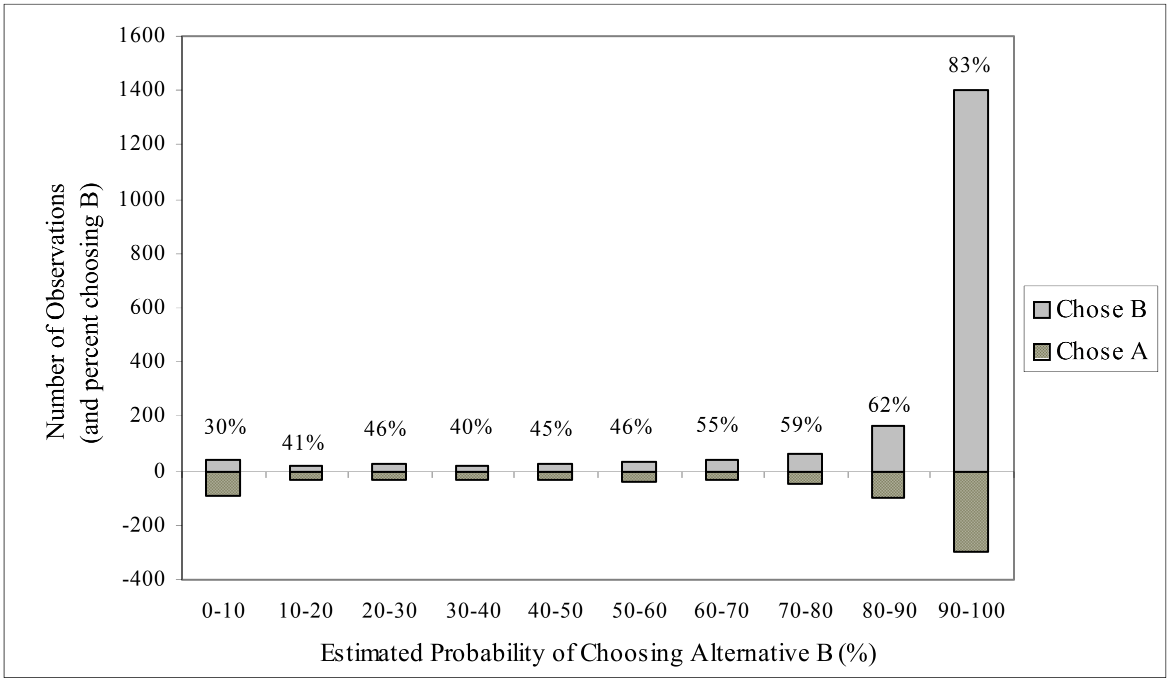

Fig. 2. Comparison of Estimated Probability and Actual Choice

8.3. Parameter Estimates

The parameter estimates are reported in Table I. The estimate of the marginal utility of money, (β_1 + β_2 $Gender_i$ + β_3 $LowIncome_i$), is positive and constant for each respondent and is a step function of income.[20] That is, utility is a spline function of income category and gender. Women have a significantly lower marginal utility of money than do men.

[20] The parameter on $LowIncome_i$ is not significant when β_4 and β_7 are estimated as random. To facilitate the comparison of this model to the same model but with only fixed parameters (the Classic Model) this variable is included. When estimating the Classic Model, β_3 is positive and significant.

TABLE I
Model Parameter Estimates

Variable	Estimate	Standard Error
β_1: (*Income - Price*)	0.141	0.014 **
β_2: (*Income - Price*) * *Gender*	-0.024	0.014 *
β_3: (*Income - Price*) * *LowIncome*	-0.001	0.028
μ_4: *Preservation*	-3.077	2.887
β_5: *Preservation* * *Age*	0.149	0.063 **
β_6: *Preservation* * *Ethnicity*	-3.216	2.100
μ_7: *Preservation*^{½}	9.548	3.073 **
β_8: *Preservation*^{½} * *Age*	-0.014	0.066
β_9: *Preservation*^{½} * *Ethnicity*	-3.737	1.947 *
σ_4^2	90.332	26.766 **
σ_7^2	72.614	22.324 **
$\sigma_{4,7}$	-27.68	12.948 **
$\rho_{4,7}$	-0.34	

