5-2007

Choice Experiments: Application to Air Quality Policy Options and Investigation of Method's Incentive Compatibility

Jill Phillips Collins
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a dissertation written by Jill Phillips Collins entitled "Choice Experiments: Application to Air Quality Policy Options and Investigation of Method's Incentive Compatibility." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.

Michael McKee, Major Professor

We have read this dissertation and recommend its acceptance:

Christian A. Vossler, Mary F. Evans, Matthew Murray, Donald G. Hodges

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a dissertation written by Jill Phillips Collins entitled "Choice Experiments: Application to Air Quality Policy Options and Investigation of Method's Incentive Compatibility." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.

_______Michael McKee_______
Michael McKee, Major Professor

We have read this dissertation
and recommend its acceptance:

____Christian A. Vossler________

____Mary F. Evans__ _ __________

____Matthew Murray___________

____Donald G. Hodges__________

Accepted for the Council:

___________Carolyn R/ Hodges____________
Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

Choice Experiments: Application to Air Quality Policy Options and Investigation of Method's Incentive Compatibility

A Dissertation Presented For The Doctor Of Philosophy Degree
The University Of Tennessee, Knoxville

Jill Phillips Collins
May 2007

DEDICATION

This dissertation is dedicated to my incredibly supportive husband, Bill, and to our beautiful daughter, Chloe, who managed to give Mommy some well-timed naps for her to complete this research.

ACKNOWLEDGMENTS

Funding for this research was provided by the University of Tennessee's J. Fred Holly Distinguished Chair in Economics and the Institute for a Secure and Sustainable Environment.

I would like to thank all who served on my dissertation committee for their guidance and insight into nonmarket valuation. I would also like to thank Daniel Hellerstein, Jeff Smith, Aaron Wells, Zach Richards and Stephen Cotten for their research assistance. Special thanks go to my parents, Jim and Julie Phillips, and the rest of my family for their boundless support and encouragement.

ABSTRACT

More than half of all Americans live in areas that violate at least one of the U.S. Environmental Protection Agency's air quality standards for ground-level ozone and fine particulate matter. The majority of these areas have many options to come into compliance with the standards, such as requiring vehicle inspection/maintenance programs, changing gasoline blends, and requiring additional controls on power plants. Chapter 1 explores the use of conjoint-based choice experiments to assist local policymakers in determining the most beneficial policy strategy using the case study of Knoxville, Tennessee. Given that different policy actions pass costs onto households in different ways and that households may have varying preferences regarding how they pay those costs, I test whether willingness to pay for air quality improvements is sensitive to the method of payment. Potential heterogeneity of preferences is modeled through a mixed logit specification. Results indicate positive willingness to pay among Knoxville area residents for improvements in air quality, with vehicle inspection and an increase in the price of gasoline as the preferred payment vehicles over an increase in the electricity bill.

Chapter 2 investigates the underlying incentive compatibility of choice experiments with tests of the mechanism in an induced value laboratory setting. The theoretical properties of both dichotomous choice and trichotomous choice elicitation formats are explored under plurality voting rules and more generally under the assumption that the respondent perceives her decision to have some influence on the outcome. Results indicate that certain belief structures can lead to incentive compatible outcomes in a trichotomous choice format, depending on how a respondent believes the agency will incorporate respondent decisions into the provision of a public good. In addition, the trichotomous choice treatments had fewer deviations from theory and were less subject to status quo bias than treatments with dichotomous choice questions. Implications for the design of choice experiments and contingent valuation surveys are discussed.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 1: VALUING AIR QUALITY POLICY OPTIONS FOR THE KNOXVILLE METROPOLITAN AREA

1.1 Introduction

More than half of all Americans live in areas where air pollution violates the standards put forth by the U.S. Environmental Protection Agency (EPA).[1] The two most pervasive ambient air pollutants are ground-level ozone and fine particulate matter, which are linked to increased incidences of respiratory and cardiopulmonary disease. While the federal government has taken some actions that will mitigate pollution problems nationwide, local policymakers in areas characterized by higher levels of pollution must also take incremental actions to ensure compliance with federal laws governing air quality.

In many areas of the country, policymakers have a great degree of flexibility in choosing emission reduction measures. In areas where several options to meet air quality standards are available, a decision must be made as to which measure, or combination of measures, would achieve air quality standards. A mechanism particularly suited to informing the policy choice from the menu of options is the stated-choice method of choice experiments (CE). Based on conjoint analysis, this method has been used to value environmental amenities since the 1990s, but has been used extensively in the marketing and transportation literature to derive relative values of a good's constituent attributes (hence the name conjoint, for "considered jointly").

[1] U.S. EPA Greenbook of Nonattainment Areas

The conjoint approach was used to estimate the willingness to pay of households in the Knoxville, Tennessee area for improved air quality. Surveys were collected from over 400 individuals representing households in this area to provide the data needed to generate estimates of willingness to pay for air quality improvements. Due to a combination of topographic conditions, proximity to coal-fired power plants, an increase in population and vehicle miles traveled, and the convergence of major trucking routes (I-75, I-40, and I-81), the Knoxville area[2] was found to be in violation with both the ozone and fine particulate matter standards in 2004.

The results of this study demonstrate how choice experiments can assess potential welfare impacts to households from various policy options to reduce both ozone and fine particulate matter emissions and, thus, inform the policy debate. Because the Knoxville area is considered by the EPA to be a basic nonattainment area, it has more flexibility in determining which actions to undertake to meet EPA standards.[3] Myriad combinations of policy actions can be utilized to meet the air quality standards, each having differing impacts on households in terms of cost, method of payment, and effect on health and visibility of scenic views. An important input to the policy process is an increased understanding of the value households place on different policy attributes and the welfare change associated with a particular policy strategy. Candidate models for analyzing the survey data include multinomial logit, nested logit, and mixed logit. The preferred model

[2] The Knoxville area designated nonattainment for ozone consists of counties belonging to its MSA (Anderson, Blount, Knox, Loudon, and Sevier), as well as neighboring Jefferson County and Cocke County (partial). Anderson, Blount, Knox, Loudon, and Roane (partial) counties were designated nonattainment for particulate matter.

[3] Basic nonattainment areas are those areas that are in violation of the 8-hour ozone standard but are in attainment with the previous 1-hour ozone standard of 0.12 ppm. Fewer prescriptive actions are required of these areas than those areas with more severe pollution problems.

is mixed logit, which provides a greater degree of behavioral realism for discrete choice data with its flexibility in modeling substitution patterns across alternatives and its ability to account for multiple choice situations for each respondent.[4] The survey design and analysis also permit consideration of an important methodological question – does the method of payment for air quality benefits affect willingness to pay?

The analysis indicates that households would be willing to pay for visibility and health improvements, with magnitudes depending on the method of payment (i.e., whether it is through a mandatory inspection and maintenance program for vehicles, an increase in the monthly electricity bill, or an increase in the price of gasoline).

1.2 Air Quality Policy

Under the Clean Air Act, states must achieve attainment of National Ambient Air Quality Standards (NAAQS) for six criteria pollutants – sulfur dioxide (SO_2), nitrogen oxide (NO), lead (PB), carbon monoxide (CO), coarse and fine particulate matter (PM_{10} and $PM_{2.5}$), and ground-level ozone (O_3). The EPA sets primary standards to protect public health and secondary standards to protect public welfare, which includes impairment of scenic views and damage to animals, crops, vegetation, and buildings. To assess compliance, the EPA requires states to monitor emissions and compares reported emissions with the pollutant's allowable concentration. If an area fails to meet pollutant standards, the state must develop within three years a separate State Implementation Plan

[4] The assumption of the independence of irrelevant alternatives implicit in the multinomial logit model was violated in this application.

(SIP) for each pollutant detailing how the state intends to come into attainment. An area that is deemed "nonattainment" with EPA standards potentially faces economic penalties in the form of costly emission controls, emission offsets from new polluting sources, conformity of the area's transportation plan to its SIP, and the potential loss of highway funds. The degree of these economic penalties depends on the severity of nonattainment.[5]

Standards for ground-level ozone and fine particulate matter were revised in 1997 due to new scientific research indicating that previous standards were not sufficient to protect public health.[6] Industry-led litigation delayed implementation of the new standards until the Supreme Court upheld EPA's authority in 2002. Cleared of legal hurdles, the EPA made attainment designations for ozone and fine particulate matter in 2004. A total of 474 counties with 159 million people were found to be in nonattainment

---

[5] If the state fails to submit or implement a SIP, or the EPA deems the SIP inadequate, a "sanctions clock" is set to prompt the state to remedy its deficiencies. If the SIP has not been corrected within 18 months, the EPA may impose offset requirements for new emission sources and existing sources undergoing modification that mandate up to 2:1 emission reductions. If the state has still not submitted an adequate SIP within six months of the offset requirements, federal highway funds could be revoked unless the funds are used for projects that improve air quality or safety. An area could also lose its highway funds if metropolitan planning officials create a Transportation Improvement Plan (TIP) that does not conform to the air quality State Implementation Plan. Finally, if an area continues to fail to meet its SIP obligations, the EPA can create its own implementation plan for the area, called a Federal Implementation Plan (FIP).

[6] In July 1997, EPA promulgated the National Ambient Air Quality Standards for Fine Particles ($PM_{2.5}$) and for Ground-level Ozone (O_3) (USEPA, 1997a and 1997b). The revised particulate matter standards added a standard for fine particles ($PM_{2.5}$) and strengthened the standard for coarse particles (PM_{10}). The annual fine particle standard is a level of 15 micrograms per cubic meter, based on the 3-year average of annual mean $PM_{2.5}$ concentrations. The 24-hour fine particle standard is a level of 65 micrograms per cubic meter, based on the 3-year average of the 98th percentile of 24-hour concentrations. The annual coarse particle standard is a level of 50 micrograms per cubic meter, based on the 3-year average of annual mean PM_{10} concentrations. The 24-hour coarse particle standard is a level of 150 micrograms per cubic meter, not to be exceeded more than once per year. The 8-hour ozone standard is a level of 0.08 parts per million (ppm), based on the 3-year average of the 4th highest concentration averaged over an 8-hour period. The previous ozone standard was 0.125 ppm averaged over one hour, based on the 4th highest concentration during a 3-year period.

with ozone, and 224 counties with 95 million people were found to be in nonattainment with particulate matter (see Figure 1.1).

The EPA classifies ozone nonattainment areas by the degree of violation of the standard. The classifications (basic, marginal, moderate, serious, severe and extreme) specify how much flexibility an area has in devising measures to attain the standard, as well as the length of time it is allowed to come into attainment. Of areas in ozone nonattainment, 172 counties with approximately 43 million people are considered "basic" while an additional 80 counties with 21.5 million people live in areas that are considered "marginal." General requirements of basic and marginal areas include reasonably available control technologies (RACT) applied to existing sources emitting more than 100 tons per year of ozone precursors and reasonable further progress towards attainment, all to be detailed in the SIP. Other requirements to ensure that sources do not worsen air quality or interfere with meeting air quality standards include transportation conformity, new source review permitting procedures, and emission offsets. These areas also have a relatively short time span to reach attainment (generally two years upon submission of the SIP). Areas in more severe violation of the ozone standard may have specific measures prescribed for them by the EPA such as a vehicle inspection and maintenance program, reformulated gasoline, stricter emission offsets, vapor controls at gasoline stations, and more emission sources subject to RACT (USEPA, 1997b). The proposed implementation rule for fine particulate matter indicates that the EPA would prefer not to have a classification system for this pollutant, but rather allow areas flexibility to meet the standard in a similar fashion as to what is required for basic and marginal ozone nonattainment areas (USEPA, 2005).

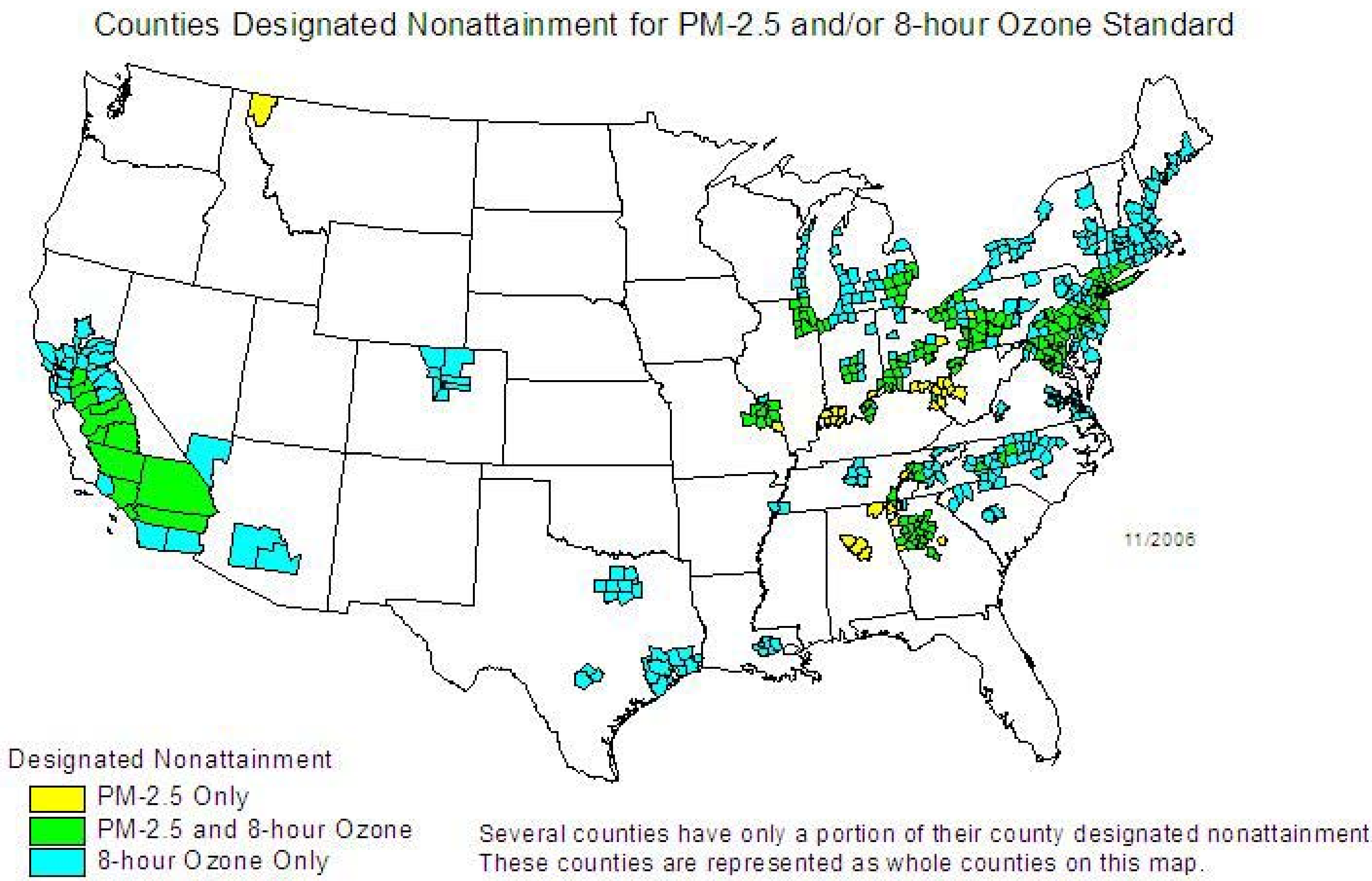


Figure 1.1: Nonattainment Counties
Source: EPA Greenbook of Nonattainment Areas

1.2.1 Health Effects of Ground-level Ozone and Fine Particulate Matter

Ground-level ozone is formed when nitrogen oxides (NO_x) and volatile organic compounds (VOCs) react in the presence of sunlight, with higher levels typically occurring between May and October. Nitrogen oxides are emitted from motor vehicles, power plants, industrial boilers, cement kilns and other sources of combustion (e.g., construction, aircraft, farming, and recreation equipment), and can be transported hundreds of miles by prevailing winds. Volatile organic compounds such as hydrocarbons occur naturally and are also emitted from motor vehicles, chemical plants, refineries, factories, consumer and commercial products, and industrial sources. Ozone acts as a respiratory irritant, with short-term exposure leading to wheezing and coughing, shortness of breath, and chest pain (USEPA, 1999). Long-term exposure has been linked with reduced lung function, inflammation of the lung lining and increased respiratory discomfort (Kunzli et al, 1997). Populations most susceptible to the effects of ozone are children, the elderly, those who have compromised immune systems, and those who spend a lot of time working or exercising outdoors (Desqueyroux et al, 2002; Hoppe et al, 2003; Deflino et al, 1998, Kinney and Lippmann, 2000; Peters et al, 1999; Thurston et al, 1997).

Fine particles less than 2.5 microns in diameter ($PM_{2.5}$) result from fuel combustion from motor vehicles, power generation, and industrial facilities, as well as from residential fireplaces and wood stoves. Coarse particles (PM_{10}) are generally emitted from vehicles traveling on unpaved roads, materials handling, crushing and grinding operations, and windblown dust. Particles can be emitted directly or can be secondarily formed by atmospheric processes that chemically transform gases to sulfates and nitrates. Haze-producing sulfate particles, formed by the chemical reaction of sulfur dioxide (SO_2) in the atmosphere, account for 50 to 70 percent of the visibility reduction in the eastern part of the United States (USEPA, 2007). Major sources of particulate matter include SO_2 emissions from power plants and diesel exhaust. Exposure to coarse particles is primarily associated with the aggravation of respiratory conditions, such as asthma (USEPA, 2000). Fine particles are most closely associated with such health effects as increased hospital admissions and emergency room visits for heart and lung disease, increased respiratory symptoms and disease, decreased lung function, and premature death (Krewski et al, 2000; Pope et al, 2002). As with ozone pollution, prevailing winds can transport fine particle pollution hundreds of miles (coarse particles tend to fall relatively close to the emission source). Populations at risk include the elderly, individuals with pre-existing conditions such as cardiopulmonary disease, and children (USEPA, 1997a).

1.2.2 Case Study: Knoxville, Tennessee

As noted above, a convergence of factors contributes to Knoxville's violation of air quality standards. The three primary culprits are proximity to coal-fired power plants operated by the Tennessee Valley Authority, three heavily used interstate highways passing through the area (I-40, I-75 and I-81), and the bowl-shaped topography of the area that concentrates and traps air pollutants. Knoxville is surrounded by the Cumberland Plateau and the Great Smoky Mountains National Park (GSMNP), which was named the most polluted national park in 2002 (National Parks Conservation Association, 2004). According to the National Park Service, annual average visibility at

GSMNP is 25 miles, compared to natural conditions of 93 miles. During severe haze episodes, visibility has been reduced to less than one mile (National Parks Service, 2001).

Knox County was first deemed nonattainment for ground-level ozone following the 1990 Clean Air Act Amendments.[7] Arguing that no violations of the standard occurred between 1989 and 1991, Knox County successfully petitioned the EPA to re-designate it in attainment with air quality standards, and became a "maintenance area" in 1991.[8] Upon notification that the entire metropolitan area plus neighboring Jefferson County was in danger of violating the new 8-hour ozone standard in 2002, the Knoxville area voluntarily agreed to sign an Early Action Compact (EAC) with the EPA to reduce emissions earlier than would be required after nonattainment designations were made in 2004. The EPA offered these compacts to areas that were in attainment with the old one-hour ozone standard, but were projected to violate the new, stricter 8-hour standard. In return for earlier emission reductions, the area could avoid nonattainment status and its attendant penalties. Local officials submitted the required Air Quality Improvement Plan to the EPA in March 2004, which proposed such emission reduction actions as a lower speed limit on rural interstates, truck stop electrification, cetane additives to diesel fuel, and a ban on open burning. Of about 30 EAC submissions nationwide, the EPA only rejected three areas as insufficient: Knoxville, Chattanooga, and Memphis (all Tennessee

---

[7] The ozone standard in 1990 was 0.120 ppm, averaged over one-hour, with violations occurring if the 4th highest concentration over the previous three year period exceeded this value.

[8] Requirements of maintenance areas include a prevention of significant deterioration permitting program and contingency measures to ensure compliance with the ozone standard for at least ten years following re-designation to attainment. Elements of Knox County's maintenance plan included modeling emissions growth, requiring fuel with reid vapor pressure of 9.0 pounds per square inch, and installing RACT on major sources of emissions.

areas), subjecting them to full nonattainment status.[9]

The Knoxville area officially became a nonattainment area for ozone and fine particulate matter in June 2004 and December 2004, respectively. The area was given two years to create the state implementation plans detailing how it will achieve attainment, and is required to meet the ozone and fine particulate matter standards by 2009 and 2010, respectively. The choice experiment application to this area demonstrates how this method can benefit policymakers by estimating the relative public support, in terms of willingness to pay, for various emission reduction measures and payment vehicles.

1.3 Methodology

1.3.1 Valuing Nonmarket Goods

Environmental economists attempt to estimate both use and non-use values for environmental goods and services that are not priced in the marketplace. Use values arise from directly consuming the environmental good, such as rock-climbing in a national park or enjoying scenic views. Non-use values do not stem from current use of the good, but are rather derived from having the option to use the good in the future ("option value"), to allow future generations to consume the good ("bequest value"), or to know that the environmental good exists ("existence value"). An example of existence value is the utility that an individual derives from knowing that the Arctic National Wildlife

[9] Chattanooga subsequently revised its early action plan to include vehicle inspection/maintenance, and was allowed to remain an EAC.

Refuge is preserved, even if that individual never intends to visit the refuge personally. Stated preference methods are survey-based methods used to estimate willingness to pay for an environmental improvement, and can estimate both use and non-use values. The most common type of stated preference method to value environmental amenities is contingent valuation (CV), where respondents are given information regarding a proposed improvement to the good and asked a question to gauge willingness to pay to realize this change. Willingness to pay can be expressed by a variety of payment vehicles, such as an increase in income taxes, a one-time charge, a user tax, an increase in the price of a particular good, etc. The payment elicitation mechanism can also vary. Initial applications of the method asked open-ended willingness to pay (e.g., "How much would you be willing to pay to provide this hiking trail?"), while more recent applications typically ask a dichotomous choice question (e.g., "Would you be willing to pay $x to provide this hiking trail? Please circle yes or no.") The first contingent valuation study was conducted by Davis (1963) to estimate the value of big game hunting in Maine. After a study of the Four Corners region in 1974 by Randall, Ives, and Eastman, CV was recognized as providing a measure of Hicksian surplus arising from the provision of public goods.[10]

Because stated preference methods utilize hypothetical markets where payment may not actually take place, the analyst must bear in mind several potential types of biases that could arise, and take the appropriate steps to correct for them. Respondents, knowing that their answers could influence policy, may not provide their true willingness

[10] Use of the CV method for policy analysis was affirmed by Federal Court in State of Ohio v. U.S. Department of the Interior, 880 F. 2nd, 474.

to pay for a public good when payment is not required. Other sorts of biases that may drive a wedge between actual and stated willingness to pay include interviewer bias (if the study is conducted face-to-face), yea-saying (the respondent feels compelled to provide the response he or she feels is "correct"), embedding/scope effects (the respondent's willingness to pay is invariant to different quantities of the good), or hypothetical bias (knowing that the exercise is only a survey, the respondent may not take the task seriously). Because the respondent is not actually observed making the payment in the marketplace to obtain the good, doubts have been cast regarding this method's validity in obtaining unbiased estimates of willingness to pay (Diamond and Hausman, 1994). Numerous refinements of the CV method have continued over the past 30 years to improve its reliability as a valid means of measuring welfare by improving survey design and implementation (Mitchell and Carson, 1989). General conclusions are that respondents should be cognizant of the relevant attributes of the good, the proposed change in the good (including details of the status quo), what exactly they are asked to value, the acceptability of giving a 'no' response, how the change in provision of the good will be achieved in a plausible manner, the degree of certainty regarding both the changed scenario and the status quo, and the distribution of the good (Hanemann, 1994).

CV began to be used in the legal arena as the basis of natural resource damage claims under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, and was most famously used to assess non-use damages arising from the Exxon Valdez oil spill in 1989 (Ward and Duffield, 1992). The National Oceanic and Atmospheric Administration (NOAA) commissioned a blue ribbon panel to evaluate the credibility of using CV to estimate nonuse values in 1993, and provided specific recommendations to improve its reliability such as the use of dichotomous choice as the elicitation mechanism (NOAA 1993). The general consensus of the literature is that stated preference methods should not be considered unreliable simply because they are based on a hypothetical market, but that reliability is a function of survey design and implementation. Furthermore, if one believes non-use values should be relevant to policymaking decisions, stated preference methods provide the only means of capturing them. Further discussion of the incentive compatibility of stated preference methods will be presented in Chapter 2 of this dissertation.

1.3.2 Choice Experiments

In the 1990s environmental economists began exploring choice experiments as an alternative to contingent valuation in valuing environmental amenities. Choice experiments are based on the assumption that individuals derive utility not from a good itself, but from its constituent attributes (Lancaster, 1966). For example, an individual does not derive utility from a car per se, but from its color, fuel economy, seat material, power, design, price, etc. The technique, developed by Louviere and Hensher (1982) and Louviere and Woodworth (1983), consists of presenting respondents with a choice set of options comprised of attributes with varying levels, and elicits the most preferred option from the choice set. In this way choice experiments are similar to real world purchase decisions where consumers are presented with a variety of goods characterized by different attribute levels and choose whatever gives them the most satisfaction. To identify relative attribute values several questions are asked per application. This method has been used extensively in the marketing and transportation literature to derive the relative values of a good's constituent attributes. Environmental applications of this technique include the valuation of rivers (Morrison and Bennett, 2004), global warming mitigation options (Layton and Brown, 2000), remnant vegetation (Blamey et al, 2000), water supply options (Blamey et al, 1999), polluted beaches and rivers (Garrod and Willis, 1999), caribou habitat (Adamowicz et al, 1998), and freshwater recreation (Adamowicz et al, 1994). Like contingent valuation, this method can estimate use as well as non-use values.

Choice experiments are based on random utility theory (Luce, 1959 and McFadden, 1973), where the utility derived by individual *n* from option *j*, denoted U_{nj} below, is posited to have a deterministic component V_{nj} that can be explained by the analyst and an unobservable, stochastic component, e_{nj}:

$$U_{nj} = V_{nj} + e_{nj}$$

Unlike conventional demand theory, an assumption must be made about the distribution of the error term e in order to make predictions from the theory (Bateman et al, 2002). According to random utility theory, an individual, when faced with alternative options, will choose that option that gives the highest level of utility. The error term captures the analyst's uncertainty about an individual's utility function.

The probability that option *j* will be selected by individual n from his available choice set can be modeled as the probability that the difference between the systematic components of utility between choice j and any alternative l in the choice set is greater than the difference between the random components:

$\Pr[(V_{nj} + e_{nj}) > (V_{nl} + e_{nl})] = \Pr[(V_{nj} - V_{nl}) > (e_{nj} - e_{nl})]$. A common practice has been to assume that the errors are independently and identically distributed (iid) extreme value. This assumption results in the conditional logit specification that requires the independence of irrelevant alternatives (IIA). The IIA property implies that the addition or change of an alternative does not change the relative probability of selection between any other alternatives. Substitution between alternatives is subsequently restricted to proportionate shifting, which is often not consistent with expectations.[11] If IIA does not hold, parameter estimates are biased. Methods to address IIA include adding socioeconomic and attitudinal variables to the model (Bennett et al, 2001a) or by analyzing choice data with the more general nested logit and mixed logit models.

In a typical choice experiment application, the analyst creates choice sets of options that differ by the levels of their constituent attributes. For example, if each choice set consisted of three options where each option *i* is described by a vector of attributes X_i, the explained portion of utility for each option could be modeled as:

Option 1: $V_1 = ASC_1 + \beta' X_1$

Option 2: $V_2 = ASC_2 + \beta' X_2$

Option 3 (baseline): $V_3 = \beta' X_3$

ASC_1 and ASC_2 are alternative specific constants for the options other than the constant baseline (Option 3), and serve to capture systematic but unobserved information

[11] Consider the classic "red bus, blue bus" example: Suppose an individual can either drive a car to work or take a red bus, and derives equal utility from either option so that the probability of either transportation mode is ½. Now assume that a blue bus service is offered, which is exactly the same as the red bus except for its color. The probability that the individual will take the red bus will therefore be the same as taking the blue bus. Because the multinomial logit model requires that the relative probability between driving a car and taking the red bus remain the same, the model predicts that the probability of each mode becomes 1/3. However, we would expect that the addition of the blue bus would not affect the probability of taking the car, and would simply split the probability of taking the red bus: prob(car) = ½ and prob (red bus) = prob (blue bus) = ¼.

regarding the choice of a particular option. Whether the alternative specific constants should be estimated separately for each option is an empirical question. Bennett et al (2001a) suggest that if the options are labeled across the choice sets (for example, by the overall policy effect of the bundle of attributes), ASC_1 and ASC_2 should be estimated separately. If, on the other hand, options are generic and do not signal any information about the alternative (e.g., simply labeled "Option 1" and "Option 2"), then the ASCs could be constrained to be equal. Socioeconomic and attitudinal variables can also be included in these equations, but only as interactions with either the ASCs or the attributes since they do not vary across options in a choice set. An advantage of choice experiments is the degree of experimental control held by the analyst in determining the range of attribute levels, which may or may not be currently experienced.

Marginal rates of substitution can be calculated for any two attributes by dividing their respective coefficients: $MRS_{mk} = -\frac{\beta_m}{\beta_k}$. If β_k is the coefficient of the payment variable, this calculation provides an estimate of the marginal willingness to pay for the attribute.[12]

If one option is held constant over all choice sets, welfare measures can be calculated from the baseline (typically the status quo) to any state that can be created from the range of levels employed in the model. Consequently, CE allows ranking of different alternatives, which assists policymakers by providing estimates of public support over competing options. The typical welfare measure calculated from a choice experiment application is compensating surplus, which defines how much money must be

[12] In the discrete choice literature marginal willingness to pay is also referred to as the "implicit price" of an attribute.

taken away from an individual after receiving an environmental improvement to make him as well off as before the change in environmental quality. Compensating surplus is therefore a measure of total willingness to pay for improvements in environmental quality (e.g., an increase in the visibility of scenic vistas). Hanemann (1984) calculated compensating surplus as:

$$\text{CS} = \frac{1}{-\beta_{payment}}\left[\ln\left(\sum_{j=1}^{J^0} e^{V_j^0}\right) - \ln\left(\sum_{j=1}^{J^1} e^{V_j^1}\right)\right]$$

where V^0 represents utility associated before the change in option(s) j, V^1 represents utility associated after the change in attribute levels, and $\beta_{payment}$ is the coefficient of the payment variable. J^0 and J^1 represent the number of options before and after the change, respectively. If welfare is being calculated from one state of the world to another, the formula reduces to:

$$\text{CS} = \frac{V^0 - V^1}{-\beta_{payment}}$$

The negative of the payment coefficient represents the marginal utility of income since it provides how much utility is increased when the cost of an option decreases by one dollar. In order to apply this formula for willingness to pay, marginal utility of income must be held constant. While this is clearly an unrealistic assumption for all income levels, it may be reasonable over the range of policy outcomes.

Relatively few studies have been conducted to test if choice experiments can result in respondents revealing their true preferences. Concern has been raised over the validity of this method because it does not contain an explicit provision rule (nor is one easily inferred) that maps how respondent choices will influence the policy outcome (e.g., a majority-rule referendum) and requires respondents to answer multiple questions where they choose one option from three or more alternatives. It is well known that any mechanism other than a binary response cannot be incentive compatible without restricting agent preferences (Gibbard, 1973 and Satterthwaite, 1975). Chapter 2 of the dissertation examines different preference structures under which the method can provide incentive compatible outcomes.

Most studies examining the incentive properties of choice experiments look for evidence of hypothetical bias where perceived response incentives may deviate from those in an analogous situation with direct financial implications.[13] Carlsson and Martinsson (2001) test for hypothetical bias using donations for environmental projects, and find no differences between actual and hypothetical marginal willingness to pay. Lusk and Schroeder (2004) find that hypothetical choices overestimate total willingness to pay for a private good, beef steaks, but that marginal willingness to pay for a change in steak quality is generally not significantly different across hypothetical and actual settings. Carlsson et al (2006) find that the estimated marginal willingness to pay for food is significantly lower when a cheap talk script is used in the survey instrument.[14] List et al (2006) find no evidence of hypothetical bias (with or without cheap talk) in a study estimating the marginal willingness to pay for attributes of a private good (Nolan

[13] A concern here is whether the hypothetical instrument used in these tests satisfies Carson, Groves, and Machina's (2000) requirement of consequentiality for a survey to be incentive compatible. This issue is addressed in Chapter 2 of the dissertation.

[14] Cheap talk refers to providing survey recipients with information regarding the tendency of overstating willingness to pay in a survey format. This script is provided before respondents are asked their willingness to pay.

Ryan baseball cards). In addition, they find that responses elicited for the provision of a public good (contributions to the University of Central Florida's Center for Environmental Policy Analysis) were not significantly different between real and hypothetical cheap talk treatments, although subjects were more likely to donate if the treatment were hypothetical without cheap talk.

Two studies of choice experiments have been conducted in a classroom setting. Boyle et al (2006) seek to explain the discrepancy of value estimates between choice experiments[15] and contingent valuation by examining various provision rules. They describe three provision rule treatments: an individual provision rule that implements for a specific individual the option that he chose, a group provision rule that implements the option receiving the most support regardless if it was chosen by a particular subject, and no provision rule that is intended to mimic field applications of choice experiments. Their results suggest that the inclusion of the individual provision rule significantly reduces the number of subjects who opt-in to the market for a private good, T-shirts, relative to the group provision rule and no provision rule treatments. In valuing a real-world public good, a local non-profit organization called *Trees Atlanta* that plants trees in the Atlanta metro area, they find that the group provision rule and no provision rule treatments yield higher marginal values than either the real or hypothetical individual provision rule treatments. The only test of the incentive compatibility of choice experiments using induced values in a lab setting is concurrent research by Carson et al (2006). They test if the rate of non-demand revealing responses significantly differs

[15] In their paper, as elsewhere in the discrete choice literature, choice experiments is referred to as "choice modeling." Choice experiments have also been referred to as conjoint-based choice experiments.

across elicitation formats that vary by the number of options (dichotomous choice vs. multiple choice) and the number of choice sets (single vs. repeated). They find that while the frequency of violations of the independence of irrelevant alternatives in the multiple choice treatments are not significant, the rate of non-demand revelation in the repeated multiple choice treatment is significantly higher than in the repeated dichotomous choice treatment.

1.4 Application

1.4.1 Description of Policy Attributes

A survey was designed to elicit household preferences over different policy options to meet regional air quality standards. Because the survey was designed to be administered to households, the attributes of different policy options (the benefits and costs) were those determined most salient to this population. Benefits include both the increase in average visibility and the number of healthy days per year (healthy days are defined as days the area is not violating any air quality standard). Potential costs of achieving air quality improvements include increases in the costs of gasoline, electricity, and the costs of complying with a vehicle inspection/maintenance program. To be consistent with welfare theory, attribute levels are defined as changes relative to the status quo. In this application (as in Blamey et al, 2000), the status quo consists of the level of benefits if no additional local action is taken. While households would incur no direct costs under the status quo, the area would remain in violation of EPA standards and be subject to costly industry and transportation controls. Due to actions already taken at the federal level regarding power plant emissions and a combination of engine and fuel standards, some improvement in visibility and the number of healthy days will already occur without local action (although not sufficient to bring the area into attainment).

In addition to determining relative values for environmental and health attributes, this study also considers the impact of differing payment vehicles. Typically choice experiments only employ one payment attribute (usually an unspecified, general tax to the respondent), but a more comprehensive treatment of this variable seems warranted for policy analysis as different policy alternatives equate to different methods of payment. A key component of this research will be to test whether elicited willingness to pay is sensitive to the method of payment.

Attribute levels encompass the potential range of policy actions (see Table 1.1). According to the EPA's AirData database, the Knoxville area averaged 40 unhealthy air quality days per year from 1999-2003.[16] Levels of this attribute are specified as improvements from this baseline (e.g., an increase of 32 healthy days). Similarly, average annual visibility levels are expressed as improvements over the current baseline of 25 miles (e.g., an increase in visibility of 7 miles). On the cost side, an inspection/maintenance program is described as requiring households to spend $20 per year to test each vehicle, with an average repair cost of $150 for a failing vehicle (Cummins, 2004). The levels derived for the choice sets included the testing fee of $20 and the repair cost averaged over the expected lifetime of the vehicle (assumed to be 5 years). According to Tennessee Valley Authority (TVA) officials, electricity rates could

[16] Accessed at http://www.epa.gov/air/data/, updated September 26, 2006.

Table 1.1 Policy Attributes and Levels

Attribute	Levels
Visibility improvement	1 mile
	7 miles
	15 miles
Healthy days improvement	16 days
	24 days
	32 days
Increase in cost of gasoline per gallon	0 cents
	4 cents
	8 cents
Increase in yearly electricity bill	$0
	$72
	$144
Vehicle inspection/maintenance cost per year	$0
	$20
	$50

increase up to 14% if TVA were required to spend at least $1 billion on additional emissions controls such as scrubbers (Powelson, 2004). Because the average monthly electricity bill for the area is approximately $85, the upper level for this attribute is an increase of $144 per year. Several potential control measures could affect the price of gasoline, such as requiring vapor recovery nozzles to capture evaporative emissions of VOCs or mandating the use of reformulated and/or lower volatility gasoline. Vapor controls and lower volatility gasoline would each cost approximately 2 cents extra per gallon (USEPA, 1991; Energy Information Administration, 1999), while reformulated gasoline would cost 5 – 8 cents extra per gallon (USEPA, 1999b). Because of the lack of knowledge regarding the respondent's expenditure on gasoline per year, the cost of gasoline was expressed as the increase in cents per gallon in the choice set. Examples were given in the survey to translate the price increase per gallon into yearly costs to the household by calculating the cost of a small car averaging 22 miles per gallon and driven 12,000 miles per year and the cost of driving a large car averaging 12 miles per gallon and driven 12,000 miles per year.

1.4.2 Experimental Design

The series of choice sets were created by using a fractional factorial design, where levels of attributes were varied in a systematic way to efficiently estimate the parameters of the model with the fewest choice sets per respondent. With five attributes having three levels each, and for each choice set that contains two varying policy bundles and one bundle fixed at status quo levels, the total factorial design that gives all possible combinations of alternatives results in 3^{5*2} = 59,049 combinations. Obviously respondents cannot be expected to face that many choice alternatives, so a fractional factorial design must be used that finds the smallest number of combinations that still enables statistical identification of the attributes. While fractional factorial designs can estimate the direct independent effects (also known as "main effects") of the attributes on choice selection, they cannot estimate the impact of attribute interactions. For example, preferences for the number of healthy days per year must be assumed to be independent of the level of visibility. This tradeoff is acceptable considering that main effects account for between 70 and 90 percent of explained variance (Louviere, 2000).

A fractional factorial of 18 choice sets was created using the D-efficiency criterion in SAS that minimizes the variance matrix of the nonlinear choice model (Kuhfeld, 2003). The SAS procedure selects alternatives from the full factorial and compares efficiency across 100 different experimental designs. Maximizing D-efficiency results in a design with the smallest possible errors around the estimated parameters. The SAS code is presented in Appendix A. To further reduce the cognitive burden to respondents, this design was blocked into three survey versions of six choice sets. The resulting combinations of attribute levels were constrained to represent plausible scenarios to respondents. For example, visibility could not improve from the status quo level if there were no increases in the monthly electricity bill since visibility improvement is primarily a function of power plant emissions of sulfur dioxide. Dominated alternatives were also discarded.

1.4.3 Survey Design and Sample

Surveys were designed following suggestions from the Dillman Total Design Method (Dillman, 2000). For example, the survey cover design consisted of a map of the relevant sample area, cover letters to the respondent were personalized and individually signed, regular postage stamps were used on all envelopes, reminder post-cards were mailed a week after the survey. An incentive to respond was provided by including an optional raffle form to win one of ten $50 gift cards to Wal-Mart from a random drawing. Respondents were informed that survey results would be considered as an input into the policymaking process and that their individual responses would remain confidential. Background information on current air quality in the Knoxville area was provided, as well as an example of a choice set, presented below in Figure 1.2. Choice sets constructed from the experimental design were then presented for the respondents to select preferred options, followed by questions on socioeconomic status and attitudes

Sample Question: Suppose the following three policies were the only options available for achieving air quality goals in the Knoxville metro area. Please indicate which policy you prefer by checking one of the boxes below.

Policy Benefits and Costs	**Local Policy A**	**Local Policy B**	**Policy C: No Local Action**
Visibility improvement	1 mile	7 miles	1 mile
Healthy days improvement	32 days	16 days	16 days
Gasoline price increase per gallon	0 cents	8 cents	0 cents
Vehicle inspection cost per year	$50	$20	$0
Increase in electric bill per year	$144	$72	$0

I would choose: ☑ Policy A ☐ Policy B ☐ Policy C

If you choose **Policy A**, you are indicating that you would prefer the policy with these outcomes:

- **Visibility improvement: 1 mile.** Under this policy option, average annual visibility would improve from 25 miles to 26 miles.
- **Healthy days improvement:** 32. Under this policy option, the number of healthy days would improve by 32 days. Instead of 40 unhealthy days per year, there would only be 8 unhealthy days per year on average.
- **Gasoline price increase per gallon: 0 cents.** This policy option does not include changes to gasoline, so gasoline prices would be unchanged.
- **Vehicle inspection cost per year: $50.** Emissions testing is a part of this policy option. The cost represents the testing fee ($20) plus the average payment if a vehicle fails inspection, spread out over a five-year lifetime of the vehicle ($30).
- **Increase in electric bill per year: $144.** This policy option would require power plants to install additional equipment, and lead to electricity price increases of $12 per month, or $144 per year.

Policy B has a similar interpretation, while **Policy C** represents the "No Local Action" scenario where benefits occur because of actions already taken at the Federal level. For this reason **Policy C** has no new costs to households, but the area may lose future business development as a result of violating air quality standards.

Figure 1.2: Example of Choice Set

toward the environment. Socioeconomic variables included age, gender, income, education, vehicle ownership, and occurrence of asthma in family or friends. Attitudinal variables included membership in an environmental organization, whether or not the respondent had read news articles about local air quality during the previous year, if the respondent believed the articles were accurate, etc. An example of the survey is included in Appendix B.

The survey was mailed to a random sample of households living in the Knoxville MSA and neighboring Jefferson County.[17] Surveys were mailed to 2,400 households on April 15, 2004, the day that EPA declared the area would formally receive a nonattainment designation with respect to the ozone standard. Two hundred additional surveys were mailed out in May to account for the high number of bad addresses in the earlier sample. The overall response rate was approximately 18%, with 403 usable surveys collected (after accounting for bad addresses, a total of 2,289 surveys were actually delivered). Table 1.2 provides summary statistics of respondents. Compared with information gathered from the 2000 U.S. Census for the Knoxville MSA, the average respondent is older, more educated, and more likely to be male than the typical individual living in the area.[18] Family income is fairly comparable, averaging $44,800 in the survey sample and $45,700 in the census. With such a low response rate, the problem of sample selection must be investigated to determine if survey respondents have fundamentally different preferences for air quality programs than the underlying population. This issue is addressed in Appendix C.

---

[17] The survey sample was obtained from Marc Publishing Company, which provides direct mailing and telemarketing services.

[18] According to the 2000 U.S. Census, the median age of the Knoxville MSA is 37.3, 76.5% of individuals have less than a bachelor's degree, and 48.4% of the population is male.

Table 1.2 Summary Statistics

Variable	Sample mean (std. dev.)	Selected Data for the Knoxville MSA
Age	50.32 (17.16)	37.3 (median)
Number of household members	2.55 (1.36)	2.38
Number of children under age 6	0.25 (0.63)	
Number of household vehicles	2.48 (1.57)	2.0
Read news articles on Knoxville air quality within past year (%)	80.5 (39.6)	
Believed news articles on air quality to be accurate (%)	84.0(36.6)	
White (%)	90.9 (28.7)	91.2
Black (%)	5.1 (21.9)	5.8
Hispanic (%)	1.5 (12.2)	1.3
Asian (%)	1.8 (13.2)	0.9
Visited Smoky Mountain National Park within last year (%)	70.0 (45.8)	
Belong to an environmental organization (%)	18.5 (38.8)	
Household income ($)	44,800 (30,041)	45,700
Male (%)	55.3 (49.7)	48.4
Republican Party affiliation (%)	51.8 (50.0)	
Democratic Party affiliation (%)	34.6 (47.6)	
Married (%)	56.0 (49.6)	57.5
Household member with asthma (%)	24.8 (43.2)	
Know someone in the area with asthma (%)	69.3 (46.1)	
Less than bachelor's degree (%)	60.5 (48.9)	76.6
Monthly electricity bill ($)	125.47 (63.18)	
Have lived in an area requiring vehicle inspection (%)	38.2 (48.6)	
Miles driven per year	15,177.0 (12,314.0)	
Work fulltime (%)	53.1 (49.9)	
Retired (%)	29.5 (45.6)	
Student (%)	3.8 (19.1)	

Data for the Knoxville MSA obtained from the 2000 U.S. Census.