* Significant at 10% level of significance
**Significant at 5% level of significance

Evaluated at the estimated mean of the random coefficients ($\hat{\mu}_4$, $\hat{\mu}_7$), the estimated expected marginal utility of the level of preservation, $\hat{\mu}_4 + \hat{\beta}_5\, Age_i + \hat{\beta}_6\, Ethnicity_i + ½\, (\hat{\mu}_7 + \hat{\beta}_8\, Age_i + \hat{\beta}_9\, Ethnicity_i)\, Preservation_j^{-1/2}$, is positive and declining for all respondents over the range of preservation levels considered (*Preservation* = 0 to 1), except for young, non-Caucasian respondents.[21] In general and as expected the estimated parameters are larger in magnitude in the Combined Model than the Classic Model. Revelt and Train (1998) and Brownstone and Train (1999) find the same.[22]

8.4. The estimated distribution of the random parameters

The estimated standard deviations of the random parameters (σ_4 and σ_7) are highly significant, indicating that the parameters do indeed vary in the population, that is, significant heterogeneity exists beyond that captured by the interaction terms. The estimated mean value of β_7, $\hat{\mu}_7$, is positive and

[21] Non-Caucasian respondents under age 27 have an estimated expected marginal utility of preservation for levels greater than 0.6 that is negative.

significantly different than zero. The estimated mean value of β_4, $\hat{\mu}_4$, is negative though not significantly different than zero; that is, β_4 is negative for approximately half of the sample.[23] Even though $\hat{\mu}_4$ is less than zero, the relative signs and magnitudes of the other estimated parameters on *Preservation* and *Preservation* ^{½} ensure that estimated E[WTP] is non-negative for the levels of preservation considered for all individuals. The estimated covariance between β_4 and β_7 is negative and significant; the correlation coefficient is $\rho = \sigma_{4,7} / (\sigma_4 * \sigma_7) = -0.36$.

Estimating random parameters on both the linear and non-linear variable of an attribute allows the curvature of utility (but not expected utility) to vary across individuals of the same type. For example, marginal utility with respect to *Preservation* declines at a slower than average rate for individuals with a smaller than average β_7. The negative covariance indicates that such an individual will have a larger than average β_4 and, thus, a higher level of marginal utility. That is, the higher an individual's marginal utility, the slower its rate of decline. The effect of the negative correlation between β_4 and β_7 on welfare estimates is discussed below.

9. Welfare Estimates

The desired consumer surplus measures are the compensating variations, CVs, associated with changes from the status quo, the level of preservation in the absence of the Title IV reductions in SO_2, to

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[22] In explanation, if there are random parameters but they are not modeled as such, the error term of the Classic Model must incorporate the variances on those random parameters. The result is an "inflated" σ^2_ε; that is, a "deflated" extreme value scale parameter, *s*, where $\sigma^2_\varepsilon = \pi^2 / 6s^2$. Since one estimates β normalized by *s*, this deflation of *s* tends to deflate β, but not necessarily all of its random elements.

[23] Like us, Train (1998) also estimates a random parameter with a significant standard deviation, but cannot reject the null that the mean is zero. His random parameter is on a campground variable suggesting that preferences regarding campgrounds at fishing sites are heterogeneous and the heterogeneity is not just in terms of magnitude but in terms of sign.

states of the world with one of the preservation options.[24] The CV is the amount of money that has to be subtracted from the individual's budget in the new state to make the individual indifferent between the two states with this "compensation" in the new state. Given the reasonable assumption that paying this compensation will not cause any individual to become poor, individual *i*'s CV for a change from the status quo, denoted *0*, to a new state, denoted, *1*, is that amount of money, *c*, that equates

$$(\beta_1 + \beta_2\, Gender_i + \beta_3\, LowIncome_i)\,(Income_i) + (\beta_{4i} + \beta_5\, Age_i + \beta_6\, Ethnicity_i)\, Preservation_0 + (\beta_{7i} + \beta_8\, Age_i + \beta_9\, Ethinicity_i)\, Preservation_0^{1/2} + \varepsilon_0$$

and

$$(\beta_1 + \beta_2\, Gender_i + \beta_3\, LowIncome_i)\,(Income_i - Price_1 - c) + (\beta_{4i} + \beta_5\, Age_i + \beta_6\, Ethnicity_i)\, Preservation_1 + (\beta_{7i} + \beta_8\, Age_i + \beta_9\, Ethinicity_i)\, Preservation_1^{1/2} + \varepsilon_1$$