1.5. Model Specifications

1.5.1 Mixed Logit

The data is analyzed using a series of mixed logit models. The mixed logit model is a generalization to the conditional logit model that allows some parameters to be randomly distributed across households. This assumption relaxes the notion that all individuals have the same preferences for a particular attribute, which is the case when a parameter is assumed to be constant across the sample. McFadden and Train (2000) have shown that any discrete choice model based on random utility maximization can be represented by a mixed logit specification.

Following Train (2003), utility for individual n from alternative j can be described in the mixed logit model as:

$$U_{nj} = V_{nj} + \varepsilon_{nj} = \beta_n' x_{nj} + \varepsilon_{nj} = x_{nj}\overline{\beta} + x_{nj}\widetilde{\beta}_n + \varepsilon_{nj}$$

where $\beta_n = \overline{\beta} + \widetilde{\beta}_n$

β_n is a vector of individual-specific coefficients on observed policy- and individual-specific variables, $\overline{\beta}$ represents the average preferences of the sample, and $\widetilde{\beta}_n$ is the stochastic deviation of the respondent's tastes relative to average tastes in the sample. Instead of being fixed over individuals, these coefficients vary over respondents with density $f(\beta / \theta)$ where θ describes the underlying parameters of the distribution (i.e., mean and covariance). ε_{nj} is a random term that is iid extreme value and independent of

β_n and x_{nj}. If preferences for a particular attribute are expected to be homogeneous across the sample, $\tilde{\beta}_n$ is simply assumed to be zero.

The unconditional probability of individual *n* choosing alternative *j* from a choice set of *K* options is found by integrating the logit probability over the distribution of the random parameters:

$$P_{nj} = \int \frac{e^{V_{nj}(\beta)}}{\sum_{k=1}^{K} e^{V_{nk}(\beta)}} f(\beta / \theta) d\beta$$

Because this probability yields no closed form solution, choice probabilities are estimated by simulated maximum likelihood. This procedure entails estimating the mean and covariance of $f(\beta / \theta)$, taking several draws of β from this density, calculating the logit probability for each draw, and averaging over the number of draws.[19] The simulated probability is given by:

$$\check{P}_{nj} = \frac{1}{T} \sum_{t=1}^{T} \left(\frac{e^{V_{nj}(\beta)}}{\sum_{k=1}^{K} e^{V_{nk}(\beta)}} \right)$$

where *T* is the number of draws. The simulated probability approaches the population probability as the number of draws increase. The simulated log-likelihood is therefore:

$$SLL = \sum_{n-1}^{N} \sum_{j-1}^{J} d_{nj} \ln \check{P}_{nj}$$

where d_{nj}=1 if *n* chose *j* and d_{nj}=0 otherwise.

---

[19] A quasi-random maximum simulated likelihood method known as Halton draws are generally used in the simulation. Halton draws use non-random sequences to improve accuracy and reduce computation time. See Hensher and Greene (2003), Train (2003), and Train (1999) for the benefits of Halton number sequences vs. random numbers.

Since $\widetilde{\beta}_n$ is common over each alternative for a given individual, the model accounts for the panel structure of the data where the same respondent answers several choice questions.[20] This capability of the model is important since it is reasonable to believe that choices made by the same individual will be influenced by common unobservable factors. The model also relaxes the assumption of the independence of irrelevant alternatives inherent in other logit models. Because the probability of choosing a particular alternative involves the integration over the density of the parameters, the ratio of probabilities for any two alternatives will depend on the attributes of all alternatives in the choice set. Consequently, more realistic substitution patterns can be generated in this model. For example, by assuming that the two action alternatives share a common alternative specific constant, the model would predict that if one of the action alternatives were dropped the probability of choosing the remaining action option would rise proportionately more than the probability of choosing the status quo.

To create a mixed logit model, the analyst specifies a distribution for the variables that are thought to vary across the sample, and also chooses which parameters should be correlated, if any. Statistical significance of the estimated standard deviation of a random parameter indicates that unobserved heterogeneity is present in the sample. Conversely, if the estimated standard deviation is insignificant, preferences for the attribute can be assumed to be homogeneous. If the parameter's distribution can span both positive and negative values, the proportion of the sample that obtains positive utility from the attribute can be calculated from the estimated mean and standard deviation. When

[20] A sequence of choices by the same individual is taken into account by simply including the product of logit probabilities over an individual's choice sets in the likelihood function.

specifying a parameter distribution, consideration should be given to the prior expectation of a variable's sign. For example, if a variable should be non-negative (i.e., a benefit such as increase in the number of healthy days), the normal distribution may be inappropriate since some proportion of the distribution could be negative.

The model for the Knoxville air quality application is defined over three options, with two alternatives consisting of local action to improve air quality, and the third option representing the status quo of no local action. An alternative specific constant is defined to equal "1" for an alternative and "0" for the status quo. The deterministic portion of utility for each option depends on the five policy attributes (visibility, healthy days, gasoline price, vehicle inspection/maintenance and electricity bill), as well as socioeconomic and attitudinal variables interacted with the alternative specific constant. The policy benefits and the alternative specific constant are allowed to vary across the sample. The cost variables were chosen as nonstochastic in order to facilitate model convergence.

Because healthy days and visibility are benefits that should have positive coefficients for all respondents, these variables are first specified with triangular distributions with the standard deviation constrained to equal the mean. The density of the constrained triangular parameters starts at zero, rises linearly to the mean, and then declines to zero at twice the mean (Hensher, 2005). A second specification that also constrains healthy days and visibility to be positive across the sample is to assume that they are log-normally distributed. The primary difference between the two distributions is that the log-normal distribution has a very long upper tail, which if not representative of the sample could inflate the distribution of willingness to pay. While the triangular and log-normal models conform to expectations that the benefits provide positive utility across the sample, for comparison purposes a third model is also specified assuming that healthy days and visibility are normally distributed. In all models, the alternative specific constant is specified as having a normal distribution since there is no *a priori* assumption regarding its sign. The interactions of the alternative specific constant with socioeconomic terms are assumed to be constant. The model is specified as follows:

Alternative 1:
$V_{n1} = \bar{\alpha} + \tilde{\alpha}_n + (\bar{\beta}_1 + \tilde{\beta}_{1n})$ * visibility + $(\bar{\beta}_2 + \tilde{\beta}_{2n})$* healthy days + β_3 *gas + β_4 *inspection + β_5 *electric bill + $\sum \beta_i$ *constant*(socioeconomic and attitudinal variables)

Alternative 2:
$V_{n2} = \bar{\alpha} + \tilde{\alpha}_n + (\bar{\beta}_1 + \tilde{\beta}_{1n})$ * visibility + $(\bar{\beta}_2 + \tilde{\beta}_{2n})$* healthy days + β_3 *gas + β_4 *inspection + β_5 *electric bill + $\sum \beta_i$ *constant*(socioeconomic and attitudinal variables)

Status Quo:
$V_{n3} = (\bar{\beta}_1 + \tilde{\beta}_{1n})$ * visibility + $(\bar{\beta}_2 + \tilde{\beta}_{2n})$* healthy days + β_3 *gas + β_4 *inspection + β_5 *electric bill

1.5.2 Estimation

The three cost variables were converted to increases in household expenditures per year for consistency. The electricity bill and vehicle inspection costs are straightforward: the increase in the electricity bill is already given in yearly expenditure per household in the survey, and the cost of vehicle inspection is calculated by simply multiplying the per-car cost by the number of vehicles in the household (provided by the respondent in the survey). The yearly household expenditures on gasoline are imputed by using the stated number of miles driven per year for the respondent and an estimate of the number of miles driven per year by the other driving-age members of the household (the survey elicited the number of household members older than sixteen).[21] The number of gallons of gasoline per year is estimated by taking the imputed total household miles driven per year and divided by an estimate of average household fuel economy, which was derived by the stated number of passenger cars versus sport utility vehicles in the household. Definitions of variables used in the analysis are given in Table 1.3.

1.6 Results

1.6.1 Analysis of Choice Probabilities

Table 1.4 presents the estimation results for the mixed logit models.[22] Model 1 has triangularly distributed benefits, Model 2 has log-normally distributed benefits, and Model 3 has normally distributed benefits.

---

[21] The 2001 National Household Travel Survey, sponsored by the U.S. Department of Transportation, was used to estimate the number of miles driven per year for non-respondent household members based on age and Tennessee residency. If the respondent was over 65, male, and married, then other members of the household older than sixteen were assumed to drive 4,000 miles per year. If the respondent was over 65, female, and married, then other members of the household older than sixteen were assumed to drive 9,500 miles per year. If the respondent was younger than 65, male, and married, other driving-age household members were assumed to drive 10,000 miles per year. If the respondent were younger than 65, female, and married, other driving-age household members were assumed to drive 20,000 miles per year. Household fuel economy was derived by assuming that vehicles meet the Corporate Average Fuel Economy (CAFE) requirements: 27.5 mpg for passenger cars and 20.7 mpg for SUVs.

[22] For comparison, multinomial logit and nested logit models were also run on the data. The procedure devised by Hausman and McFadden (1984) confirmed that the IIA assumption did not hold for the multinomial logit model when "Local Policy A" was dropped from the sample (Hausman test statistic = 78.0). A nested logit model was specified where local policy options were partitioned into an "action" nest

Table 1.3 Variables Used in Mixed Logit Models

Variable	Definition
Policy Specific	
Constant	Alternative specific constant =1 if Local Policy A or Local Policy B, else zero (status quo)
Visibility	Visibility improvement in miles
Healthy days	Number of healthy days improvement
Gas	Yearly household increase in gas cost
Inspection	Yearly household vehicle inspection cost
Electric bill	Yearly household increase in electricity bill
Individual Specific	
Lbach	Less than bachelors degree*Constant
Elbill	Monthly electricity bill*Constant

and a "status quo" nest to relax the IIA assumption between nests. However, the inclusive value coefficient for the action nest exceeded one, indicating that the nest structure did not improve upon the multinomial logit specification. Even if the IIA assumption were not violated, the multinomial logit and nested logit models cannot account for unobserved preference heterogeneity or temporal correlation across choice questions answered by the same individual.

Table 1.4 Mixed Logit Results

	Model 1	Model 2	Model 3
Constant	3.756***	3.279***	3.325***
	(0.943)	(0.980)	(1.036)
Visibility	0.074***	-4.195***	0.047***
	(0.007)	(0.328)	(0.012)
Healthy days	0.041***	-5.947***	0.016
	(0.006)	(0.026)	(0.012)
Gas	-0.005***	-0.006***	-0.004***
	(0.001)	(0.001)	(0.001)
Inspection	-0.004***	-0.003***	-0.002**
	(0.001)	(0.001)	(0.001)
Electricity	-0.009***	-0.007***	-0.010***
	(0.001)	(0.001)	(0.001)
Elbill*Constant	0.012**	0.008	0.018***
	(0.004)	(0.006)	(0.007)
Lbach*Constant	-2.066***	-2.424***	-2.231***
	(0.708)	(0.744)	(0.779)
Standard deviation of random parameters			
Constant	5.254***	5.504***	5.225***
	(0.544)	(0.718)	(0.578)
Visibility	0.074***	2.347***	0.089***
	(0.007)	(0.118)	(0.013)
Healthy days	0.041***	4.363***	0.116***
	(0.006)	(0.010)	(0.014)
Model Statistics			
Log-Likelihood	-1658.597	-1591.175	-1596.458
Number of choice sets	2058	2058	2058
Likelihood ratio index	0.264	0.294	0.292

Standard errors in parentheses. *,**, and *** denote parameter is statistically different from zero at the 10%, 5%, and 1% significance levels, respectively. 1000 Halton draws were used for each model.[23] Distribution of random parameters across models: Model 1: Constant (normal), Visibility (triangular), Healthy Days (triangular); Model 2: Constant (normal), Visibility (log-normal), Healthy Days (log-normal); Model 3: Constant (normal), Visibility (normal), Healthy Days (normal).

[23] Sensitivity of coefficients to the number of Halton draws was tested using several different numbers of replications. In general, coefficients began to converge by 500 draws for each model.

Results of the mixed logit specification with triangularly distributed parameters (Model 1) indicates that visibility and healthy days positively affect the probability of a particular alternative being chosen, and are significant at the 1% level. As expected, the cost variables negatively affect the likelihood of an alternative being chosen, and are also significant at the 1% level. Heterogeneity around the mean of the random parameters is taken into account by interacting the random attributes with socioeconomic variables. The only socioeconomic variables found to significantly affect the mean of at least one random parameter are "education level less than bachelor's degree" and "monthly electricity bill." The coefficient on the interaction term between individuals with less than a bachelor's degree and the constant is negative, suggesting that these individuals have a greater preference for the status quo relative to those with at least a college education. Individuals with higher electricity bills are positively associated with the constant term in the full model, suggesting that those with higher monthly bills prefer an action alternative. The significance of the standard deviations of the random parameters indicates that there is still significant heterogeneity in tastes regarding the improvement in healthy days and visibility, as well as in the constant term, even after including heterogeneity around the mean. The likelihood ratio index, which measures the percentage improvement in the log-likelihood function of the specified model over a model with zero parameters, was approximately 0.26.[24] Hensher and Johnson (1981) and Ben-Akiva and Lerman (1985) state that a likelihood ratio index between 0.2 and 0.4 indicates the model provides a good fit for the data.

[24] This metric is also known as adjusted rho-squared.

The results of the log-normal specification (Model 2) parallel those of Model 1 in terms of signs and significance of the coefficients, except that the interaction of the constant and electricity bill no longer significantly affects the probability that an option will be chosen.[25] The likelihood ratio index improves to 0.29, suggesting a slightly better fit of the data relative to the constrained triangular model.

The model with normally distributed parameters (Model 3) closely resembles the triangular model in terms of significant variables, with the notable exception that healthy days no longer significantly determines the probability of choice. The likelihood ratio index is approximately 0.29. While this seems to indicate that specifying the random parameters with normal distributions fits the data better than with triangular distributions, a consequence of normal distributions is the possibility that a beneficial attribute might have negative values for some portion of the sample. To determine the percentage of the sample that the model predicts will derive negative utility from the policy benefits, the estimated mean and standard deviation of the parameters are used to calculate the cumulative normal distribution evaluated at zero. Following this procedure, the model predicts that 28.7% of the sample has a negative value for visibility and 43.8% has a negative value for healthy days. Obviously this is not consistent with underlying preferences and is thus a drawback of using normally distributed parameters.

[25] The mean effect of a log-normally distributed coefficient β with standard deviation s is obtained by $\exp(\beta + s/2)$.

1.6.2 Testing the Equality of Payment Vehicles

An objective of the study is to investigate whether the type of payment affects willingness to pay. Wald tests were employed to test the equality of the three payment coefficients, with results presented in Table 1.5.[26]

Using a series of pair-wise tests, all models strongly reject that the three payment coefficients are equal. However, in the log-normal specification, the hypothesis that the gas price coefficient is equal to the electricity bill coefficient cannot be rejected. These results suggest that the method of payment affects willingness to pay for improvements in air quality, and that households may be less averse to paying for policy benefits through vehicle inspection or gas prices than through an increase in their electricity bill.[27] While we would expect respondents to be indifferent between paying $1 to improve air quality through gas prices and paying $1 through vehicle inspection, preferences may be affected by the payment label. For instance, individuals may have a visceral negative response to any increase in the electricity bill and therefore believe that vehicle inspection is a more tolerable means of improving air quality. Another possibility is that the discrepancy is due to survey framing since the choice sets in the survey presented the increase in the price of gasoline as cents per gallon, the increase in the electricity bill as dollars per year, and the requirement of a vehicle inspection and maintenance program as dollars per year

[26] The Wald statistic provides a test of model restrictions and has a limiting chi-squared distribution with degrees of freedom equal to the number of restrictions.

[27] This finding is robust to alternative assumptions in the calculation of gas costs. Specifically, models were run assuming that all other driving age members of the household drive 5,000, 15,000 and 25,000 miles per year. Wald tests rejected all hypotheses that payment coefficients were equal in these models, with the exception of the hypothesis that Gas = IM in the triangular and normal specifications when other drivers in the household were assumed to drive 15,000 per year (p=0.342 and p=0.058), and in the triangular, log-normal and normal specifications in the model assuming other drivers drive 5,000 miles per year (p=0.225, p=0.779 and p=0.660).

Table 1.5 Testing the Equality of Payment Vehicles

	Model 1	Model 2	Model 3
Gas=IM	4.45 (p=0.035)	22.60 (p=0)	5.56 (p=0.018)
Gas=Electricity	21.97 (p=0)	0.47 (p=0.493)	33.48 (p=0)
IM=Electricity	37.02 (p=0)	18.04 (p=0)	49.02 (p=0)

Entries in table are Wald test statistics with p-values in parentheses.

per vehicle. However, since increases in gas prices are typically stated in the media as additional cents per gallon, survey framing effects may be irrelevant for the ranking of policy options if policymakers are only interested in how the public perceives costs.

Evidence that the method of payment affects willingness to pay has also been found in other stated preference studies. In their meta-analysis of wetland values derived from contingent valuation applications, Brouwer, Langford, Bateman and Turner (1999) examined several studies employing different methods of payment and found that individuals would be willing to pay twice as much if the method of payment were an income tax as opposed to any other method (e.g., consumer price increases, trip expenditures). Bergstrom et al (2004) conducted a combination dichotomous choice/open-ended CV study valuing groundwater in Maine and Georgia and found through a split-sample survey design that respondents are willing to pay more to improve water quality through a tax reallocation than through a special tax.[28] The tax reallocation asked respondents to trade off improved groundwater with a reduction in other public

[28] The hypothesis of equal willingness to pay for both the special tax and tax reallocation was rejected for both the open-ended and dichotomous choice elicitation mechanisms.

goods (purposefully kept vague to reduce protest behavior) that are funded by general taxes. A working paper by Nunes and Travisi (2006) examined the effect of different payment vehicles in their choice experiment that values railway noise reduction. They also find evidence that respondents are willing to pay more for the same amount of noise reduction if the reduction is financed through a reallocation of the public budget rather than through a new local tax. In contrast to Bergstrom et al, they specify how the reallocation of the public budget would occur and find that respondents would prefer that noise reduction be achieved through a decrease in public administration rather than through public transport.

1.6.3 Willingness to Pay Calculations

The primary objective of the study is to calculate the public's willingness to pay for air quality improvements in order to rank competing policy options. Willingness to pay is calculated for both marginal and discrete changes. Marginal willingness to pay for visibility and healthy days is constructed by dividing the attribute coefficient by each of the three payment coefficients, with results presented in Table 1.6. Confidence intervals are constructed around the median marginal willingness to pay measure using the simulation method of Krinsky and Robb (1986).

Results indicate that the public in general is willing to pay to improve air quality, but this willingness to pay depends on the method of payment. For example, the model with triangularly distributed benefits indicates that the typical household would be willing to pay $18.94 for a 1-mile improvement in visibility if paid through an inspection and maintenance program, $13.97 if paid through an increase in the price of gasoline, and

Table 1.6 Marginal Willingness to Pay ($)

	Visibility			Days		
	Gas	IM	Electric Bill	Gas	IM	Electric Bill
Model 1	13.97 (11.06-18.78)	18.94 (13.91-27.93)	8.04 (6.91-9.29)	7.81 (5.88-10.58)	10.53 (7.53-15.79)	4.47 (3.32-5.78)
Model 2	7.68 (4.68-12.44)	16.02 (9.26-31.31)	6.93 (4.35-10.82)	3.60 (2.71-5.29)	7.40 (4.73-15.71)	3.26 (2.61-4.60)
Model 3	12.96 (7.11-29.13)	23.23 (9.84-124.58)	4.89 (2.78-6.95)	4.32 (-2.85-12.26)	7.66 (-8.29-35.58)	1.66 (-0.78-4.07)

Entries in table are median estimates derived by the Krinsky and Robb method. 95% confidence intervals are in parentheses.

only \$8.04 if paid through an increase in the household's electricity bill. For an extra healthy day per year, households are willing to pay \$10.53 if paid through vehicle inspection and maintenance, \$7.81 if paid through an increase in the price of gasoline, and \$4.47 if paid through an increase in the electricity bill. The log-normal model indicates lower median willingness to pay for air quality benefits compared to the triangular model, although confidence intervals are somewhat larger. While vehicle inspection is again the preferred method of payment, in this model there is no clear preference between raising gas prices and increasing the electricity bill. As already shown, the model with normally distributed benefits stipulates that some portion of the sample actually derives negative utility from improved air quality. While median willingness to pay from this model is in general only somewhat lower than the triangular models, the consequence of normal distributions is more readily seen in the much wider confidence intervals.

To illustrate how choice experiments can provide information on the desirability of any policy spanned by the levels of the attributes, willingness to pay for discrete changes in visibility and the number of healthy days were also calculated. Two levels of benefits were specified: a "medium" level with an improvement in visibility of 7 miles and an increase of 24 healthy days per year, and a "high" level with an improvement in visibility of 15 miles and an increase of 32 healthy days per year (the high level comprises the upper bound of the attribute levels). Total willingness to pay is found by using Hanemann's (1984) formula for compensating surplus. In this case the status quo is not zero due to existing federal actions that will improve visibility by one mile and the number of healthy days by 16, even without any additional local action to reduce emissions.

Table 1.7 reports total willingness to pay estimates for the medium and high level of benefits. Again, these results suggest that households are willing to pay for improvements in healthy days and visibility, and that they would rather pay for these benefits with a vehicle inspection program or higher gas price than with a higher electricity bill. For example, in the triangular model (Model 1), compensating surplus for policy options that result in 32 additional healthy days per year and 15 miles of additional visibility would be worth approximately $434 if payment were made through vehicle inspection, but only $184 if achieved by an increase in the electricity bill. The same qualitative differences between models in calculating marginal willingness to pay also occur in measuring total willingness to pay.

The ability to compute willingness to pay for any "state of the world" that encompasses the range of attribute levels is an advantage of choice experiments. Not only can policymakers rank different policy options that are currently available, but can also compute willingness to pay for scenarios that materialize with additional information. This method also lends itself to providing a measure of benefits in cost benefit analysis.

Table 1.7 Total Willingness to Pay ($)

	Medium Benefits			High Benefits		
	Gas	IM	Electric Bill	Gas	IM	Electric Bill
Model 1	145.94 (116.49-194.90)	197.97 (146.63-292.78)	83.77 (69.65-100.10)	319.48 (255.42-427.36)	433.68 (321.06-643.61)	183.68 (153.85-218.22)
Model 2	75.26 (53.75-111.97)	155.60 (99.01-300.81)	67.96 (51.17-93.09)	165.75 (117.45-248.13)	344.10 (217.44-664.51)	149.94 (111.04-207.16)
Model 3	110.73 (52.86-246.54)	201.48 (74.51-1037.46)	42.46 (16.59-67.73)	247.63 (123.98-545.65)	450.52 (170.04-2286.14)	94.68 (39.51-147.78)

Entries in table are median estimates derived by the Krinsky and Robb method. 95% confidence intervals are in parentheses. Medium benefits are an increase of 24 healthy days and 7 miles visibility. High benefits are an increase of 32 healthy days and 15 miles visibility.

1.7 Conclusion

The results of this study indicate that choice experiments are a powerful method of determining the preferred set of options for policymakers facing many possible pollution reduction measures. By using choice experiments, policymakers are able to rank policy options and choose the combination of measures that maximizes welfare as well as meeting air quality standards. In one application choice experiments can encompass a wide range of options that could facilitate the choice of policy as more information on the effects of different control measures becomes available. This method is particularly beneficial for policymakers in EPA nonattainment areas who have substantial flexibility in determining which emission reduction measures to undertake in order to achieve compliance with air quality standards. This is not a trivial observation considering that there are approximately 150 ozone nonattainment counties and 224 particulate matter nonattainment counties with this kind of flexibility.

The present study of Knoxville, TN indicates that households would receive substantial welfare gains if air quality were improved, and that willingness to pay is sensitive to the method of payment. Requiring vehicle inspection seems to be the payment method to which households are least averse, more than doubling willingness to pay estimates when it is employed rather than an increase in the household electricity bill. This finding has important implications for future choice experiments. In particular, future applications should be explicit about the payment mechanism and policymakers should acknowledge that results could vary on this basis.

The ability to rank payment options gives policymakers valuable information in determining the appropriate course of action. For example, if it is determined that instituting a vehicle inspection and maintenance program and reformulated gasoline is sufficient to bring the area into attainment, requiring additional controls on power plants would be inefficient since the residents express the lowest WTP values when this payment vehicle is imposed. The valuation of attributes is also important for determining total benefits to an area for coming into attainment with the EPA standards. Although it was not known at the time the study was conducted how much healthy days and visibility would improve in the Knoxville area once it achieved attainment, the choice experiment framework allows for the calculation of total benefits once these levels are determined (provided the span of attributes encompasses this range).

A caveat to this conclusion is the uncertainty regarding whether sensitivity to the payment vehicle is a result of survey framing since not all costs were expressed as household expenditures per year, although the preamble to the survey questions did express this. Future research will test sensitivity to such differences in the presentation of choice sets. It is also important to realize that the willingness to pay measures derived from this application are short run benefits. In the long run we would expect for individuals to change their behavior in order to lower costs (e.g., buy a hybrid car to reduce gasoline costs).

This study also takes preliminary steps to account for sample selection bias in a mixed logit framework. As this model represents the new standard in analysis of multinomial choice data, it is imperative that methods are found to alleviate bias that results when the decision to respond to the survey is correlated in an unknown way with the choice of policy options. While the present study is inconclusive due to the lack of convergence of the sample selection model, the demonstrated method is a promising tool for addressing this problem. Future research will examine the properties of this model.

CHAPTER 2: INDUCED-VALUE TESTS OF THE INCENTIVE COMPATIBILITY OF CHOICE EXPERIMENTS

2.1 Introduction

Stated preference methods, in particular contingent valuation (CV) and more recently choice experiments (CE), have been used extensively to elicit values for environmental goods for use in benefit-cost analyses and natural resource damage litigation. While CV and CE differ in design, both methods use surveys to determine how respondents trade off a good and money, although no exchange of money actually takes place. These methods afford the analyst a great degree of control in survey design, can value potential changes in environmental quality that may not exist in reality, and can assess passive use values such as the existence value arising from the protection of an endangered species.

The most common type of stated preference method to value environmental amenities is contingent valuation (CV), where respondents are given information regarding a proposed improvement to the good and asked what they would willing to pay to realize this change. Initial applications of the method asked open-ended willingness to pay (e.g., "How much would you be willing to pay to provide this hiking trail?"), while more recent applications typically ask a dichotomous choice question (e.g., "Would you be willing to pay $x to provide this hiking trail? Please circle yes or no.") In the 1990s environmental economists began exploring choice experiments as an alternative to contingent valuation in valuing environmental amenities. Choice experiments are derived from conjoint analysis, which has been used extensively in the marketing and transportation literature since the 1970s to estimate relative values of a good's attributes. Like contingent valuation, this method can estimate use as well as non-use values. Choice experiments are based on the assumption that individuals derive utility not from a good itself, but from its constituent attributes (Lancaster, 1966). The technique, developed by Louviere and Hensher (1982) and Louviere and Woodworth (1983), consists of presenting respondents with a choice set of options comprised of attributes with varying levels, and elicits the most preferred option from the choice set. In this way choice experiments are similar to real world purchase decisions where consumers are presented with a variety of goods characterized by different attribute levels and choose whatever gives them the most satisfaction. To identify relative attribute values several questions are asked per application. Environmental applications include the valuation of rivers (Morrison and Bennett, 2004), global warming mitigation options (Layton and Brown, 2000), remnant vegetation (Blamey et al, 2000), water supply options (Blamey et al, 1999), polluted beaches and rivers (Garrod and Willis, 1999), caribou habitat (Adamowicz et al, 1998), and freshwater recreation (Adamowicz et al, 1994).

Choice experiments (CE) have been proposed as an alternative to the contingent valuation (CV) method for valuing public goods for two primary reasons. First, choice experiments are potentially more cost-effective than CV since multiple attributes of a good can be simultaneously valued within a single application, facilitating benefit transfer applications. Second, choice experiments may also avoid yea-saying and anchoring that have been shown to cause hypothetical bias in dichotomous choice CV applications.[29] With an orthogonal design of option attributes (including price) and a task that requires respondents to choose the most preferred outcome rather than answering a "yes or no" question regarding willingness to pay, it may be less clear to respondents which option is the "best for the environment" or how much a particular environmental improvement should cost. However, response rates depend on complexity of the survey format, and choice experiments impose a heavier cognitive burden by requiring respondents to compare levels of multiple attributes across options over a series of choice questions. In addition, DeShazo and Ferma (2002) have shown that choice inconsistencies may result from the choice set complexity.

Relatively few studies have been conducted to test the incentive properties of choice experiments. An incentive compatible elicitation mechanism is one where the decision maker can do no better than to truthfully reveal her preferences, i.e. there is no strategic incentive to lie. In order for survey questions to provide results consistent with economic theory, Carson, Groves and Machina (2000) assert that these questions must be consequential, which they define by two criteria: (1) a respondent cares about the potential policy to be enacted and (2) she believes her approval of a policy increases the probability of policy implementation. Other necessary conditions for a stated preference question to be incentive compatible are that the government can coercively collect payment upon policy implementation, the good cannot be provided in any other way, and that the stated preference question involve only two choices. Carson et al (2004) find empirical evidence that respondent decisions are invariant to the stochastic nature of their

[29] Yea-saying occurs when the respondent misrepresents his preferences in order to please the experimenter or conform to social norms. Anchoring occurs when the respondent uses the payment stated in the survey as the basis for determining his willingness to pay.

influence on policy outcomes, as long as the probability of policy implementation increases with respondent approval. Other evidence supporting the notion of consequentiality includes research by Liu et al (2006) that finds systematic differences in the distribution of willingness to pay between respondents who state that they believe a valuation study is inconsequential and others in the study.

Most studies examining the incentive properties of choice experiments look for evidence of hypothetical bias where perceived response incentives may deviate from those in an analogous situation with direct financial implications.[30] Carlsson and Martinsson (2001) test the validity of choice experiments with donations for environmental projects, and find no differences between actual and hypothetical marginal willingness to pay. Lusk and Schroeder (2004) find that hypothetical choices overestimate total willingness to pay for a private good, beef steaks, but that marginal willingness to pay for a change in steak quality is generally not significantly different across hypothetical and actual settings. Carlsson et al (2005) find that the estimated marginal willingness to pay for food is significantly lower when a cheap talk script is used in the survey instrument.[31] List et al (2006) find no evidence of hypothetical bias (with or without cheap talk) in the marginal willingness to pay for attributes of baseball cards. In addition, they find that responses elicited for the provision of a public good (contributions to the University of Central Florida's Center for Environmental Policy Analysis) were not significantly different between real and hypothetical cheap talk

[30] See Murphy et al (2004) and List and Gallet (2001) for meta-analyses of hypothetical bias in stated preference valuation.
[31] Cheap talk refers to providing survey recipients with information regarding the tendency of overstating willingness to pay in a survey format. This script is provided before respondents are asked their willingness to pay.

treatments, although subjects were more likely to donate if the treatment were hypothetical without cheap talk.

Two studies of choice experiments have been conducted in a classroom setting. Boyle et al (2006) seek to explain the discrepancy of value estimates between choice experiments[32] and contingent valuation by examining various provision rules. They describe three provision rule treatments: an individual provision rule that implements the option that an individual actually chose, a group provision rule that implements the option receiving the most support regardless if it was chosen by a particular subject, and no provision rule that is intended to mimic field applications of choice experiments. Their results suggest that the inclusion of the individual provision rule significantly reduces the number of subjects who opt-in to the market for a private good, T-shirts, relative to the group provision rule and no provision rule treatments. In valuing a real-world public good, a local non-profit organization called *Trees Atlanta* that plants trees in the Atlanta metro area, they find that the group provision rule and no provision rule treatments yield higher marginal values than either the real or hypothetical individual provision rule treatments. The only test of the incentive compatibility of choice experiments using induced values in a lab setting is concurrent research by Carson et al (2006). They test if the rate of non-demand revealing responses significantly differs across elicitation formats that vary by the number of options (dichotomous choice vs. trichotomous choice) and the number of choice sets (single vs. repeated). They find that while the frequency of violations of the independence of irrelevant alternatives in the

[32] In their paper, as elsewhere in the discrete choice literature, choice experiments is referred to as "choice modeling." Choice experiments have also been referred to as conjoint-based choice experiments.

multiple choice treatments are not significant, the rate of non-demand revelation in the repeated trichotomous choice treatment is significantly higher than in the repeated dichotomous choice treatment.

The main shortcoming of this literature, from the purview of this paper, is a lack of studies that employ both a hypothetical and a real payment scenario that are theoretically incentive compatible, at least under plausible assumptions. Without incentive compatibility, or at least a strong foundation of the incentive properties of the elicitation mechanisms in both hypothetical and real payment settings, it is difficult to decipher what is driving observed differences between the two. Further, absent incentive compatibility and individual rationality, it is impossible to know whether the observed results will be replicable. The vast majority of studies exploring hypothetical bias use a purely hypothetical setting, for which incentive compatibility seems very unlikely. Carson et al (2004) show that this has a dramatic effect on survey responses, with respondents answering a dichotomous choice referendum-type CV question differently depending on whether there is a positive probability that the vote will be binding. Certainly in field surveys, respondents are at least generally led to believe that policy may be influenced by survey responses and thus may not treat the survey as a purely hypothetical exercise.

This study offers a fresh perspective on hypothetical bias by testing the choice experiment format for incentive compatibility in an induced-value, laboratory setting. The laboratory experiments compare the performance of dichotomous choice and trichotomous choice questions across three real payment provision rules: plurality voting (PV), a vague decision rule based solely on respondent decisions (V1), and a vague decision rule based on both respondent decisions and the actions of the implementing agency (V2). The plurality vote rule serves as a benchmark. The induced value framework used in the study serves to mitigate confounding factors that appear to plague many of the previous studies on hypothetical bias such as participant altruism and attitudes toward risk. Participants do not know the range or distribution of group values so they cannot discern which response would improve the payoff of other subjects, and subjects have no incentive to engage in risk-averse or risk-loving behavior since values are certain across all treatments.

While the typical CE field application does not explicitly contain or infer a decision rule describing how responses affect a good's provision (as opposed to a CV referendum-type dichotomous choice question), respondents are generally informed that survey responses will be taken into consideration in the policymaking process. It therefore seems reasonable to believe that CE applications meet Carson, Groves, and Machina's requirement of consequentiality, although the respondent is uncertain as to how much influence her responses will have on eventual policy outcomes. The vague decision rule treatments in the laboratory experiment therefore give subjects incomplete information to parallel field applications where respondents may be relatively uninformed about how their responses map into agency actions as opposed to a political election or debated public referendum. Polome (2003) also explores the performance of this kind of provision rule in an induced value dichotomous choice CV experiment. The vague provision rule used in his study asks respondents to make their decisions as if the provision rule were a referendum, but notes that a different kind of provision rule could be used ex ante. He finds that while only half of the subjects truthfully revealed their willingness to pay, deviations from theory were not correlated with induced values, suggesting that deviations may occur from some individual behavioral characteristics.

This study investigates the theoretical properties of both dichotomous choice and trichotomous choice elicitation formats under plurality voting rules and more generally under the assumption that the respondent perceives her decision to have some influence on the outcome. It is well-known that multiple choice formats cannot be incentive compatible without placing restrictions on preferences (Gibbard, 1973 and Satterthwaite, 1975).[33] However, the trichotomous choice format is incentive compatible when certain assumptions are made on the prior beliefs an individual has about the preferences of others, such as if the respondent believes each option has equal support from the group. This kind of belief seems plausible in the context of a field survey where, unlike a political race, there is no clear signal about the preferences of other survey respondents. However, certain belief structures, such as believing the majority of respondents prefer that no action is taken, can give rise to status quo bias, which is often an issue of concern in choice experiment applications. Status quo bias reflects the tendency of individuals to have an endowment effect for the current state and to require compensation to undertake an action, even one that would otherwise leave utility unchanged. The experimental design allows for direct tests of status quo bias by including choice sets with a status quo option where all participants receive a positive return and alternative option(s) that result in gains and losses relative to the status quo. The empirical analysis focuses on the demand revealing properties of the elicitation mechanisms, the effects of vague provision rules on responses, and tests of status quo bias.

[33] Multiple choice formats refer to choice situations with more than two alternatives.

The paper is organized as follows: Section 2.2 explores the theoretical basis for incentive compatibility of dichotomous and trichotomous choice elicitation formats, Section 2.3 describes the experimental design, Section 2.4 presents empirical results and Section 2.5 concludes.

Results indicate that certain belief structures can lead to incentive compatible outcomes in a trichotomous choice format, depending on how a respondent believes the agency will incorporate respondent decisions into the provision of a public good. While experimental evidence shows that both dichotomous and trichotomous formats can lead to accurate assessments of willingness to pay, the trichotomous choice format surprisingly had fewer deviations from theory and was less subject to status quo bias. Of particular interest is the presence of fewer deviations from theory in the CE dichotomous choice format relative to empirical studies of dichotomous choice contingent valuation. This suggests that CV applications may be improved by adopting the attribute-based CE format for two options.

2.2 Theoretically Incentive Compatible Elicitation Mechanisms

One argument for the choice of the dichotomous choice referendum elicitation format in contingent valuation is the well-known result of its incentive compatibility, provided that the agency can compel payment if the good is provided and that a single issue is involved (Carson, Groves, and Machina, 2000). This result is not restricted to binding plurality vote mechanisms, but occurs as long as the survey instrument is consequential (the respondent believes there is a non-zero probability that her responses will influence the agency's action).

What of the incentive compatibility of a choice set with three alternatives? It is well-known that any mechanism other than a binary response cannot be incentive compatible without restricting agent preferences (Gibbard, 1973 and Satterthwaite, 1975). The question, then, is to what degree agent preferences must be restricted to achieve an incentive compatible outcome or under what circumstances this outcome is likely to occur. The voting literature states that an expected utility maximizing agent who faces three choices with a simple plurality winner will generally limit her choice to the two options that provide the highest unconditional expected utility. Affecting the respondent's strategic response is her preferred choice, her expectation of what others will choose, and her perception of how the agency will aggregate and incorporate survey data in policy decisions. In a political context such as the dominant two-party structure in the U.S., this typically implies that while a third party candidate may be the voter's preferred choice, the voter will likely select one of the major two party candidates since she believes (possibly from the common release of public opinion polls) only they have a realistic chance of winning. Stated preference surveys, on the other hand, usually inquire about the provision of public goods, with which respondents may be less familiar than political races and consequently have fewer prior beliefs about which options are most likely to be enacted.

Following McKelvey and Ordeshook (1972), an agent derives utility from each option available. When faced with three choices, she will compare her expected utility from her unconditional top two choices, denoted options 1 and 2. Assuming risk neutrality, this is equivalent to comparing her expected payoffs from her unconditional top two choices. Letting E_1 and E_2 represent her expected payoffs from choosing options 1 and 2 respectively, we have:

$$E_1 = p_{12}(b_1 - b_2) + p_{13}(b_1 - b_3) \quad (2.1)$$

$$E_2 = p_{12}(b_2 - b_1) + p_{23}(b_2 - b_3) \quad (2.2)$$

where b_i denotes the respondent's payoff if option *i* is implemented and p_{ij} is the pivot probability between options *i* and *j*. The pivot probability represents the probability that an agent will be decisive in breaking a tie between the two options. Given this notation, the respondent's decision rule can be written as follows:

If $E_1 - E_2 > 0$, choose option 1

If $E_1 - E_2 < 0$, choose option 2

where

$$E_1 - E_2 = 2p_{12}(b_1 - b_2) + p_{13}(b_1 - b_3) - p_{23}(b_2 - b_3) \quad (2.3)$$

If the respondent strategically chooses the option that provides the highest payoff b_i, then the elicitation mechanism can be characterized as incentive compatible. However, the respondent may select his second-most preferred option due to the impact of the pivot probabilities in (2.3). We assume the pivot probabilities depend on respondent beliefs about the likelihood that the agency will implement either option so that:

$$p_{ij} = f\lfloor A_i(\cdot), A_j(\cdot)\rfloor$$

where A_i is the perceived likelihood that the agency will implement option i. A_i depends on the respondent's beliefs regarding the total voter support of the option (including her own choice), denoted T_i, as well as other factors, Y_i, that measure the strength of policymaker preferences (independent from voter preferences) for option i.[34] The provision rule, denoted r, is expected to impact both total voter support as well as Y_i. Therefore,

$$A_i = A_i\left(T_i(r), Y_i(r)\right)$$

and

$$p_{ij} = f\left[A_i\left(T_i(r), Y_i(r)\right), A_j\left(T_j(r), Y_j(r)\right)\right].$$

The provision rule describes how the agency will use respondent choices to determine a policy strategy and determines whether other factors besides votes, such as policymaker preferences, can influence the agency decision. If a survey is thought to be inconsequential, as would be the case if the survey were purely methodological and respondents were told that responses would not be used as an input to any policy making, the pivot probabilities between any two choices would be zero and theory has little to say about what is driving responses. Studies that use purely hypothetical treatment to explore bias are thereby flawed.

The CE format generally has three options – the status quo and two generic departures from the status quo. If the survey is carefully designed to ensure the plausibility of any of these options so the respondent does not simply dismiss an option out-of-hand, it is reasonable that in many cases prior beliefs may be uniformly distributed

[34] For example, policymaker preferences could depend on the cost of implementing the option, the timeframe of implementation, or other political considerations.

among the options. This is because, unlike public referenda, there is generally little publicity surrounding policies in valuation surveys and hence only crude information, such as beliefs about the distribution of environmental preferences, from which to form a reasonable prior. The experimental design of CE applications may render beliefs as relatively uninformative since attribute levels are systematically varied, making options more difficult to categorize. For example, a CE application related to air quality improvements might define options with the following attributes: the number of healthy days per year, improvement in scenic visibility per year, and a cost measure such as an increase in yearly electricity bills. To enable statistical identification, levels of the attributes vary orthogonally such that respondents who in general want better air quality must still trade off the two attributes of air quality (assuming that the number of healthy days and visibility are not perfectly correlated). This kind of variation may make it difficult to determine how other respondents will choose between the options, as well as to determine how the agency will use a sequence of such choices. Given the assumption of uninfomed prior beliefs across options, we show in the next section that under certain circumstances, the trichotomous choice format can be incentive compatible.

It is possible, however, that respondents may have prior beliefs regarding the status quo option that is typically present in CE applications. Respondents may feel that the status quo is unlikely and thus only choose between the other two "action" options, or may believe that the cost associated with an action alternative understates the true cost and so chooses the status quo even if one of the action alternatives would be preferable. Consequently researchers should evaluate on a case-by-case basis the likelihood of prior beliefs causing strategic departures from the truthful revelation of preferences and strive to ensure the plausibility of all options, including the status quo.

2.3 Experimental Design

One hundred and ninety-six students were recruited at the University of Tennessee in the spring of 2006. Experiments were conducted in a laboratory setting, in groups ranging in size from five to twenty. Each participant received an initial balance of $7, with final earnings determined by the option implemented for everyone in the group. Experiments were short, lasting no more than 45 minutes.