Since there is only one alternative in each state of the world, and given the standard assumption that the epsilon draw is not state specific, $\varepsilon_1 = \varepsilon_0$, the epsilons drop out of the calculation of the CV. Solving

$$\begin{aligned} CV_i = {} & (1/(\beta_1 + \beta_2\, Gender_i + \beta_3\, LowIncome_i) \\ & \times [\, (\beta_{4i} + \beta_5\, Age_i + \beta_6\, Ethnicity_i)(\, Preservation_1 - Preservation_0\,) \\ & +(\beta_{7i} + \beta_8\, Age_i + \beta_9\, Ethinicity_i)\,(Preservation_1^{1/2} - Preservation_0^{1/2}\,] \end{aligned} \tag{7}$$

However, unobservable randomness remains because β_{4i} and β_{7i} are correlated random variables and so the best we can do as observers is calculate our expectation of the CV.[25]

$$\begin{aligned} E[CV_i\,] = {} & (1/(\beta_1 + \beta_2\, Gender_i + \beta_3\, LowIncome_i) \\ & \times [\, (\,\mu_4 + \beta_5\, Age_i + \beta_6\, Ethnicity_i)(\, Preservation_1 - Preservation_0\,) \\ & +(\,\mu_7 + \beta_8\, Age_i + \beta_9\, Ethinicity_i)\,(Preservation_1^{1/2} - Preservation_0^{1/2}\,] \end{aligned} \tag{8}$$

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[24] Choice studies, such as this one, that ask the individual to choose over different "states" with only one alternative in each state include Adamowicz *et al.* (1996), Roe *et al.* (1996), Johnson and Desvousges (1997), Stevens *et al.* (1997), Layton and Brown (2000) and Swait *et al.* (1998).

[25] When there are random parameters and more than one alternative in each state of the world, $E[CV_i]$ is obtained by simulation over the PDF of β.

Note that $E[CV_i]$ is unaffected by the randomness of β_4 and β_7 but causes the actual CV's for individuals of type *i*, to vary.

The estimate of $E[CV_i]$ is a function of $\hat{\boldsymbol{\mu}}$, a vector consisting of random variables, so that the estimate of $E[CV_i]$ is itself a random variable and its distribution is induced by the sampling distribution of $\hat{\boldsymbol{\mu}}$. To approximate the confidence interval on estimated $E[CV_i]$, its distribution is simulated by taking a large number of random draws from the estimated variance-covariance matrix for $\hat{\boldsymbol{\mu}}$, and calculating $E[CV_i]$ for each draw.[26] Using an order statistic, deleting the top and bottom 2.5% of the distribution forms the 95% confidence interval.[27] This method is also used for approximating the confidence interval on estimated mean E[CV] for the sample.

The estimated mean E[CV] and confidence intervals are shown in Table II. Recall that these are one-time payments for preservation benefits that will be realized many years into the future. The estimated $E[CV_i]$s are positive and significantly so for all individuals except non-Caucasian individuals 27 and younger.

TABLE II
Combined Model Estimated Median and Mean E[CV]
and Confidence Intervals

	Median	Mean	Confidence Interval
Option A	$40.47	$37.53	($29.13 - $47.71)
Option B	$60.44	$56.45	($46.01 - $69.22)
Option C	$93.94	$86.58	($73.40 - $102.49)

In terms of the means of the E[CV], WTP is a function of the scope (level) of preservation.

[26] Note that the applicable variance-covariance matrix is that of $\hat{\boldsymbol{\mu}}$; the elements of $\hat{\mathbf{L}}$ are not relevant.

[27] Throughout this paper, the simulations use a sufficiently large number of draws, *d*, so that the mean E[CV] are not sensitive to *d*. In most of the simulations reported, *d* = 30,000.