Comparing the performance of dichotomous choice (DC) with trichotomous choice (TC) across three provision rules, there are six treatments. Each participant was given a copy of the instructions pertaining to the relevant treatment, which were read aloud in each session. Instructions described how six choice questions would be presented, with each question consisting of a set of options. Each option specified how many units of two goods would be provided and the total cost associated with their provision. The two goods were labeled as Red and Blue, and were worth money to participants, based on their induced values, if provided. An example of a choice question was given to demonstrate the outcomes in terms of the number of Red and Blue goods provided and the cost of provision for all options within the question. The DC format consisted of two options, while the TC format consisted of three options per choice set. The structure of the TC choice set is similar to how a choice set is presented in a field survey. Each choice set contained a status quo option where one unit of both Red and

Blue goods was provided at zero cost. Having positive levels of the number of goods in the status quo option was designed to mimic field applications where some amount of a public good will be provided regardless of policy action, and researchers are attempting to discover if there is support for additional amounts of the good. The status quo was the same for all questions while the attributes in the other options varied per question. Participants were told that one of the options would be implemented for everyone in the experiment based on choices made by everyone in the experiment, and were shown how earnings would be calculated for this implemented option. To control for order effects, each treatment was subdivided into five orderings of questions. Subjects were told that for a particular question everyone faces the same options, but that everyone would not see the questions in the same order. Figure 2.1 and Figure 2.2 provide examples of the choice question in the DC and TC formats.

To ensure that participants understood earnings calculations, another example choice question was presented to respondents followed by questions regarding their earnings if a particular option were implemented. For the DC format respondents were asked to calculate earnings for the two options in the choice set, while the TC format required earnings calculations for all three options. All participants were checked by the experimenter before being able to continue with the experiment. Those subjects who calculated earnings for each option correctly earned $2.

Subjects were then told how an option would be implemented according to the provision rule associated with the subject's treatment. After answering all six choice questions, a volunteer rolled a six-sided die to determine which choice question would be used to calculate earnings. The outcome determined by the provision rule was announced

Suppose the following two options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B: Status Quo**
Number of Red goods provided	3 units	1 unit
Number of Blue goods provided	1 unit	1 unit
Total cost per person	$4	$0

I would choose: ☐ Option A ☐ Option B

Figure 2.1: Dichotomous Choice Sample Question

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	3 units	2 units	1 unit
Number of Blue goods provided	1 unit	3 units	1 unit
Total cost per person	$4	$6	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

Figure 2.2: Trichotomous Choice Sample Question

to the group who could then calculate earnings for the session. The experiment concluded with a questionnaire that gathered basic demographics and information on the number of economics classes taken, previous knowledge of public goods, academic major, prior voting in state/national elections, and the degree to which the subject understood the experiment instructions.

2.3.1 Induced Values

Subjects received a "Value Card" indicating their per-unit induced value for Red and Blue goods and describing how their earnings are calculated for any option that is implemented. Subjects were told that not everyone had the same values, so that they should closely examine their values and not reveal them to anyone in the group. Subjects were not told the range or distribution of values for participants in their group. Subjects received induced values of $1, $2, or $3 for the Red and Blue goods, with all combinations used in the design except for ($3.00, $3.00) for a total of 8 sets of induced values.

2.3.2 Factorial Design of Options

Each option consisted of three attributes: the number of Red and Blue units provided and the total cost of the option. For options other than the status quo, each attribute had two levels. The number of Red goods could equal either 1 or 2, the number of Blue goods could equal 1 or 3, and the total cost could equal $2.50 or $4.00. The full factorial of options for the DC format is therefore $2^3 = 8$, and $2^{3x2} = 64$ for the TC format. After deleting options that were either dominated by the other options (e.g., one unit each of Red and Blue goods were provided but at a positive cost) or duplicate another choice set but with a different order of options, six choice sets were available for the DC format and seven choice sets remained for the TC format. In order to keep the number of questions constant between treatments, six questions were used for both DC and TC formats.

2.3.3 Provision Rules

2.3.3.1 Plurality Vote Provision Rule

The plurality vote rule is straightforward: the option that receives the most votes is implemented for everyone in the group. The DC plurality vote rule serves as the benchmark since it is well-established that a theoretical incentive compatible elicitation in a stated preference survey requires a "one-shot" DC question coupled with a coercive provision rule such as a referendum vote (Carson, Groves, and Machina, 2000). In a TC context, the incentive compatibility of the plurality rule relies on respondent beliefs. In the model discussed previously, these beliefs are manifested in the pivot probabilities. Because the plurality rule only relies on other voters as determinants of a good's provision, the decision of the respondent will be based on her preferences and what she believes are the preferences of the other people in the group. The belief regarding the agency's likelihood of implementing a particular option, then, is reduced from $A_i = A_i(T_i(r), Y_i(r))$ to $A_i = A_i(T_i(r))$. To operationalize equation (2.3), assume that the net payoff of option *i* can be represented as: $b_i = V_{red} \times red_i + V_{blue} \times blue_i -$ $Cost_i$ where V_{red} and V_{blue} are the per-unit induced values for Red and Blue goods, red_i

and $blue_i$ are the number of Red and Blue goods provided in option *i*, and $Cost_i$ is the total cost of providing option *i*. In general, the pivot probability between options *i* and *j* can be rewritten as the absolute value of the difference between the probability that an option will be implemented when the respondent chooses option *i*: p_{ij} = abs [prob(*i* + 1) – prob(*j*)] where prob(*i* + 1) represents the probability that option *i* is implemented given the respondent chooses it and prob(*j*) represents the probability that option *j* is implemented. Suppose that there are N participants in the group with a choice set of three options and that N_1 represents the number of votes for option 1, N_2 the number of votes for option 2, and N_3 the number of votes for option 3. The probability then that option *i* is implemented is the probability that $N_i > N_j$ for $i \neq j$. If the respondent believes that preferences among the three options are distributed uniformly so that, without his vote, $N_1 = N_2 = N_3$, then $p_{ij} = 1$ since $N_i = N_j$. In other words, if the respondent believes that preferences are distributed uniformly across each option, then the probability that he is pivotal becomes 1. According to (2.3), he would then choose the option that yields the highest payoff. Since the range of induced values is unknown and generic goods are used in the experiment, we therefore expected that subjects would answer truthfully under this provision rule.

2.3.3.2 Vague Provision Rule (V1)

The vague provision rule (V1) again limits the agency to depend solely on respondent decisions for implementation of the good, but is not as straightforward as the plurality voting rule. Subjects were instructed that the experimenters will place poker chips in a bag according to the option that each subject selected for the choice question that is used to determine experiment earnings. For example, if the subject chose Option A, the experimenters placed a white chip in the bag, a black chip was placed in the bag if Option B were chosen, and if the treatment was trichotomous choice, a green chip was placed in the bag for Option C. A volunteer then drew a poker chip out of the bag, and the color of the drawn chip determined which option was implemented for the entire group. This provision rule satisfies the consequentiality requirement of Carson, Groves, and Machina since the subject's choice increases the probability of implementation, but allows more subject uncertainty than the simple plurality voting rule in how responses lead to public good provision. This rule may more closely mimic field applications of choice experiments where respondents are led to believe that their decisions will be considered in the policymaking process but do not know how much influence their responses have.

Following the model discussed previously, subjects would take into consideration beliefs about how others in the group are choosing options as well as how they believe the agency (the experiment coordinators) will use respondent decisions. The uncertainty of this rule is reflected in how the total number of votes for option i, T_i, affects the probability that option i is implemented, A_i. Obviously T_i will affect A_i less under this provision rule than the plurality voting rule, reducing the respondent's pivot probability (assuming again that subjects in this experiment essentially have no informative beliefs regarding relative support for each option among other subjects). While the probability of implementation increases with a subject's vote, the probability that a subject is pivotal decreases with this rule compared with the plurality rule. Assuming again that preferences are uniformly distributed, the pivot probability now becomes: p_{ij} = abs[(N_i + 1)/N – N_j/N] = 1/N since $N_i = N_j$. While it would still be in the best interest of the subject to reveal her true preferences according to (2.3), the incentive to do so may be weakened relative to the plurality rule since she has less of a chance of being pivotal between options.

2.3.3.3 Vague with Regulator Provision Rule (V2)

The "vague with regulator" provision rule (V2) is similar to the vague provision rule, but now provision depends only partially on respondent decisions. Subjects were again instructed that different colored chips would be placed in the bag according to their choice for the randomly chosen question (white for Option A, black for Option B, and, if a trichotomous choice treatment, green for Option C), but now additional blue chips would be added by the experimenter. The number of blue chips added by the experimenter would equal the number of people in the group, so half of the chips in the bag come from subject decisions and half come from the experimenter. If the chip randomly drawn from the bag were a blue chip, the experimenter then revealed whether Option A, Option B, or in the trichotomous choice format, Option C was to be implemented. Subjects were told that the experimenter had written down on a piece of paper the option that corresponds to a blue chip being drawn, and were shown that folded piece of paper during the instructions. The option was kept secret until a blue chip was drawn at the end of the experiment. Sample instructions for this provision rule within the trichotomous choice elicitation format are included in Appendix D.

This provision rule intends to capture uncertainty respondents have in actual choice experiments over preferences of the implementing agency, as well as those of other respondents. Again assuming that subjects have uninformative beliefs regarding others in the group (and hence assume a uniform distribution of preferences), incentive compatibility relies on the effect of subject's beliefs about the likelihood of agency implementation on the pivot probabilities between options. Like the vague rule, this rule reduces the impact of voters on the pivot probability relative to the plurality rule. However, the respondent now considers other factors Y, which may increase or decrease the pivot probability relative to the vague rule. If the subject believes that the regulator will choose option *i*, the pivot probability becomes: p_{ij} = abs[($N_i + N$ +1)/(2*N*) – N_j/(2*N*)] = (*N*+1)/(2*N*) since $N_i = N_j$, which is greater than the pivot probability under the vague rule. If the subject believes the regulator will choose option *j*, then p_{ij} = (*N* - 1)/(2*N*), which again is greater than the pivot probability under the vague rule if $N > 3$. If the subject believes the regulator will choose an option other than *i* or *j*, then p_{ij} = 1/(2*N*). The latter belief results in a lower pivot probability relative to the vague rule. While the incentive remains to truthfully reveal preferences regardless of the belief regarding agency implementation (assuming uniformly distributed preferences among subjects), it cannot be predicted *a priori* whether V1 or V2 has the stronger incentive without making assumptions regarding which option subjects believe the regulator will choose. For example, if subjects believe the regulators are equally likely to choose any of the three options, then p_{ij} = abs[(N_i + *N*/3 +1)/(2*N*) – (N_j +*N*/3)/(2*N*)] = 1/(2*N*) since $N_i = N_j$, and we would predict that V1 would have the stronger incentive than V2.

In summary, we would expect to find evidence of incentive compatibility with all three provision rules given the assumption of uninformative beliefs regarding other voters. The strongest incentive to reveal preferences occurs under the plurality rule. We cannot predict the relative strength of the incentive to truthfully reveal preferences between V1 and V2 unless subjects believe that regulator preferences are uniformly distributed, in which case V1 has the stronger incentive.

2.4 Results

Summary statistics on decisions that deviate from theory are presented in Table 2.1. Decision deviations are defined as choices that do not conform to theory by maximizing payoffs in a particular choice set. Those DC questions that have equal payoffs for both options are excluded from this definition since it is impossible to deviate from theory. Since there were no TC questions that had equal payoffs for all three options, all TC questions were included in this metric. An immediate observation is that, contrary to expectations, the TC format has fewer deviations than the DC format across all three provision rules, and that V2 has fewer deviations than V1 across elicitation formats. The fact that there were fewer deviations in TC treatments than DC treatments is particularly striking since more opportunities exist to make deviations in this format. As expected, the plurality vote rule has the fewest deviations across treatments, although it is surprising that the TC plurality vote treatment has fewer deviations than the DC plurality vote treatment. Large deviations are defined as those questions where net earnings of the alternative chosen are at least $1 less than the next-best alternative.

Table 2.1 Deviations from Theory

Treatment	N	Deviations	Large Deviations
DCP	34	2.2%	0.5%
DCV1	31	18.2%	9.7%
DCV2	31	8.4%	5.9%
TCP	34	1.0%	0.0%
TCV1	31	8.6%	4.3%
TCV2	32	3.1%	0.5%

Deviation = Alternative chosen does not maximize expected net earnings; Large deviation = Net earnings of alternative chosen are at least $1 less than next-best alternative; DCP = Dichotomous Choice Plurality Provision Rule; DCV1 = Dichotomous Choice Vague Provision Rule; DCV2 = Dichotomous Choice Vague with Regulator Provision Rule; TCP = Trichotomous Choice Plurality Provision Rule; TCV1 = Trichotomous Choice Vague Provision Rule; TCV2 = Trichotomous Choice Vague with Regulator Provision Rule.

One immediate observation involves the rate of deviations in the dichotomous choice plurality rule treatment. This treatment closely resembles referendum CV questions since only two options are presented and the option that receives the most support is implemented. As noted in Table 2.1, the rate of deviations is 2.2% (for large deviations the rate is 0.5%). Other induced value studies that test hypothetical referendum CV questions have resulted in higher rates: Vossler and McKee (2006) find deviation rates of 6.9% (2.1% for large deviations) while Taylor et al (2001) find deviation rates of 16.7%. Since the incentive properties should be the same across formats, the discrepancy could partially be explained by the difference in elicitation format. Perhaps the choice experiment framework, where the subject simply picks the most preferred option of attributes, leads to a higher rate of demand revelation than the CV format that requires an all-or-nothing decision. Other possible explanations could include differences in experimental design such as the distribution of values and costs across the samples or the presence or absence of an example that describes how earnings are calculated.

To enable comparison across treatments in the current study, Table 2.2 reports deviations by spread, which is defined as the difference in payoffs between the top two alternatives within a choice question. The DC format had a range of spreads from zero to $5.50, while the range of spreads in the TC format extended from zero to $4.50. The table is reported as the percentage of deviations in the number of questions with a particular spread. A spread equal to zero, for example, implies that two options yield the same payoffs. As one would expect, this reduces the chance of deviating in the TC format (it is impossible to deviate under the DC format under a zero spread), and indeed the percentage of deviations from these types of questions is zero for V1 and V2 trichotomous choice treatments. While questions with zero spread account for both deviations in the TC plurality rule treatment, the deviations were committed by the same individual. Because no deviations occurred for DC formats at a spread of $5 or $5.50, these spreads are not included in the table.

Table 2.3 presents tests of decision deviations by spread. All hypotheses are tested using the Fisher exact test. The hypothesis that all DC formats are equal to all TC formats is rejected at the 5% significance level for a spread of $1, and at the 10% level at a spread of $2, while it cannot be rejected at any other spread. Under the DC treatment, the hypothesis that the plurality rule is equal to V1 can be rejected at the 5% level at a spread of $2.00 and at the 10% level for spreads of $1.00 and $3.00. Under the TC treatment this hypothesis can be rejected at the 5% level at spreads of $0.50 and $1.00.

Table 2.2 Deviations by Spread

Spread	DCP	DCV1	DCV2	TCP	TCV1	TCV2
0	NA	NA	NA	6.7%	0.0%	0.0%
0.5	8.3%	23.5%	5.9%	0.0%	14.3%	3.1%
1.0	4.8%	27.8%	5.6%	0.0%	25.0%	0.0%
1.5	0.0%	6.9%	10.3%	0.0%	8.3%	0.0%
2.0	0.0%	12.1%	12.1%	0.0%	0.0%	4.2%
2.5	0.0%	16.7%	0.0%	0.0%	0.0%	0.0%
3.0	0.0%	15.0%	5.0%	0.0%	0.0%	0.0%
3.5	0.0%	9.1%	18.2%	0.0%	0.0%	12.5%
4.0	0.0%	0.0%	0.0%	0.0%	0.0%	25.0%
4.5	0.0%	11.1%	0.0%	0.0%	0.0%	0.0%

Entries in table are the ratios of deviations from theory to the number of questions with a particular spread. Spread = Difference in earnings between top two alternatives; DCP = Dichotomous Choice Plurality Provision Rule; DCV1 = Dichotomous Choice Vague Provision Rule; DCV2 = Dichotomous Choice Vague with Regulator Provision Rule; TCP = Trichotomous Choice Plurality Provision Rule; TCV1 = Trichotomous Choice Vague Provision Rule; TCV2 = Trichotomous Choice Vague with Regulator Provision Rule; NA = not applicable.

Table 2.3 Tests of Deviations by Spread

Spread	Hypothesis						
	All DC= All TC	DCP = DCV1	DCP = DCV2	DCV1 = DCV2	TCP = TCV1	TCP = TCV2	TCV1 = TCV2
0.0	NA	NA	NA	NA	0.492	0.492	NA
0.5	0.047	0.106	1.000	0.083	0.001	0.240	0.030
1.0	0.550	0.073	1.000	0.177	0.018	NA	0.047
1.5	0.461	0.222	0.102	1.000	0.235	NA	0.489
2.0	0.085	0.050	0.050	1.000	NA	1.000	1.000
2.5	0.455	0.429	NA	1.000	NA	NA	NA
3.0	0.569	0.092	0.465	0.605	NA	NA	NA
3.5	0.641	0.478	0.217	1.000	NA	1.000	NA
4.0	0.543	NA	NA	NA	NA	0.467	0.467
4.5	NA	0.474	NA	1.000	NA	NA	NA

Entries in table provide the Fisher exact p-value. DCP = Dichotomous Choice Plurality Provision Rule; DCV1 = Dichotomous Choice Vague Provision Rule; DCV2 = Dichotomous Choice Vague with Regulator Provision Rule; TCP = Trichotomous Choice Plurality Provision Rule; TCV1 = Trichotomous Choice Vague Provision Rule; TCV2 = Trichotomous Choice Vague with Regulator Provision Rule; NA = not applicable.

The hypothesis that the plurality rule is equal to V2 cannot be rejected for any spread under TC, but can be rejected at the 5% level at a spread of $2.00 under DC. The hypothesis that V1 is equal to V2 is rejected for the DC treatment at the 10% level at a spread of $0.50, and at a 5% level under TC at spreads of $0.50 and $1.00. These results suggest that there is some evidence that the TC format has significantly fewer deviations than the DC format and that the plurality rule treatments do not in general differ from the V2 treatments, but do differ from the V1 treatments. The majority of significant differences between the benchmark plurality rule and the other provision rules occur at relatively lower spreads where the opportunity cost of deviating from theory is lower.

To formally model decision deviations, probit models were estimated within and across elicitation formats using design conditions and respondent characteristics as explanatory variables (see Table 2.4 for definitions of the variables). Results are presented in Table 2.5 as marginal effects for ease of interpretation. Each participant answered six questions, and since it is likely that the unobserved heterogeneity is correlated across the responses from the same individual, we arbitrarily allow for this type of correlation by using the Huber-White “sandwich” covariance matrix estimator. This is consistent with a random effects type of error structure without assuming the random effect is additive with a specific distribution. The full model consisting of observations across elicitation formats suggests that respondents in the TC treatments are 4.2% less likely to deviate from theory than those in DC treatments, those in the V1 treatment are 9.4% more likely to deviate than respondents in the plurality treatment, and those in the V2 treatment are no more likely to deviate from theory than those in the plurality treatment. While it is unclear why more deviations occurred in the

Table 2.4 Description of Explanatory Variables

Variable name	Description	Sample Mean (std. dev.)
TC	= 1 if elicitation mechanism is trichotomous choice	0.602 (0.489)
V1	= 1 if provision rule is vague	0.321 (0.467
V2	= 1 if provision rule is vague with regulator	0.327 (0.469)
Group Size	Number of participants in the subject's group	15.150 (3.553)
Distance	Absolute value of net earnings	3.962 (2.034)
Spread	Difference between earnings of top two alternatives within a choice question	1.463 (1.232)
Age	Subject's age, in years	20.820 (3.461)
Male	= 1 if subject is male	0.618 (0.486)
Math	= 1 if subject has a math-intensive major (e.g., engineering, statistics)	0.413 (0.492)
Experience	= 1 if subject participated in a previous economics experiment	0.757 (0.429)
Voted	= 1 if subject in any prior state or national election	0.690 (0.463)
Public Goods	= 1 if subject had studied the economics of public goods	0.587 (0.493)
Constant	Alternative specific constant = 1 if choice represents an 'action' alternative as opposed to the status quo	0.600 (0.490)

Table 2.5 Probit Analysis of Deviations

	All Observations	Dichotomous Choice	Trichotomous Choice
TC	-0.042*		
	(0.024)		
V1	0.094**	0.139**	0.045
	(0.041)	(0.058)	(0.056)
V2	0.046	0.081	0.026
	(0.034)	(0.055)	(0.038)
Group Size	-0.002	-0.003	-0.002
	(0.002)	(0.003)	(0.006)
Spread	-0.011	-0.019**	-0.004
	(0.007)	(0.009)	(0.008)
Age	0.002*	0.004**	0.002
	(0.001)	(0.002)	(0.002)
Male	0.012	0.008	0.011
	(0.019)	(0.031)	(0.017)
Experience	-0.020	0.014	-0.051
	(0.026)	(0.036)	(0.040)
Voted	0.007	0.008	0.006
	(0.019)	(0.031)	(0.020)
Model Statistics			
Log-Likelihood	-214.710	-129.590	-81.086
Likelihood ratio index	0.116	0.113	0.126
N	1080	521	559

Dependent variable = 1 if respondent deviates from theory; = 0 otherwise. Entries in table are marginal effects. Standard errors are in parentheses. *,**, and *** denote parameter is statistically different from zero at the 10%, 5% and 1% significance levels, respectively. The likelihood ratio index provides the percentage increase in the log-likelihood function relative to the model estimated with constants only.

DC format relative to the TC format, the other results are consistent with the theoretical model of voting described earlier. The addition of poker chips by the experimenters may have led some respondents to believe their choice was more pivotal, and consequently encouraged the selection of the choice that maximized earnings. It is harder to explain the discrepancy between the TC and DC elicitation formats. One possibility is that participants adopted simple heuristics for questions with only two options while the three-option format may have stimulated participants to think about the exercise more deeply. The only other variable significantly affecting the probability of making an error is the subject's age, with the probability of deviating from theory increasing by 0.2% with each additional year. None of the other respondent characteristics significantly affected the probability of committing a deviation, nor did the number of individuals in a particular experimental session.

Turning now to the DC elicitation format, those in the V1 treatment are 13.9% more likely to deviate from theory relative to the plurality group. The probability of deviating decreases in this format by 1.3% for every dollar increase in the difference between earnings of the two options. Older respondents are again more likely to deviate from theory in the DC format, as the probability increases by 0.4% for each additional year. None of the explanatory variables significantly impact the probability of deviating from theory in the TC elicitation format.

To further examine evidence of hypothetical and status quo bias, choice models were run for all six treatments. Mixed logit models were used to account for heterogeneity of preferences, repeated questions per subject, and to relax the restrictive independence of irrelevant alternatives assumption (IIA) inherent in the commonly used conditional logit model to analyze choice data. Following Train (2003), utility for person n from alternative j can be described as:

$$U_{nj} = \beta_n' x_{nj} + \varepsilon_{nj} = x_{nj}\overline{\beta} + x_{nj}\widetilde{\beta}_n + \varepsilon_{nj}$$

where $\beta_n = \overline{\beta} + \widetilde{\beta}_n$

β_n is a vector of individual-specific coefficients on observed policy- and individual-specific variables, $\overline{\beta}$ represents the average preferences of the sample, and $\widetilde{\beta}_n$ is the stochastic deviation of the respondent's tastes relative to average tastes in the sample. Instead of being fixed over individuals, these coefficients vary over respondents with density $f(\beta / \theta)$ where θ describes the underlying parameters of the distribution (i.e., mean and covariance). ε_{nj} is a random term that is iid extreme value and independent of β_n and x_{nj}. If preferences for a particular attribute are expected to be homogeneous across the sample, $\widetilde{\beta}_n$ is simply assumed to be zero.

The unconditional probability is found by integrating the logit probability over the distribution of the random parameters:

$$P_{nj} = \int \frac{e^{V_{nj}(\beta)}}{\sum_{k=1}^{K} e^{V_{nk}(\beta)}} f(\beta / \theta) d\beta$$

Since $\widetilde{\beta}_n$ is common over each alternative and individual-specific, the model accounts for the panel structure of the data where the same respondent answers several choice questions.[35] This capability of the model is important since it is reasonable to believe that

[35] A sequence of choices by the same individual is taken into account by simply including the product of logit probabilities over an individual's choice sets in the likelihood function.

choices made by the same individual will be influenced by common unobservable factors. The model also relaxes the assumption of the independence of irrelevant alternatives inherent in other logit models. Because the probability of choosing a particular alternative involves the integration over the density of the parameters, the ratio of probabilities for any two alternatives will depend on the attributes of all alternatives in the choice set. Consequently, more realistic substitution patterns can be generated in this model. To create a mixed logit model, the analyst specifies a distribution for the variables that are thought to vary across the sample, and also chooses which parameters should be correlated, if any. Significance of the estimated standard deviation of a random parameter indicates that unobserved heterogeneity is present in the sample. Conversely, if the estimated standard deviation is insignificant, preferences for the attribute can be assumed to be homogeneous.

Because induced values for the Red and Blue goods were uniformly distributed among subjects, these coefficients were allowed to be random with a uniform distribution. The constant coefficient, which represents an "action" alternative as opposed to the status quo, was allowed to vary randomly with a normal distribution. Socioeconomic factors that might impact status quo bias were allowed to interact with the mean of the constant term. Several specifications were attempted, but only age and male were found to be significant when interacted with the constant. Evidence of status quo bias would then be manifested in the signs and significance of the constant term and its interactions. Results of the mixed logit models are presented in Table 2.6. In five of the six treatments none of the socioeconomic factors seem to impact any bias toward the status quo, and the constant term has an insignificant mean coefficient and standard

Table 2.6 Mixed Logit Models

	DCP	DCV1	DCV2	TCP	TCV1	TCV2
Constant	-9.976	-2.689	-0.056	32.832	-37.658***	13.346
	(13.609)	(7.501)	(4.373)	(31.675)	(13.524)	(10.834)
Red	7.950***	3.380***	4.191***	11.772***	15.766***	7.064***
	(3.105)	(1.096)	(1.063)	(4.384)	(3.515)	(2.325)
Blue	6.652***	3.466***	3.397***	12.645**	8.166***	6.230***
	(2.292)	(0.907)	(0.680)	(6.123)	(2.520)	(1.437)
Cost	-3.141***	-1.172**	-1.146*	-6.295**	-4.474***	-3.161**
	(0.891)	(0.504)	(0.607)	(3.157)	(1.659)	(1.289)
Constant*Age	0.292	0.052	-0.159	-1.945	0.684*	-0.535
	(0.464)	(0.367)	(0.221)	(1.533)	(0.409)	(0.466)
Constant*Male	1.714	0.111	1.562	-0.639	11.106***	-2.808
	(1.922)	(1.308)	(1.250)	(4.199)	(4.224)	(2.096)
Standard Deviation of random parameters						
Constant	0.086	1.474	0.011	1.003	5.446	1.092
	(24.942)	(1.223)	(46.282)	(5.142)	(5.320)	(2.946)
Red	0.092	1.576	0.010	15.296	15.557***	6.539**
	(40.913)	(3.477)	(57.678)	(11.066)	(4.830)	(2.944)
Blue	5.638**	3.463**	2.563***	9.146***	8.712***	4.085***
	(2.424)	(1.604)	(0.848)	(3.427)	(3.108)	(1.505)
Model Statistics						
Log-Likelihood	-64.401	-82.308	-74.837	-75.588	-85.390	-100.176
Number of choice sets	204	185	186	193	180	192
Likelihood ratio index	0.524	0.325	0.390	0.635	0.557	0.514

Standard errors are in parentheses. *,**, and *** denote parameter is statistically different from zero at the 10%, 5% and 1% significance levels, respectively. 500 Halton draws were used for each model. DCP = Dichotomous Choice Plurality Provision Rule; DCV1 = Dichotomous Choice Vague Provision Rule; DCV2 = Dichotomous Choice Vague with Regulator Provision Rule; TCP = Trichotomous Choice Plurality Provision Rule; TCV1 = Trichotomous Choice Vague Provision Rule; TCV2 = Trichotomous Choice Vague with Regulator Provision Rule.

deviation. There is some evidence of status quo bias in the TCV1 treatment as seen by the significant negative constant coefficient, which is somewhat mitigated by the positive coefficients on the interaction terms with age and male. However, status quo bias does appear to be affected by elicitation mechanism. Several questions in both formats had zero spread with the status quo option, meaning that the respondent would be indifferent between the two options if maximizing his earnings. Examining the frequency of the status quo choice leads to interesting findings between the two formats. In every single instance where the subject was indifferent in a DC treatment, the subject chose the status quo. However, those subjects in TC treatments tended to randomize equally when faced with such a question.[36] Further research is needed to determine how respondents view these formats and if different decision heuristics might arise according to the number of options presented.

Finally, incentive compatibility is tested by comparing the experimental choice models with constructed choice models predicted by theory where subjects choose to maximize their earnings. Choice experiments can calculate the marginal willingness to pay for each attribute if a payment attribute is included in the choice set. Marginal willingness to pay for Red and Blue goods under empirical and theoretical treatments is presented in Table 2.7. Distributions around the median estimates were constructed according to the numerical resampling procedure described by Krinsky and Robb (1986). To determine if responses are demand revealing, these distributions were compared using the complete combinatorial convolution approach of Poe et al (2005). Table 2.8 presents

[36] A Fisher exact test cannot reject the hypothesis that the choice between status quo and action options that have equal earnings in the TC treatments is purely random ($p = 0.445$).

Table 2.7 Empirical and Theoretical Marginal WTP ($)

	Experimental		Theory	
	Red	**Blue**	**Red**	**Blue**
DCP	2.50 (0.588 – 4.945)	2.10 (0.839 – 3.747)	2.35 (1.651 – 3.620)	2.06 (1.574 – 3.197)
DCV1	2.85 (1.008 – 10.643)	2.92 (1.453 – 10.434)	2.13 (1.449 – 3.510)	2.13 (1.544 – 3.791)
DCV2	3.44 (-9.560 – 18.898)	2.82 (-7.378 – 14.882)	2.87 (1.905 – 5.131)	2.35 (1.689 – 4.379)
TCP	1.81 (-0.854 – 5.968)	1.98 (-0.312 – 4.808)	2.44 (2.046 – 3.962)	2.02 (1.316 – 4.041)
TCV1	3.53 (2.507 – 8.073)	1.81 (1.229 – 3.464)	2.38 (1.977 – 3.756)	2.02 (1.601 – 3.109)
TCV2	2.22 (1.275 – 5.091)	1.93 (1.097 – 6.985)	2.37 (1.888 – 3.771)	2.04 (1.616 – 3.128)

95% confidence intervals are in parentheses. DCP = Dichotomous Choice Plurality Provision Rule; DCV1 = Dichotomous Choice Vague Provision Rule; DCV2 = Dichotomous Choice Vague with Regulator Provision Rule; TCP = Trichotomous Choice Plurality Provision Rule; TCV1 = Trichotomous Choice Vague Provision Rule; TCV2 = Trichotomous Choice Vague with Regulator Provision Rule.

Table 2.8 Comparing Empirical and Theoretical WTP distributions

Treatment	Red	Blue
DCP	0.454	0.489
DCV1	0.271	0.228
DCV2	0.372	0.372
TCP	0.768	0.532
TCV1	0.664	0.669
TCV2	0.604	0.555

Entries in table provide the p-value derived by Poe et al (2005) of the hypothesis that the difference between the experimentally and theoretically generated estimates of willingness to pay is zero. DCP = Dichotomous Choice Plurality Provision Rule; DCV1 = Dichotomous Choice Vague Provision Rule; DCV2 = Dichotomous Choice Vague with Regulator Provision Rule; TCP = Trichotomous Choice Plurality Provision Rule; TCV1 = Trichotomous Choice Vague Provision Rule; TCV2 = Trichotomous Choice Vague with Regulator Provision Rule.

the test statistic that is comparable to a p-value of the hypothesis that the difference between the experimentally and theoretically generated estimates of willingness to pay is zero. As all test statistics cannot be rejected at any significance level, there is no evidence of incentive incompatibility. While some treatments result in a higher rate of deviations from theory than others, all appear to be demand revealing.

2.5 Conclusion

This study provides a test of the incentive compatibility of choice experiments, which represents a promising new method for valuing nonmarket goods. The success of choice experiments as an alternative to contingent valuation depends on its ability to yield demand-revealing responses. Theoretical evidence demonstrates that under certain plausible beliefs the trichotomous choice framework can be incentive compatible. Specifically, if the survey respondent is relatively uninformed regarding the support each option might garner within the population, he will have the incentive to answer truthfully, even under the vague provision rules. Many choice experiment surveys describe nonmarket goods that are relatively unfamiliar to respondents, so this belief structure may characterize numerous applications. In order to assess the likelihood of truthful responses, researchers must include debriefing questions in a choice experiment survey to ascertain previous knowledge of the good in question and the respondent's belief regarding relative support for the good in the population and the plausibility that the relevant agency will provide the good.

As opposed to previous tests of the incentive properties of choice experiments, this study more closely mimics field applications by including a consequential experimental design. Previous tests have in general compared real responses with a purely hypothetical question in which respondents had zero probability of influencing the actual provision of the good. As Carson, Groves, and Machina (2000) have shown, a necessary condition for incentive compatibility is that the survey is consequential. Field applications of choice experiments, however, generally include language stating that responses will be considered in the policymaking process. To incorporate consequentiality, this study includes vague provision rule treatments in an induced value laboratory setting that lead respondents to believe they have input in the provision of the public good, although this influence is more uncertain than the referendum provision rule found in CV applications.

The empirical evidence gathered indicates that choice experiments with trichotomous options and repeated choice sets can be incentive compatible under reasonable assumptions regarding the distribution of preferences over options. While the induced-value design of the experiment in this paper controlled for many potential sources of status quo bias such as cost uncertainty, plausibility of implementation and other respondent beliefs, differences in the rate of deviations from theory still exist among treatments. An interesting finding is the occurrence of fewer errors in the trichotomous choice formats relative to the dichotomous choice formats, and the tendency of dichotomous choice subjects to choose the status quo. Assuming the cognitive task involved is simpler in the dichotomous choice context, further research is needed to discover why respondents might employ different decision heuristics when answering trichotomous choice versus dichotomous choice questions. Further research will also address situations where the cost of provision is uncertain.

An important implication of this study is evidence that the choice experiment referendum format results in fewer deviations from theory than similarly constructed referendum CV responses. This suggests that CV applications may be improved by adopting the attribute-based CE format for two options.

LIST OF REFERENCES

List of References

Adamowicz, W.L., J. Louviere, and M. Williams. 1994. "Combining State and Revealed Preference Methods for Valuing Environmental Amenities." *Journal of Environmental Economics and Management* 26: 271-292.

Adamowicz, W.L., P. Boxall, M. Williams and J. Louviere. 1998. "Stated Preference Approaches for Measuring Passive Use Values: Choice Experiments and Contingent Valuation." *American Journal of Agricultural Economics* 80(1): 64-75.

American Journal of Respiratory and Critical Care Medicine. 1999. Vol. 159: 768-775.

Bateman, Ian J. et al. 2002. *Economic Valuation with Stated Preference Techniques: A Manual.* Cheltenham, UK: Edward Elgar.

Ben-Akiva, M. and Lerman, S.R. 1985. *Discrete Choice Analysis: Theory and Applications to Travel Demand.* Cambridge, MA: MIT Press.

Bennett, J. and V. Adamowicz. 2001a. "Some Fundamentals of Environmental Choice Modelling." In *The Choice Modelling Approach to Environmental Valuation,* edited by J. Bennett and R. Blamey. Cheltenham, UK: Edward Elgar.

Bennett, J., J. Rolfe and M. Morrison. 2001b. "Remnant Vegetation and Wetlands Protection: Non-market Valuation." In *The Choice Modelling Approach to Environmental Valuation,* edited by J. Bennett and R. Blamey. Cheltenham, UK: Edward Elgar.

Bergstrom, J.C., K.J. Boyle, and M. Yabe. 2004. "Trading Taxes vs. Paying Taxes to Value and Finance Public Environmental Goods." *Environmental & Resource Economics* 28: 533-549.

Blamey, R., J. Rolfe, J. Bennett and M. Morrison. 2000. "Valuing Remnant Vegetation in Central Queensland Using Choice Modelling." *The Australian Journal of Agricultural and Resource Economics* 44(3): 439-456.

Blamey, R., J. Gordon and R. Chapman. 1999. "Choice Modelling: Assessing the Environmental Values of Water Supply Options." *Australian Journal of Agricultural and Resource Economics* 43(3): 337-57.

Boyle, K. J. 2003. "Contingent Valuation in Practice." In *A Primer on Nonmarket Valuation*, edited by Patricia Champ, Kevin J. Boyle, and Thomas C. Brown. Dordrecht: Kluwer Academic Publishers.

Boyle, K., M. Morrison and L. Taylor. 2006. "Markets and the Incentive Compatibility of Choice Surveys." Working Paper, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University.

Brown, T., P. Champ, R. Bishop, and D. McCollum. 1996. “Response Formats and Public Good Donations.” *Land Economics* 72: 152-166.

Cameron, T.A., W.D. Shaw, and S.R. Ragland. 1999. “Nonresponse Bias in Mail Survey Data: Salience vs. Endogenous Survey Complexity.” In *Valuing Recreation and the Environmental: Revealed Preference Methods in Theory and Practice*, edited by J. Herriges and C. Kling. Cambridge: Edward Elgar.

Carlsson, F. and P. Martinsson. 2001. “Do Hypothetical and Actual Marginal Willingness to Pay Differ in Choice Experiments?” *Journal of Environmental Economics and Management* 41:179-192.

Carlsson, F., P. Frykblom and C.J. Lagerkvist. 2005. “Using Cheap Talk as a Test of Validity in Choice Experiments.” *Economics Letters* 89: 147-152.

Carson, K.S., S.M. Chilton and W.G. Hutchinson. "A 'Choice Experiment' Experiment," Talk presented at the 3rd World Congress of Environmental and Resource Economists, Kyoto, Japan, July 3-7, 2006.

Carson, R., T. Groves and M. Machina. 2000. “Incentive and Information Properties of Preference Questions.” Working Paper, Department of Economics, University of California, San Diego.

Carson, R., T. Groves, J. List, and M. Machina. 2004. “Probabilistic Influence and Supplemental Benefits: A Field Test of the Two Key Assumptions Underlying Stated Preferences.” Working Paper, Department of Economics, University of California, San Diego.

Cummings, R. and L. Taylor. 1999. “Unbiased Value Estimates for Environmental Goods: A Cheap Talk Design for the Contingent Valuation Method.” *American Economic Review* 89: 649-665.

Cummings, R., S. Elliott, G. Harrison, and J. Murphy. 1997. “Are Hypothetical Referenda Incentive Compatible?” *Journal of Political Economy* 3: 609-621.

Cummings, R.G., G.W. Harrison, and E. Rutstrom. 1995. “Homegrown Values and Hypothetical Surveys: Do Dichotomous Choice Questions Elicit Real Economic Commitments?” *American Economic Review* 85(1): 260-266.

Cummins, J. 2004. "Estimates of Potential Emission Reductions for the Knoxville Early Action Compact Area" Department of Civil and Environmental Engineering, The University of Tennessee.

Davis, R.K. 1963. "Recreation Planning as an Economic Problem." *Natural Resources Journal* 3(3): 239-249.

Delfino, R.J., Murphy-Moulton, A.M., and Becklake, M.R. 1998. "Emergency Room Visits for Respiratory Illnesses among the Elderly in Montreal: Association with Low Level Ozone Exposure." *Environmental Research* 76 (Section A): 67-77.

DeShazo, J.R., and G. Fermo. 2002. "Designing Choice Sets for Stated Preference Methods: The Effects of Complexity on Choice Consistency." *Journal of Environmental Economics and Management* 44:123-43.

Desqueyroux, H., Pujet, J.C., Prosper, M., Le Moullec, Y., Momas, I. 2002. "Effects of Air Pollution on Adults with Chronic Obstructive Pulmonary Disease." *Archives of Environmental Health* 57(6): 554-560.

Diamond, P.A. and J.A. Hausman. 1994. "Contingent Valuation: Is Some Number Better Than No Number?" *The Journal of Economics Perspectives* 8(4): 45-64.

Dillman, D.A. 2000. *Mail and Internet Surveys: The Tailored Design Method.* New York: John Wiley & Sons.

Energy Information Administration. 1999. "Environmental Regulations and Changes in Petroleum Refining Operations." Tancred C.M. Lidderdale.

Garrod, G. and K.G. Willis. 1999. *Economic Valuation of the Environment*. Cheltenham, UK: Edward Elgar.

Gibbard, A. 1973. "Manipulation of Voting Schemes: A General Result." *Econometrica* 41(3): 587–602.

Greene, W. H. 2000. *Econometric Analysis.* 4th edition. New Jersey: Prentice-Hall.

Haab, T.C., J-C. Huang, J.C. Whitehead. 1999. "Are Hypothetical Referenda Incentive Compatible? A Comment." *Journal of Political Economy* 107 (1): 186-196.

Hanemann, W.M. 1984. "Welfare Evaluations in Contingent Valuation Experiments with Discrete Responses." *American Journal of Agricultural Economics* 66(3): 332-41.

Hausman, J. and D. McFadden. 1984. "Specification Tests in Econometrics." *Econometrica* 46: 1251-1271.

Hellerstein, D. 2006. "The Mixed Logit Estimator: As Implemented in the DISCRETE program." Accessed at http://grbl.danielh.org/grbl2/.

Hensher, D.A. and Johnson, L.W. 1981. *Applied Discrete Choice Modeling.* Halsted Press. New York, New York.

Hensher, D.A. and W.H. Greene. 2003. "The Mixed Logit Model: The State of the Practice." *Transportation* 30: 133-176.

Hensher, D.A., J.M. Rose, and W.H. Greene. 2005. *Applied Choice Analysis: A Primer*. Cambridge University Press.

Höppe, P., A. Peters, G. Rabe, G. Praml, J. Lindner, G. Jakobi, G. Fruhmann, and D. Nowak. 2003. "Environmental Ozone Effects in Different Population Subgroups." *International Journal of Hygiene and Environmental Health* 206: 505-516.

Kinney, P.L. and Lippmann, M. 2000. "Respiratory Effects of Seasonal Exposures to Ozone and Particles." *Archives of Environmental Health* 55(3): 210-216.

Krewski, D. et al. 2000. "Reanalysis of the Harvard six cities study and the American Cancer Society study of particulate air pollution and mortality." Health Effects Institute.

Krinsky, I. and A. Robb. 1986. "A Non-Parametric Approach to the Estimation of Welfare Measures in Discrete Response Valuation Studies." *Land Economics* 66: 135-39.

Kuhfeld, W. 2003. *Marketing Research in SAS: Experimental Design, Choice, Conjoint and Graphical Techniques*. SAS 9.1 Edition, TS-689.

Kunzli, N., F. Lurmann, M. Segal, L. Ngo, J. Balmes, and I.B. Tager. 1997. "Association Between Lifetime Ambient Ozone Exposure and Pulmonary Function in College Freshmen—Results of a Pilot Study." *Environmental Research* 72: 8-23.

Lancaster, K. 1966. "A New Approach to Consumer Theory," *Journal of Political Economy* 74: 132-157.

Layton, D.F. and G. Brown. 2000. "Heterogeneous Preferences Regarding Global Climate Change." *The Review of Economics and Statistics* 82(4): 616-624.

List, J.A., P. Sinha, and M.H. Taylor. 2006. "Using Choice Experiments to Value Non-Market Goods and Services: Evidence from Field Experiments." *Advances in Economic Analysis & Policy* 6(2): 1-37.

List, J.A., R. Berrens, A. Bohara, and J. Kerkvliet. 2004. "Examining the Role of Social Isolation on Stated Preferences." *American EconomicReview* 4(3): 741-752.

Little, J. and R. Berrens. 2004. “Explaining Disparities Between Actual and Hypothetical Stated Values: Further Investigation Using Meta-Analysis.” *Economics Bulletin* 3(1): 1-13.

Liu, C., J. Herriges, and C. Kling. 2005. “The Consequences of Consequentiality.” Working Paper, Department of Economics, Iowa State University.

Louviere, J.J. 2001. “Choice Experiments: an Overview of Concepts and Issues.” In *The Choice Modelling Approach to Environmental Valuation,* edited by J. Bennett and R. Blamey. Cheltenham, UK: Edward Elgar.

Louviere, J.J. and D. Hensher. 1982. “On the Design and Analysis of Simulated Choice or Allocation Experiments in Travel Choice Modelling.” *Transportation Research Record* 890: 11-17.

Louviere, J.J. and G. Woodworth. 1983. “Design and Analysis of Simulated Consumer Choice or Allocation Experiments: an Approach Based on Aggregate Data.” *Journal of Marketing Research* 20: 350-367.

Luce, R.D. and P. Suppes. 1965. “Preference, Utility and Subjective Probability.” In *Handbook of Mathematical Psychology, vol. III*, edited by R.D. Luce, R.R. Bush and E. Galanter. New York: John Wiley.