10. Heterogeneity

10.1. E[CV] estimates: mean and median

The estimated mean and median E[CV] are shown in Table III for the Combined Model and three restricted models: the Homogeneous Model (no interaction terms, no random parameters), the Classic Model (no random parameters), and the RPL Model (no interaction terms). Compared with the Combined Model, the estimates of mean E[CV] for the restricted models differ by as much as 14% and the estimated median E[CV] differ by as much as 23%, but these differences are not statistically significant. From a policy perspective, these differences are not likely to be consequential. Since the significance of the parameter estimates and the LRTs indicate that the Combined Model is superior to each of the restricted models, our best estimate of mean and median E[CV]'s are the ones from the Combined Model.

TABLE III
Comparison of Estimated Mean and Median E[CV] across Models

	Estimated Mean E[CV]			Estimated Median E[CV]		
	Option A	Option B	Option C	Option A	Option B	Option C
Combined Model	$38	$56	$87	$40	$60	$94
Homogeneous Model	$35	$51	$75	$35	$51	$75
Classic Model	$38	$56	$82	$31	$47	$73
RPL Model	$38	$57	$88	$38	$57	$88

In contrast, Train (1998), Layton and Brown (2000) and Breffle and Morey (2000) also compare welfare estimates derived from models assuming homogeneous preferences and models that specify heterogeneity via random parameters. In each of these studies, significant heterogeneity exists across individuals and the mean welfare estimates differ by as much as 50%. Sometimes the RPL models yield mean welfare estimates that are greater and sometimes less than the homogenous preferences models.

10.2. E[CV] estimates: predicted differences across individuals

Interacting gender, income group, age and ethnicity with preservation level causes estimated $E[CV_i]$ to vary substantially as a function of these individual characteristics. For example, estimated $E[CV_i]$ for Option A varies across individuals from $13 to $54, from $15 to $88 for Option B, and from $14 to $145 for Option C.

Women are willing to pay, on average, 21% more for preservation men. This finding is supported by the attitudinal survey data showing that female respondents believe that the monuments are more important than do male respondents and, thus, are willing to pay more for preserving them. Older respondents are willing to pay more for preservation than are younger respondents. This finding is not suggested by the attitudinal data: there were no systematic differences by age to the attitudinal questions. Generally, for the changes in preservation encompassed in the survey, for each one year increase in age, E[CV] increases by up to $1.17 and up to 6%. The increase is greater in dollar and percentage terms at higher levels of preservation.

A substantial difference is observed in E[CV] between Caucasians and non-Caucasians. This is consistent with the attitudinal data: across almost all attitudinal questions, the answers of non-Caucasians indicate that the existence and condition of the monuments is less important to them. Depending on the age and income level of the individual, a representative non-Caucasian's E[CV] ranges from 24% to 60% of that of a Caucasian. The difference is most dramatic for young, non-Caucasian respondents, especially for greater amounts of preservation.

Estimated E[CV] does not depend on whether the household is poor. This surprised us, in particular because the E[CV] is a function of whether the household is poor in the model that includes classic heterogeneity but no random parameters. Interestingly, the attitudinal data indicated that respondents with lower incomes believe that the monuments are more important than do other respondents. Possibly their higher level of concern is being offset by their decreased ability to pay.

Combining random parameters with the interaction terms provides additional information about the extent of heterogeneity but provides limited (additional) information about the nature of the heterogeneity. Indeed, a model with random parameters and no interaction terms provides no information about how preferences or WTP vary by individual characteristics nor even which individuals have high or low estimated WTP. This limitation of the RPL provides a strong argument for the inclusion of interaction terms in RPL models.

10.3. Covariance

While adding random parameters does not yield any additional variation in E[CV_i], it does increase the variation in CV_i across individuals. Estimating the correlation of the random parameters (on *Preservation* and *Preservation*^{½}) allows for differences in the curvature of CV_i with respect to level of preservation across individuals of the same type. The negative correlation between β_4 and β_7 indicates that relative to other individuals of the same type, individuals with a higher marginal CV_i have a more linear than average CV_i function. Note that the slope of the marginal CV_i with respect to *Preservation* is a function of β_7 but not β_4. Given the negative covariance, an individual with a lower than average β_7 will have a relatively flat CV_i function, a larger than average β_4, and thus higher marginal CV_i. Figure 3 is an illustration for individuals who are 45 years old, Caucasian, non-low-income, and male. WTP estimates are compared for three different values of β_4 ($\hat{\mu}_4 + 1.96\hat{\sigma}_4$, $\hat{\mu}_4$, and $\hat{\mu}_4 - 1.96\hat{\sigma}_4$), each combined with the expectation of β_7 conditional on β_4.[28]