Lusk, J. and T. Schroeder. 2004. “Are Choice Experiments Incentive Compatible? A Test with Quality Differentiated Beef Steaks.” *American Journal of Agricultural Economics* 86(2): 467-482.

McFadden, D. and K. Train. 2000 “Mixed MNL Models of Discrete Response.” *Journal of Applied Econometrics* 15: 447-470.

McKelvey, R.D. and P.C. Ordeshook. 1972. “A General Theory of the Calculus of Voting.” In *Mathematical Applications in Political Science,* edited by James F. Herndon and Joseph L. Bernd. Charlottesville: University Press of Virginia.

Mitchell, R.C. and R.T. Carson. 1989. *Using Surveys to Value Public Goods: the Contingent Valuation Method.* Washington, D.C: Resources for the Future.

Morey, E.R. and K.G. Rossmann 2003. "Using Stated-Preference Questions to Investigate Variations in Willingness to Pay for Preserving Marble Monuments: Classic Heterogeneity, Random Parameters, and Mixture Models." *Journal of Cultural Economics* 27: 215-229.

Morrison, M. and J. Bennett. 2004. "Valuing New South Wales Rivers for Use in Benefit Transfer." *Australian Journal of Agricultural and Resource Economics* 48(4): 591-611.

Murphy, J. J. and T.H. Stevens and D. Weatherhead. 2005. "A Meta-Analysis of Hypothetical Bias in Contingent Valuation." *Environmental & Resource Economics* 30(3): 313-325.

National Oceanic and Atmospheric Administration (NOAA). 1993. "Natural Resource Damage Assessments under the Oil Pollution Act of 1990." Federal Register 58:4601-4614.

National Parks Conservation Association Press Release. "Smokies Named to List of Endangered Parks: Air Pollution, Inadequate Funding Returns Popular National Park to the List." January 14, 2004.

National Parks Service. "Great Smoky Mountains National Park Management Folio #2: Air Quality." Accessed at http://www.nps.gov/grsm/pphtml/subenvironmentalfactors23.html, revised September 2001.

Nunes, P.A.L.D and C.M. Travisi. 2006. "Comparing Tax and Tax Reallocations Payments in Financing Rail Noise Abatement Programs: Results from a CE valuation study in Italy." Working Paper, Fondazione Eni Enrico Mattei.

Peters, J.M., E. Avol, W.J. Gauderman, W.S. Linn, W. Navidi, S.J. London, H. Margolis, E. Rappaport, H. Vora, H. Gong, and D.C. Thomas. 1999. "A Study of Twelve Southern California Communities with Differing Levels and Types of Air Pollution II. Effects on Pulmonary Function." *American Journal Of Respiratory And Critical Care Medicine* 159 (3): 768-775.

Poe, G.L., K.L. Giraud, and J.B. Loomis. 2005. "Computational Methods for Measuring the Difference of Empirical Distributions." *American Journal of Agricultural Economics* 87: 353–365.

Polome, P. 2003. "Experimental Evidence on Deliberate Misrepresentation in Referendum Contingent Valuation." *Journal of Economic Behavior & Organization* 52: 387-401.

Pope C.A. III, R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito, and G.D. Thurston. 2002. "Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution." *Journal of the American Medical Association* 287(9): 1132-41.

Powelson, Richard, "TVA wins latest tiff with EPA" *The Knoxville News Sentinel*, May 4, 2004.

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

Satterthwaite, M. 1975. "Strategy-Proofness and Arrow Conditions: Existence and Correspondence Theorems for Voting Procedures and Welfare Functions." *Journal of Economic Theory* 10(2): 187–217.

Taylor, L. 1998. "Incentive Compatible Referenda and the Valuation of Environmental Goods." *Agricultural and Resource Economics Review* 27: 132-139.

Taylor, L.O., M. McKee, S.K. Laury, and R.G. Cummings. 2001. "Induced-Value Tests of the Referendum Voting Mechanism." *Economics Letters* 71: 61-65.

Thurston, G.D., M. Lippmann, M.B. Scott, and J. M. Fine. 1997. "Summertime Haze, Air Pollution and Children with Asthma." *American Journal of Respiratory and Critical Care Medicine* 155: 654-660.

Train, K.E. 2003. *Discrete Choice Methods with Simulation.* Cambridge University Press.

U.S. Environmental Protection Agency. 1991. "Technical Guidance – Stage II Vapor Recovery Systems for Control of Vehicle Refueling Emissions at Gasoline Dispensing Facilities" EPA 450/3-91-022a.

U.S. Environmental Protection Agency. 1997a. National Ambient Air Quality Standards for Particulate Matter; Final Rule, Federal Register, Vol. 62, No. 138.

U.S. Environmental Protection Agency. 1997b. National Ambient Air Quality Standards for Ozone; Final Rule, Federal Register, Vol. 62, No. 138.

U.S. Environmental Protection Agency. 1999. "Smog—Who Does It Hurt? What You Need to Know About Ozone and Your Health." EPA-452/K-99-001.

U.S. Environmental Protection Agency. 1999. "Emission Facts." EPA420-F-99-040.

U.S. Environmental Protection Agency. 2001. "National Air Quality: 2000 - Status and Trends -Particulate Matter." EPA 454/K-01-002.

U.S. Environmental Protection Agency. 2005. "Proposed Rule to Implement the Fine Particle National Ambient Air Quality Standards." 40 Code of Federal Regulations, Part 51.

U.S. Environmental Protection Agency. 2007. "Effects of Acid Rain – Visibility," accessed at http://www.epa.gov/acidrain/effects/visibility.html, updated on February 3, 2007.

Vossler, C.A. and J. Kerkvliet. 2003. "A Criterion Validity Test of the Contingent Valuation Method: Comparing Hypothetical and Actual Voting Behavior for a Public Referendum." *Journal of Environmental Economics and Management* 45(3): 631-649.

Vossler, C.A. and M. McKee. 2006. "Induced-Value Tests of Contingent Valuation Elicitation Mechanisms." *Environmental & Resource Economics* 35: 137-168.

Ward, K.L. and J.W. Duffield. 1992. *Natural Resource Damages: Law and Economics*. New York: John Wiley & Sons, Inc.

APPENDICES

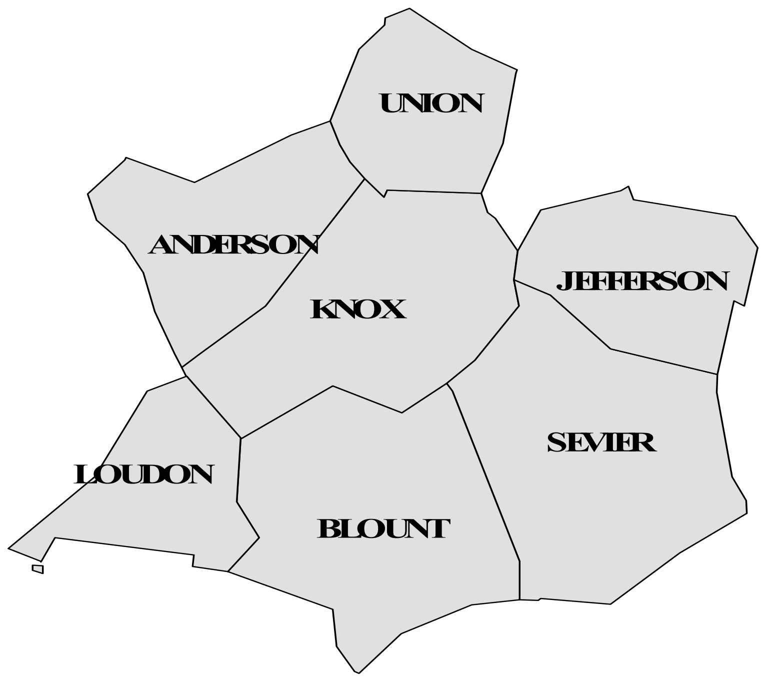
Appendix A. SAS Code

```
%macro where;
bad = (x5 & x1 = 2) + (x5 & x1 = 3);
%mend;
%mktex(3 3 3 3 3, n=3*3*3*3*3, seed = 238, restrictions = where)
data final(drop=i);
set design end=eof;
retain f1-f2 1 f3 0;
output;
if eof then do;
array x[8] x1-x5 f1-f3;
do i = 1 to 8; x[i] = i le 5 or i eq 8; end;
output;
end;
run;
%choiceff(data=final, model=class(x1-x5), nsets=18, maxiter=100,
flags=f1-f3, beta=zero);
%mktblock(data=best, nalts=3, nblocks=3, factors=x1-x5)
data key;
input visibility days gasoline IM Electricity;
format IM dollar5.0;
format Electricity dollar5.0;
datalines;
1 16 0 0 0
7 24 4 20 72
15 32 8 50 144
;
%mktlab (data=blocked, key = key);
Variable Mapping:
X1 : visibility
X2: days
X3: gasoline
X4: IM
X5: electricity

proc print; run;
```

Appendix B. Example of Knoxville Survey Instrument

Air Quality in the Knoxville Metropolitan Area And Your Household



Knoxville Metropolitan Area Air Quality Survey

Introduction

The University of Tennessee is undertaking a research project to help policymakers better understand the value of air quality in the Knoxville metropolitan area. We would like your opinion on the quality of air in this area, and if policies should be undertaken to address this issue. The major goal of this study is to provide accurate information to policymakers.

We would be grateful if you would take about 10-15 minutes to complete the attached survey that asks you to compare different policy options. This survey should be completed by an adult over eighteen years of age who participates in deciding household expenses. Your address was chosen at random. Your participation in this survey is completely voluntary. Should you choose to participate in our survey, your answers will remain confidential.

If you would like to enter a random drawing for one of ten $50 Wal-Mart gift certificates, please fill in the optional form at the end of the survey. This form will be immediately separated from returned, completed questionnaires. The University of Tennessee will release no information as to how any particular survey was answered.

Thank you in advance for taking the time to fill out and return this survey.

If you would like us to send you a copy of the results of the study after it is completed, or if you have questions or comments contact:

Jill Collins
Department of Economics
College of Business Administration
505A Stokely Management Center
University of Tennessee
Knoxville, TN 37996-0550
(865) 974-4193
jphilli9@utk.edu

SECTION A: General Issues

To start off, we would like to find out what you think about some general issues facing the Knoxville metropolitan area.

Question 1

Please circle the number on a scale from 1 to 5, with "1" indicating the issue is not at all important and "5" indicating the issue is very important to you:

	Not important → Very important				
Improving education in TN	1	2	3	4	5
Local environmental quality	1	2	3	4	5
Homeland security issues in TN	1	2	3	4	5
Health care in TN	1	2	3	4	5
Local economy/unemployment	1	2	3	4	5

Question 2

One of the issues mentioned in Question 1 was "Local environmental quality." Please circle the number on a scale from 1 to 5, with "1" indicating not at all important and "5" indicating very important to you:

	Not important → Very important				
Reducing water pollution	1	2	3	4	5
Reducing air pollution	1	2	3	4	5
Preventing global warming	1	2	3	4	5
Preserving natural areas	1	2	3	4	5

SECTION B: Air Quality Issues in the Knoxville Metro Area

Ozone and Particulate Matter Emissions

In a report by the American Lung Association titled, "State of the Air: 2003," the Knoxville metro area (Anderson, Blount, Knox, Loudon, Sevier and Union Counties) was listed as having the 9th worst air quality in the nation. Indeed, since 1999, the Knoxville metro area has had, on average, 40 days per year when the air quality was considered "unhealthy" by the Environmental Protection Agency (EPA). On these "unhealthy" days, the Knoxville area violated the EPA standard for a regulated pollutant. EPA sets these air quality standards to protect human health, using the best available scientific information. Violations occur in the Knoxville area because of excess ground-level ozone and particulate matter.

Ground-level Ozone

Unlike ozone in the upper atmosphere that protects against the sun's ultraviolet rays, ground-level ozone is a pollutant that has negative effects on health.

What is ground-level ozone and what causes it?

- Ground-level ozone is an airborne pollutant that occurs mostly in warmer, summer months
- Caused by a reaction between sunlight and two pollutants: nitrogen oxides and hydrocarbons
- Major sources are: motor vehicle exhaust, coal-fired power plants, industrial emissions, gasoline vapors, and chemical solvents

What are the effects of ground-level ozone?

- Wheezing, coughing, breathing difficulties during outdoor activities
- Aggravated asthma
- Increased susceptibility to respiratory illnesses such as bronchitis and pneumonia
- Children, the elderly, and people with respiratory difficulties are most susceptible, as well as those who spend a lot of time outdoors
- Repeated exposure may cause permanent lung damage

Particulate Matter

Particulate matter is the other major source of air quality problems in the Knoxville area.

What is particulate matter and what causes it?

- Particulate matter are suspended particles in the air including road dust, diesel soot, wood smoke, fly ash, and sulfate aerosols
- Major sources are: coal-fired power plants, industrial boilers, diesel and gas-powered vehicles, and wood stoves

What are the effects of particulate matter?

- Aggravated asthma
- Coughing and difficult or painful breathing
- Chronic bronchitis
- Reduced visibility (haze)
- Premature death

SECTION C: Policy Options for Improving Air Quality

Over the next few years, air quality will improve because of actions already taken by the federal government. These measures will likely improve local visibility by about one mile, and reduce the number of unhealthy days in the area from 40 to 24 unhealthy days per year. However, the Knoxville area is still projected to violate the EPA standards even with these national measures in place. Local air quality officials are currently deciding what **additional** pollution reduction measures are needed to meet the EPA air quality standards. Possible pollution reduction measures include:

- Vehicle inspection and maintenance
- Different blends of gasoline and diesel fuel
- Lower speed limits on rural interstates
- Additional regulations on power plants

We may need to undertake several of these actions to meet the EPA standards. As a result of these measures, your household may realize environmental and health benefits but at a cost to your household budget. The purpose of this survey is to find out what households think about some of these additional pollution reduction options.

Please consider the following benefits and costs associated with implementing one or more of these policy options:

POLICY BENEFITS

Improvement in Visibility

Currently the annual average visibility in the Great Smoky Mountains is 25 miles. Average visibility would be 93 miles under natural conditions with no pollution. Visibility is mostly affected by levels of particulate matter. If additional pollution reduction measures are undertaken by the Knoxville area, visibility could improve by up to 15 miles.

Improvement in Healthy Air Quality Days

From 1999 – 2003, the Knoxville metro area averaged approximately 40 unhealthy air quality days per year. Most of the unhealthy days in the Knoxville area have been due to ozone pollution. If the Knoxville area takes additional measures to reduce pollution, the number of healthy air quality days could be improved by up to 32 days, which would make the average number of unhealthy days about 8 days per year.

POLICY COSTS

Increase in Gasoline Price

Some pollution reduction measures would require cleaner-burning fuel such as reformulated gasoline. Reformulated gasoline meets the power requirements of all gasoline vehicles, but costs more to produce. Other measures that could affect the price of gasoline would be the use of special equipment at gas stations to recover vapor emissions. The possible range of price increases per gallon of gasoline is from zero (no actions relating to gasoline are taken) to 8 additional cents per gallon. For a small car averaging 22 miles per gallon and driven 12,000 miles per year, a 4-cent price increase would cost about $22 per year, while an 8-cent increase would cost $44 per year. For a large vehicle averaging 12 miles per gallon and driven 12,000 miles per year, a 4-cent price increase would cost $40 per year, while an 8-cent increase would cost $80 per year.

Vehicle Inspection and Maintenance

A vehicle inspection and maintenance program would test emissions of all registered passenger cars and trucks each year. If a vehicle fails the emissions test, it would need to be repaired and re-tested before the owner could renew registration. The yearly inspection fee is $20, and if a car fails, the average repair cost is $145. Most vehicles do not need to be repaired each year. The range of costs per vehicle for this program is from zero (no vehicle inspection program) to $50 per year (average repair costs over the lifetime of the vehicle plus the yearly inspection fee).

Increase in Electricity Bill

Power plants emit pollutants that contribute to both ozone and particulate matter pollution. To reduce emissions, power plants may need to purchase control equipment, which in turn could lead to increases in the monthly electricity bill for your household. Possible increases in a household's electricity bill range from zero (no additional controls are required of power plants) to $12 extra per month.

SECTION D: Your Preferred Policy Options

This section will present various combinations of the benefits and costs of achieving air quality goals in the Knoxville metro area. Over the next six questions, you are asked to choose the option that you most prefer. Remember, if a particular policy option is implemented, you would be required to pay the amount identified by the cost attributes, and will have less to spend on other goods and services.

The "No Local Action" option refers to the situation where no additional pollution reduction measures are taken by the Knoxville area, and the area will remain in violation of the EPA standards. Because the area will be violating EPA standards, the Knoxville area may also lose federal highway funds and future business development under the "No Local Action" option.

Please note that the number of healthy days can be improved without improving visibility because of the different effects of ozone and particulate matter.

While the following six questions may seem similar, your responses to **all** questions are extremely important for our policy analysis.

Sample Question

Suppose the following three policies were the only options available for achieving air quality goals in the Knoxville metro area. Please indicate which policy you prefer by checking one of the boxes below.

Policy Benefits and Costs	**Local Policy A**	**Local Policy B**	**Policy C: No Local Action**
Visibility improvement	1 mile	7 miles	1 mile
Healthy days improvement	32 days	16 days	16 days
Gasoline price increase per gallon	0 cents	8 cents	0 cents
Vehicle inspection cost per year	$50	$20	$0
Increase in electric bill per year	$144	$72	$0

I would choose: ☑ Policy A ☐ Policy B ☐ Policy C

If you choose **Policy A**, you are indicating that you would prefer the policy with these outcomes:

- **Visibility improvement: 1 mile.** Under this policy option, average annual visibility would improve from 25 miles to 26 miles.
- **Healthy days improvement: 32.** Under this policy option, the number of healthy days would improve by 32 days. Instead of 40 unhealthy days per year, there would only be 8 unhealthy days per year on average.
- **Gasoline price increase per gallon: 0 cents.** This policy option does not include changes to gasoline, so gasoline prices would be unaffected.
- **Vehicle inspection cost per year: $50.** Emissions testing is a part of this policy option. The cost represents the testing fee ($20) plus the average payment if a vehicle fails inspection, spread out over a five-year lifetime of the vehicle ($30).
- **Increase in electric bill per year: $144.** This policy option would require power plants to install additional equipment, and lead to electricity price increases of $12 per month, or $144 per year.

Policy B has a similar interpretation, while **Policy C** represents the “No Local Action” scenario where benefits occur because of actions already taken by the federal government. For this reason **Policy C** has no new costs to households, but the area may lose future business development as a result of violating air quality standards.

Question 3

Suppose the following three policies were the only options available for achieving air quality goals in the Knoxville metro area. Please indicate which policy you prefer by checking one of the boxes below.

Policy Benefits and Costs	**Local Policy A**	**Local Policy B**	**Policy C: No Local Action**
Visibility improvement	7 miles	15 miles	1 mile
Healthy days improvement	32 days	24 days	16 days
Gasoline price increase per gallon	0 cents	8 cents	0 cents
Vehicle inspection cost per year	$20	$0	$0
Increase in electric bill per year	$144	$72	$0

I would choose: ☐ Policy A ☐ Policy B ☐ Policy C

Question 4

Suppose the following three policies were the only options available for achieving air quality goals in the Knoxville metro area. Please indicate which policy you prefer by checking one of the boxes below.

Policy Benefits and Costs	**Local Policy A**	**Local Policy B**	**Policy C: No Local Action**
Visibility improvement	1 mile	15 miles	1 mile
Healthy days improvement	32 days	24 days	16 days
Gasoline price increase per gallon	4 cents	0 cents	0 cents
Vehicle inspection cost per year	$0	$20	$0
Increase in electric bill per year	$72	$144	$0

I would choose: ☐ Policy A ☐ Policy B ☐ Policy C

Question 5

Suppose the following three policies were the only options available for achieving air quality goals in the Knoxville metro area. Please indicate which policy you prefer by checking one of the boxes below.

Policy Benefits and Costs	**Local Policy A**	**Local Policy B**	**Policy C: No Local Action**
Visibility improvement	15 miles	7 miles	1 mile
Healthy days improvement	32 days	32 days	16 days
Gasoline price increase per gallon	4 cents	0 cents	0 cents
Vehicle inspection cost per year	$0	$20	$0
Increase in electric bill per year	$144	$72	$0

I would choose: ☐ Policy A ☐ Policy B ☐ Policy C

Question 6

Suppose the following three policies were the only options available for achieving air quality goals in the Knoxville metro area. Please indicate which policy you prefer by checking one of the boxes below.

Policy Benefits and Costs	**Local Policy A**	**Local Policy B**	**Policy C: No Local Action**
Visibility improvement	15 miles	1 mile	1 mile
Healthy days improvement	16 days	32 days	16 days
Gasoline price increase per gallon	8 cents	4 cents	0 cents
Vehicle inspection cost per year	$0	$50	$0
Increase in electric bill per year	$72	$0	$0

I would choose: ☐ Policy A ☐ Policy B ☐ Policy C

Question 7

Suppose the following three policies were the only options available for achieving air quality goals in the Knoxville metro area. Please indicate which policy you prefer by checking one of the boxes below.

Policy Benefits and Costs	**Local Policy A**	**Local Policy B**	**Policy C: No Local Action**
Visibility improvement	15 miles	1 mile	1 mile
Healthy days improvement	16 days	32 days	16 days
Gasoline price increase per gallon	0 cents	4 cents	0 cents
Vehicle inspection cost per year	$20	$0	$0
Increase in electric bill per year	$72	$0	$0

I would choose: ☐ Policy A ☐ Policy B ☐ Policy C

Question 8

Suppose the following three policies were the only options available for achieving air quality goals in the Knoxville metro area. Please indicate which policy you prefer by checking one of the boxes below.

Policy Benefits and Costs	**Local Policy A**	**Local Policy B**	**Policy C: No Local Action**
Visibility improvement	7 miles	1 mile	1 mile
Healthy days improvement	32 days	32 days	16 days
Gasoline price increase per gallon	0 cents	4 cents	0 cents
Vehicle inspection cost per year	$50	$20	$0
Increase in electric bill per year	$144	$72	$0

I would choose: ☐ Policy A ☐ Policy B ☐ Policy C

SECTION E: About You and Your Household

In this section of the questionnaire, we would like to ask you a few questions about yourself and your family background to make sure the people we are surveying are representative of the Knoxville metro area population. **All answers will be kept in strict confidentiality.**

Question 9

(a) Have you read any news articles within the past year about Knoxville's air quality?