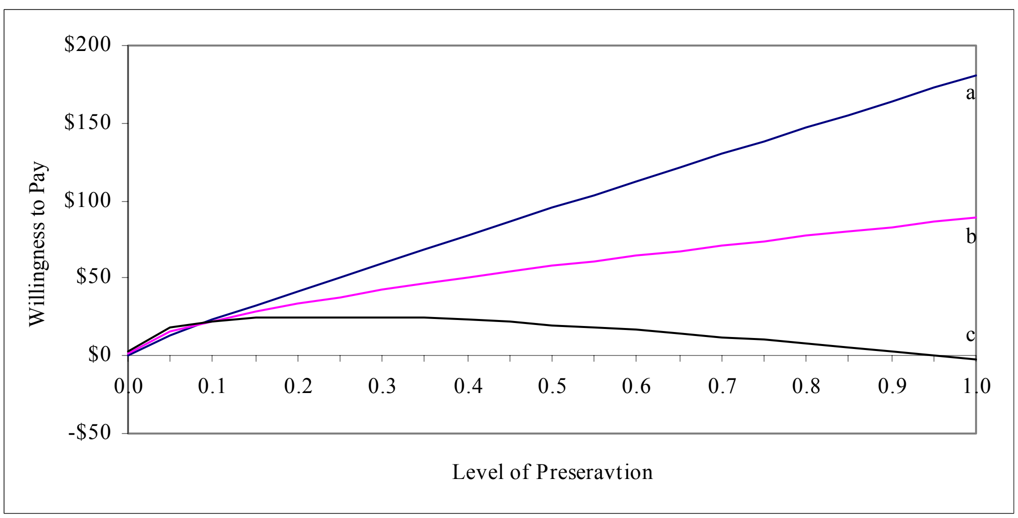

Fig. 3. Estimated WTP for different values of β_4 and E[β_7| β_4]

[28] This function is a "pseudo-CV" function, in that except for β_4 and β_7 (as indicated above) the expected values of all of parameters are used.

This figure illustrates that for individuals of the same type, all are willing to pay roughly the same amount for small amounts of preservation (*Preservation* <= .2). For some individuals, additional preservation is of limited value (e.g. individual c). For others, marginal WTP persists across higher levels of preservation. The change in utility and WTP—not just the level—can vary across individuals of the same type.[29] In contrast, the assumption of zero covariance holds the slope of the marginal CV_i constant across individuals of the same type.

11. Summary

This paper reports the methods and results of a study designed to value the reduction in acid-deposition injuries to Marble monuments in Washington, D.C. as a result of Title IV of the Clean Air Amendments. The emphasis is on modeling and estimating preference heterogeneity in WTP to preserve these monuments.

Repeated choice questions are used to elicit preferences for different levels of preservation. Their use in this context seems necessary and is defensible.

Two methods of incorporating preference heterogeneity into discrete-choice random-utility models are combined: random parameters and interacting alternative attributes with characteristics of the individual. The Model that includes both types explains choices significantly better than models that include only one type or no heterogeneity. Results suggest that individuals in the target population have significant WTP for the preservation of these monuments but this WTP varies greatly as a function of gender, age, race and whether the individual is poor. However, even after these systematic variations in preferences are accounted for much random variation remains.

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[29] For comparison, Layton and Brown (2000) allow for correlation across the influence of three elevation change variables and find that the correlation is positive: individuals who dislike forest loss of 600 feet more than average, also dislike forest loss of 1200 feet more than average. *CV* is linear in elevation and thus curvature of the *CV* is not relevant. Revelt and Train (1998) also estimate the correlation between random parameters, though these parameters are on distinctly different attribute variables (as opposed to different specifications of the same attribute). Again, covariance does not effect the curvature of the *CV* function across individuals, only the level.

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