☐ Yes

☐ No

(b) If you responded "yes," did the news articles give a favorable or unfavorable view of air quality in the Knoxville metro area?

☐ Favorable

☐ Unfavorable

(c) In your opinion, were the news articles you read accurate?

☐ Yes

☐ No

Question 10

(a) Including yourself, how many people live in your household? ____________

(b) How many of these people (including yourself) are members of your family? ______

(c) How many of these people (including yourself) are 16 years of age or older? _______

(d) How many of these people are 6 years of age or younger? ____________

Question 11

How old are you? ____________ years old.

Question 12

What is your gender?

Male ☐

Female ☐

Question 13

What is the highest level of education you have completed?

Elementary or some High School ☐

High School Graduate/GED ☐

Trade or Vocational Certification ☐

Some College/Associate Degree ☐

College Graduate ☐

Post-Graduate Degree ☐

Question 14

If you are a registered voter, with which political party do you most identify?

Democratic ☐

Republican ☐

Green Party ☐

Independent ☐

Libertarian ☐

Question 15

What is your race?

Asian ☐

Black ☐

Hispanic ☐

White ☐

Other (please specify) ______________________________

Question 16

What is your current marital status?

☐ Married ☐ Divorced

☐ Single ☐ Widowed

Question 17

(a) Because income is often a very good indicator of perspectives on outdoor recreation and perspectives on community improvements, we would like to ask you a sensitive question. Please remember your name will not be used in any way relating to your responses. What was your approximate 2003 household income, including income from interest and dividend income and/or retirement income before taxes?

Less than $10,000 ☐

$10,000 to $19,999 ☐

$20,000 to $29,999 ☐

$30,000 to $39,999 ☐

$40,000 to $49,999 ☐

$50,000 to $59,999 ☐

$60,000 to $69,999 ☐

$70,000 to $79,999 ☐

$80,000 to $89,999 ☐

$90,000 to $99,999 ☐

More than $100,000 ☐

(b) Was this yearly income unusual in any way?

☐ No

☐ Yes, unusually high

☐ Yes, unusually low

Question 18

Please describe your employment status.

☐ Employed full time ☐ Unemployed, between jobs

☐ Employed part time ☐ Full time student ☐ Retired

Question 19

Do you now, or have you ever belonged to a group that promotes environmental causes?

☐ Yes

☐ No

Question 20

(a) Does anyone in your household have asthma or other respiratory diseases such as Chronic Obstructive Pulmonary Disease (COPD)?

☐ Yes

☐ No

(b) Do you know someone outside your household in the Knoxville area who has asthma or other respiratory diseases?

☐ Yes

☐ No

Question 21

Have you ever lived in an area that requires vehicle emissions testing?

☐ Yes

☐ No

Question 22

(a) How many passenger cars does your household own/lease? ____________

(b) How many sport utility vehicles or trucks does your household own/lease?
____

(c) Do you own any vehicles that are at least five years old?

☐ Yes

☐ No

Question 23

Approximately how many miles do you typically drive per year? ___________ miles

Question 24

(a) Have you visited the Great Smoky Mountain National Park within the last year?

☐ Yes

☐ No

(b) If you answered "Yes," approximately how many times did you visit last year?

_______ number of visits

Question 25

How long do you plan on living in the Knoxville metro area?
____

Question 26

How much is your typical electricity bill per month?
____

Question 27

Which policy benefit do you think is more important?

☐ Visibility improvement

☐ Healthy days improvement

Question 28

Please rank the policy payment methods from "1" to "3," with "1" representing the method you would most support if placed on a ballot:

☐ Vehicle inspection and maintenance

☐ Electricity bill

☐ Gasoline price

<u>Your comments will be appreciated, either here or in a separate envelope.</u>

All your answers will be kept strictly confidential

<u>Thank you very much for your assistance. We greatly appreciate your effort and time.</u>

Please return your questionnaire in the enclosed envelope to:

Jill Collins
Department of Economics
The University of Tennessee
505A Stokely Management Center
Knoxville TN 37996

Appendix C. Sample Selection Bias

Because of the low response rate to the survey, an analysis of sample selection was attempted using a two-stage, Heckman type selection model. The survey was mailed to a random sample of Knoxville area households in the hope that respondents would accurately reflect the preferences of the entire population. If the only differences between respondents and the underlying population are based on observed factors such as age, gender, education, etc., then the model can provide consistent estimates of willingness to pay by simply using the population metrics. If, on the other hand, preferences of survey respondents systematically differ from non-respondents based on unobservable factors, estimates of willingness to pay will be biased (Cameron et al, 1999).

The bias from sample selection arises from an incidentally truncated sample. Suppose that an individual derives utility from completing the survey (net of any costs associated with survey completion) and that this utility is determined by a vector of observable factors w and a stochastic component, u. This propensity to respond to the survey cannot be observed by the analyst, who can only observe if the survey is completed. Responses are only gathered for individuals whose latent net utility from completing the survey is greater than zero.

Let $z^*{}_n = \theta' w_n + u_n$ describe the latent utility function of individual n that also serves as the model selection equation. Since $z^*{}_n$ is unobservable, the binary outcome, z_n, is equal to one if the survey is returned and zero otherwise. Following Heckman

(1979), this selection equation can be estimated with a probit model, assuming that u_n ~ N(0,1). The probability that z_n =1 is $\Phi(\theta' w_n)$ and the probability that z_n =0 is 1-$\Phi(\theta' w_n)$ where $\Phi(\theta' w_n)$ describes the cumulative density function for a variable with a normal distribution evaluated at $\theta' w_n$. Let y_n represent the primary outcome of interest (i.e., the choice of policy option in the current study) that is observed only if z_n =1. Following Greene (2005), if $y_n = \beta' x_n + \varepsilon_n$ and u_n and ε_n ~ bivariate normal [$0,0,1,\sigma_\varepsilon,\rho$], then $\mathrm{E}[y|z_n = 1] = \beta' x_n + \rho\sigma_\varepsilon \lambda_n(\theta' w_n)$ and $\mathrm{Var}[y|z_n = 1] = \sigma_\varepsilon{}^2[1-\rho^2\delta_n(\theta' w_n)]]$ where λ_n (the inverse mills ratio) $= \dfrac{\phi(\theta' w_n)}{\Phi(\theta' w_n)}$ and $\delta_n = \lambda_n(\lambda_n - \theta' w_n)$.

Essentially the bias from ignoring the issue of sample selection results from omitting a relevant variable, the inverse mills ratio. The Heckman two-stage model includes the inverse mills ratio constructed from the selection equation as an additional variable in the second stage linear regression model to correct for any selection bias. However, this model is not readily applicable to a second stage equation with non-normal errors such as the mixed logit specification. Following Hellerstein (2006), instead of assuming that u_n is correlated with the extreme value error of each alternative, this model assumes that u_n and $\tilde{\beta}_n$ (the stochastic, individual and observation-specific component of a random parameter) have a bivariate normal distribution. A random parameter in the two-stage mixed logit model is therefore modeled as

$$\beta = \hat{\bar{\beta}} + \hat{\tilde{\beta}}_n \hat{\rho} \ \lambda_n + \left(\hat{\tilde{\beta}}_n \sqrt{1-\hat{\rho}^2 \ \delta_n} \right) nor$$

where $\hat{\bar{\beta}}$ is the estimated value of the mean of the random parameter, $\hat{\tilde{\beta}}_n$ is the estimated standard deviation of the random parameter, $\hat{\rho}$ is the estimated correlation between u_n and $\tilde{\beta}_n$, *nor* is a random number drawn from the standard normal distribution and λ_n and δ_n are given by the first stage estimation. While this model can correct for correlation among the unobservable factors in the selection equation and in the stochastic elements of the random parameters, it constrains the specification of the random parameters to normal distributions in order to utilize the bivariate normal distribution. Also, in a model with multiple random parameters, the correlations between u_n and the stochastic element of each random parameter are assumed to be independent.

To estimate the model, socioeconomic characteristics were gathered on the entire mailing sample through use of the 2000 U.S. Census at the zip code level. While the ideal would be to have specific data on all recipients at the household level, aggregation at the zip code level may still capture some heterogeneity of survey recipients if neighborhoods are relatively homogenous. A total of 63 zip codes were used in the model, with respondents distinguished from non-respondents by the completion of the Wal-Mart raffle form returned with the completed survey (approximately 291 respondents, 72% of returned surveys, completed this form). Non-respondent zip codes were known from the original mailing.

The vector w_n includes Census zip code characteristics (see Table A.1) suggested by Cameron et al (1999) in their selection model related to a mail survey on water-based recreational participation within the Columbia River systems, in addition to a dummy variable equal to one if the household resides in Knox County.

Table A.1 Variables Used in Selection Model

Variable	Definition	Sample Mean (std. dev.)
White	Proportion white	0.90 (0.12)
Language isolated	Proportion language-isolated	0.01 (0.01)
Longtime resident	Proportion long-term resident (at least 5 years)	0.94 (0.01)
Long commute	Proportion with long commute (at least 20 minutes)	0.54 (0.11)
College degree	Proportion college-educated	0.22 (0.13)
Median income	Median household income ($000s)	37.59 (10.79)
Retirement income	Proportion with retirement income	0.18 (0.04)
Knox	=1 if household resides in Knox County, 0 otherwise	0.68 (0.47)

All variables defined according to relevant zip code area.

Hellerstein's model was run for the identified 291 respondents, assuming that un has a bivariate normal distribution with the stochastic element of the three random parameters: the alternative specific constant, visibility and healthy days. The Gauss-based program developed by Hellerstein is still in its initial stages of development, and consequently only preliminary results are presented here. The first stage selection equation is presented in Table A.2. Marginal effects are shown for ease of interpretation. Only the presence of retirement income and Knox County residence appear to significantly affect the probability of returning the survey. The dominant effect comes from retirement income, with each percentage increase in the proportion of residents receiving retirement income increasing the likelihood to respond by 49.2%. Residence in Knox County increases the propensity to respond by 3.7%. However, the model does not seem to provide a good fit for the data, with a likelihood ratio index of only 0.008.

Table A.2 Selection Model Results

Variable	Marginal Effect (Standard Error)
White	-0.057
	(0.074)
Language isolated	-0.114
	(1.325)
Longtime resident	-0.300
	(0.768)
Long commute	0.099
	(0.101)
College degree	0.090
	(0.121)
Median income	-0.000
	(0.001)
Retirement income	0.492**
	(0.216)
Knox	0.037**
	(0.017)
Model Statistics	
Log-Likelihood	-864.506
Likelihood ratio index	0.008
N	2289

Dependent variable = 1 if responded to the survey, 0 otherwise. *,**, and *** denote parameter is statistically different from zero at the 10%, 5% and 1% significance levels, respectively. The likelihood ratio index provides the percentage increase in the log-likelihood function relative to the model estimated with constants only.

Second stage results could not be obtained due to a lack of model convergence. Further testing will be conducted with the ongoing development of the software.

Appendix D. Trichotomous Choice Vague with Regulator Treatment

Instructions

Welcome

This is an experiment about decision making. Funds for this research have been provided by a grant. Please pay careful attention to the instructions. By following them carefully, you may earn considerable money that will be paid to you in cash at the end of the experiment.

You will never be asked to reveal your identity to anyone during the course of the experiment. Your name will never be associated with any of your decisions. In order to keep your decisions private, please do not reveal your choices to any other participant.

We have some simple yet very important rules:

- Do not communicate with anyone in the room except a coordinator.
- Please do not hesitate to ask questions. If you have a question, raise your hand and a coordinator will answer it.

In this experiment we are giving you a starting balance of $7. Your earnings will ultimately depend on two things. First, before we get to the main experiment you will go through some examples. You will be paid by correctly performing calculations within the context of these examples. Second, your earnings will depend on the choices that you and the other participants make in the experiment.

We will read the instructions together; please follow along on your copy.

The Setting

In this experiment you will be presented with six choice questions. For each question you will be asked to select among a set of options. Each option specifies an amount of two goods that would be provided and the total cost associated with their provision. We have labeled the two goods as Red and Blue. You value both Red and Blue goods in the sense that they are worth money to you if provided. Others in the experiment value these goods as well, although values differ across people.

You have all been given a Value Card that shows **your** per-unit value of Red and Blue goods. In other words, your Value Card tells you how much money you receive, per unit, when these goods are provided. Know that values differ across people so do not show anyone your card. Using your Value Card, you will be selecting options that you prefer, depending on how many units of Red and Blue goods are provided in each option and how much the option costs.

Example choice question

In the experiment you will face choice questions similar to that in the following example.

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	3 units	2 units	1 unit
Number of Blue goods provided	1 unit	3 units	1 unit
Total cost per person	$4	$6	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

If you choose **Option A**, you are indicating that you would prefer the option with these outcomes:

- **Number of Red goods provided: 3 units.**
- **Number of Blue goods provided: 1 unit.**
- **Total cost per person: $4.**

If you choose **Option B**, you are indicating that you would prefer the option with these outcomes:

- **Number of Red goods provided: 2 units.**
- **Number of Blue goods provided: 3 units.**
- **Total cost per person: $6.**

If you choose **Option C,** you are indicating that you would prefer the "Status Quo" option with these outcomes:

- **Number of Red goods provided: 1 unit.**
- **Number of Blue goods provided: 1 unit.**
- **Total cost per person: $0.**

Based on your choice and the choices of the other participants, one of the options will be implemented for everyone in the experiment. Your earnings for the implemented option will be:

	Your per-unit value of the Red good × the number of Red goods provided
+	Your per-unit value of the Blue good × the number of Blue goods provided
–	Total cost per person
+	Your starting balance of $7
$	**Your earnings**

Understanding Earnings Calculations

It is very important for our research that you understand how your earnings will be determined in the experiment. We ask that you please answer the three questions below, using the following Example Value Card. Please note that this Example Value Card is different from the Value Card that you will use in the experiment. We will pay you **$2** if you correctly answer all questions.

EXAMPLE VALUE CARD

Your value of Red goods: $2 per unit

Your value of Blue goods: $2 per unit

For any option that is implemented, you will:

- Pay the cost of the option
- Receive your value of $2 for every unit of the Red good provided
- Receive your value of $2 for every unit of the Blue good provided
- Receive your starting balance of $7

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Example Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	2 units	1 unit	1 unit
Number of Blue goods provided	1 unit	3 units	1 unit
Total cost per person	$8	$6	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

1. Suppose that Option A is implemented for the group. Using the Example Value Card, what will your earnings be if Option A is implemented?

_______ × _______ units of Red goods
\+ _______ × _______ units of Blue goods
– ________ Total cost per person
\+ Your starting balance of $7

EARNINGS *$* _______________

2. Now suppose that instead Option B is implemented for the group. Using the Example Value Card, what will your earnings be if Option B is implemented?

_______ × _______ units of Red goods
\+ _______ × _______ units of Blue goods
– ________ Total cost per person
\+ Your starting balance of $7

EARNINGS *$* _______________

3. Finally, now suppose that instead Option C is implemented for the group. Using the Example Value Card, what will your earnings be if Option C is implemented?

	_______ × _______ units of Red goods
+	_______ × _______ units of Blue goods
–	________ Total cost per person
+	Your starting balance of $7
EARNINGS *$*	_______________

Please stop and wait for the coordinator to go over the calculations with you.

Determining which Option is Implemented

Based on the option that you select and the options that others in this experiment select, we will implement one and only one of the options for everyone in the group. We will do this using poker chips and a bag as follows. For each person that selects Option A we will place a white chip in the bag. For each person that selects Option B we will place a black chip in the bag. For each person that selects Option C we will place a green chip in the bag. In addition, the experiment coordinators will place a certain number of blue chips in the bag. The number of blue chips the coordinators will place in the bag will equal the number of people in the group. We will then have a volunteer pull a chip out of the bag. The option that corresponds with the color of poker chip chosen will be implemented. The coordinators have written down on a piece of paper the option that corresponds to a blue chip. This will be revealed to you in the event a blue chip is drawn from the bag.

Here is an example. Suppose there are 20 people in the group. Three people select Option A so we put 3 white chips in the bag. Seven people choose Option B so we put 7 black chips in the bag, and the rest choose Option C so we put 10 green chips in the bag. Because there are 20 people in the group, the coordinators will put 20 blue chips in the bag. If a white chip is drawn, Option A is implemented, if a black chip is drawn Option B is implemented, if a green chip is drawn Option C is implemented, and finally, if a blue chip is drawn the coordinators will reveal the option on the piece of paper that will be implemented.

Earning money in this experiment

You will be paid for only one of the questions. After all six choice questions have been answered, we will ask a volunteer to roll a six-sided die. The number rolled will correspond to the question you will be paid for.

For this randomly selected question, we will use the procedure above to determine which option is implemented. Your earnings will be calculated by subtracting the cost of the selected option from your value of the units provided, plus your starting balance of $7. Your value of the units provided will equal your per-unit value of the Red good multiplied by the number of Red units provided, plus your per-unit value of the Blue good multiplied by the number of Blue units provided.

Please note that you must pay the amount associated with the policy option that is drawn from the bag of chips, even if you selected another option while answering the choice question.

Just about ready…

For all six choice questions there will be a "Status Quo" option where one unit of Red and one unit of Blue are provided at no additional cost to each person. The characteristics of the other options will vary from one question to the next.

For a particular Question, everyone faces the same options as you do. However, everyone will not see the questions in the same order. Finally, keep in mind that while the following six questions may seem similar, your responses to **all** questions are extremely important since any one of the six questions may be chosen by the roll of the die.

Question 5

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	1 unit	2 units	1 unit
Number of Blue goods provided	3 units	1 unit	1 unit
Total cost per person	$4	$2.50	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

In the event that this question is selected to determine your earnings, please use the space below to calculate your earnings.

Option implemented: _________

Your earnings based on this implemented Option:

_______ × _______ units of Red goods

\+ _______ × _______ units of Blue goods

– ________ Total cost per person

\+ Your starting balance of $7

EARNINGS $ ________________

Question 2

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	2 units	1 unit	1 unit
Number of Blue goods provided	1 unit	3 units	1 unit
Total cost per person	$4	$2.50	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

In the event that this question is selected to determine your earnings, please use the space below to calculate your earnings.

Option implemented: _________

Your earnings based on this implemented Option:

_______ × _______ units of Red goods

\+ _______ × _______ units of Blue goods

– ________ Total cost per person

\+ Your starting balance of $7

EARNINGS $ ________________

Question 3

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	1 unit	2 units	1 unit
Number of Blue goods provided	3 units	3 units	1 unit
Total cost per person	$2.50	$4	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

In the event that this question is selected to determine your earnings, please use the space below to calculate your earnings.

Option implemented: _________

Your earnings based on this implemented Option:

_______ × _______ units of Red goods

\+ _______ × _______ units of Blue goods

– ________ Total cost per person

\+ Your starting balance of $7

EARNINGS $ ________________

Question 6

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	2 units	2 units	1 unit
Number of Blue goods provided	1 unit	3 units	1 unit
Total cost per person	$2.50	$4	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

In the event that this question is selected to determine your earnings, please use the space below to calculate your earnings.

Option implemented: _________

Your earnings based on this implemented Option:

_______ × _______ units of Red goods

\+ _______ × _______ units of Blue goods

– ________ Total cost per person

\+ Your starting balance of $7

EARNINGS $ ________________

Question 1

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	2 units	2 units	1 unit
Number of Blue goods provided	3 units	1 unit	1 unit
Total cost per person	$4	$2.50	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

In the event that this question is selected to determine your earnings, please use the space below to calculate your earnings.

Option implemented: _________

Your earnings based on this implemented Option:

_______ × _______ units of Red goods

\+ _______ × _______ units of Blue goods

– ________ Total cost per person

\+ Your starting balance of $7

EARNINGS $ ________________

Question 4

Suppose the following three options were the only options available to produce Red and Blue goods. Please examine your Value Card and indicate which option you prefer by checking one of the boxes below.

	Option A	**Option B**	**Option C: Status Quo**
Number of Red goods provided	2 units	1 unit	1 unit
Number of Blue goods provided	1 unit	3 units	1 unit
Total cost per person	$2.50	$4	$0

I choose: ☐ Option A ☐ Option B ☐ Option C

In the event that this question is selected to determine your earnings, please use the space below to calculate your earnings.

Option implemented: _________

Your earnings based on this implemented Option:

_______ × _______ units of Red goods

\+ _______ × _______ units of Blue goods

– ________ Total cost per person

\+ Your starting balance of $7

EARNINGS $ ________________

QUESTIONNAIRE

Please answer the following questions. This is for our information only and your participation is optional. Your responses will only be associated with your subject identification number and will in no way affect your earnings.

1. What is your age? ____________

2. What is your gender? (*circle one*) Male Female

3. What is your major? ______________________________________

4. What are you classified as for the current or upcoming semester? (*circle one*)

Freshman	Sophomore	Junior	Senior
Master's Student	Law Student	Doctoral Student	
Other ____________			

5. What is your student status for the current semester? (*circle one*)

Full-time student	Part-time student (taking fewer than 12 hours/sem)
Not a student	Other (please specify)

6. How many economics courses have you taken at the university level? (include this term) _____________________

7. Have you previously participated in an economics experiment? (*circle one*) YES NO

8. On a scale of 1 ("poorly understood) to 5 ("well understood"), please indicate how well you understood the experiment instructions:
   (*circle one*) 1 2 3 4 5

9. Have you ever voted in a state or national election (either in the U.S. or in your home country)? (*circle one*) YES NO

10. In your previous economics classes, have you studied the economics of public goods? (*circle one*) YES NO

11. How would you best describe your current employment situation? (*circle one*)

    Full-time employment outside of the university
    Part-time employment outside of the university
    Student only
    Work at the university/research assistantship

VITA

Jill Phillips Collins was born in Knoxville, TN on April 10, 1975. She was raised in Rogersville, TN and graduated from Cherokee High School in 1993. She received her Bachelor of Arts in Economics from Wellesley College in 1997. After working at PricewaterhouseCoopers in Phoenix, AZ and the U.S. Environmental Protection Agency in Washington, DC, she returned to academia to receive her M.S. in Economics at Arizona State University in 2002 and her Ph.D. in Economics from the University of Tennessee at Knoxville in 2007. Jill will be joining the faculty of Eckerd College in St. Petersburg, FL as Assistant Professor of Economics in August 2007.