WESTERN REGIONAL RESEARCH PUBLICATION

W-1133
Benefits and Costs of Resource Policies Affecting Public and Private Land

Papers from the Annual Meeting
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Eighteenth Interim Report
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Introduction

This volume contains most of the papers presented at the of the 2005 Annual Meeting of W-1133, The Western Regional Project: “Benefits and Costs of Resource Policies Affecting Public and Private Land.”

As with previous years, the meetings were well attended. There were 45 attendees representing academic faculty, graduate students, Federal government employees, and the private sector.

The papers presented at the meetings and those contained in this volume, represent the diverse nature of the current research addressing the W-1133 project objectives, and indicate the collaboration that is occurring between different project participants.

The success of the 2005 W-1133 meetings were in large part due to the assistance of the executive officers: Ron Flemming (Secretary Treasurer) and Klaus Moltner (Vice President). I am thankful to Paul Jakus (Utah State) for assisting with the audio-visual equipment and conference planning. Finally, the participation of Don Snyder (Utah State) and Fen Hunt (USDA-CSREES) as our advisor and administrative liaison, respectively, is much appreciated.

It was a pleasure and an honor to serve as President of the W-1133 in 2005.

Sincerely yours,

Steven Shultz
North Dakota State University

W-1133 Project Objectives:

1. Estimate the Economic Benefits of Ecosystem Management of Forests and Watersheds.
2. Estimate the Economic Value of Changing Recreational Access for Motorized and Non-Motorized Recreation.
3. Calculate the Benefits and Costs of Agro-Environmental Policies.
4. Estimate the Economic Values of Agricultural Land Preservation and Open Space.

W-1133 Participating Institutions:

AL, AZ, CA-A, CA-B, CA-D, CTS, GA, IA, KY, LA, ME, MD, MA, MI, NH, NYC, ND, OH, OR, PA, TX, UT, WA, WVA, and WY.

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2005 W-1133 Meetings
Salt Lake City

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Program

Final Agenda: 2005 W1133 Meetings, Salt Lake City, Day 1

Day/Time/Authors	W1133 Objective	Sessions, Moderators and Paper Titles
Monday February 14		
8.00-9:15		**Session 1: HVM- Farmland Amenities. (**Klaus Moeltner)
John Bergstrom (U of GA), R. Ready U of PA	Ag Land (#4)	What Have We Learned from 20 Years of Farmland Amenity Valuation Research And What Does it All Mean for Land Use Policy?
James Wasson, McLeod, Bastian, WY	Ag Land (#4)	Hedonic Pricing of WY Ag. Lands and Property Tax Assessments: Implications for Open Space Protection
Noel Netusil (Oregon)	Forests (#1)	The Economic Benefits of Large Patches of Tree Canopy in Portland, Oregon.
9.15- 10:30		**Session 2: Methodological CVM Issues Part I. (**Ron Flemming)
John Duffield (MT)		Response format effects in a cash/hypothetical contingent valuation experiment
Robert Johnston, (RI) D Joglekar		Validating Choice Experiments Using Binding Public Referenda: Implications for SP Valuation
10:50-12:30		**Session 3: Conservation Issues.** (John Loomis)
Joe Kerkvliet et al (OR)	Forests (#1)	Economic Consequences of Reserving Federal Land for Biodiversity Protection in the U.S. Pacific NW.
Randy Rosenberger (OR), English (Forest Service) Sperow (WV)	Forests (#1)	Protected Natural Areas as a Catalyst for Rural Economies in Transition: A Duration Model Analysis of Wilderness in Appalachia
D. Hellerstein (USDA), K.Egan (Iowa)	Ag/Env. (#3)	CRP's impact on recreation expenditures.
Joan Poor (MD)	Ag Land (#4)	Socio-Economic Equity of Preserved Farmlands in the United States
2:00-3:15		**Session 4: Methodological CVM Issues Part II. (**R.Rosenberger)
Patty Champ (USDA Forest Service), Bishop, Moore (WI)		Methods for Mitigating Hypothetical Bias
John Loomis (CO)& Gonzalez-Caban (FS).	Forests (#1)	Comparison of Videotape and Phone Interview Survey Administration in CV of Forest Fire Reduction.
Ron Flemming (KY)	Ag Land (#4)	WTP for Non-Consumptive Use Access to Private Lands when Affirmative Responses are Poisson Events.
3:15-4:30		**Session 5: TCM & Recreation Modeling.** (Joan Poor)
Scott Shonkwiler, Klaus Moeltner (NV)	Recreation(#2)	Intercept and Recall: Examining Avidity Carryover in On-Site Sample Data
D. Layton (WA), **Klaus Moeltner (NV)**	Recreation(#2)	Incorporating Past Trip Information in Multi-period/site Recreation models- A Bayesian Approach
Paul Jakus (UT) & John Bergstrom (U of GA)	Watersheds (#1)	Response Modeling to Estimate Changes in Recreation Use of 35 TVA Reservoirs
4:45-5:35		**Session 6: Bio-Economics/Risk Modeling.** (Steve Shultz)
Caplan (UT), Finoff (WY)	Watersheds (#1)	A Bioeconomic Model of the Great Salt Lake Watershed
Don Snyder and Fen Hunt		Cooperative/collaborative W1133 research & CSREES Updates

Final Agenda: 2005 W1133 Meetings, Salt Lake City, Day 2

Tuesday February 15		
8.00-9:15		**Session 6: Conjoint Analyses & Stated Choice Methods (**P.Jakus)
Don Dennis (Forest Service)	Forests (#1)	A Conjoint Survey of Urban Forestry Opportunities in Baltimore" (preliminary)
Rich Ready		A Pilot Test of a New Stated Choice Method: Continuous Attribute-Based Stated Choice
David Layton (WA), Lew (NMFS), Rowe (CO)		Incorporating Model Uncertainty into Experimental Designs: A Bayesian Approach
9.15- 10:30		Session 7: Snowmobiling at Yellowstone and ATV Use (Frank Lupi)
Reed Johnson (NC), Loomis (CO)	Recreation (#2)	Visitor Preferences for Winter Management Options at Yellowstone National Park.
Chris Bastian (WY), John Loomis (CO)	Recreation (#2)	Economic Welfare Effects of Recreation Site Closure on Multiple Destination Visitors using a Random Utility Model: The Case of Yellowstone Snowmobiling.
Tom Holmes (USDA Forest Service), Englin (NV)	Recreation(#2)	Economic analysis of user fees and the demand for Off-Highway Vehicle recreation in N.C
10:50-12:15		**Session 8: Applied State Preference Studies.** (John Hoehn)
Semra Ozdemir, & Johnson		Agreeing to Disagree: W1133 Members' Stated Preferences for Stated-Preference Methods
Frank Lupi, Kaplowitz, and Hoehn (MI)	Watersheds (#1)	Public Preferences and WTP for Great Lakes Coastal Wetland Programs
Ed Morey (CO), Thacher (NM), Breffle (CO)	Watersheds (#1)	A latent-class model of angler preferences for Green Bay: estimated jointly with attitudinal data and SP choice data
1:30 -3:10		**Session 8: Miscellaneous Topics** (Steve Shultz)
Leroy Hansen (USDA ERS)	Watersheds (#1)	'Indicators as a Popular (and Sometimes Proper) Substitute for Economics'
Krishna Paudel, Burke, Dunn	Watersheds (#1)	Optimal extraction of groundwater under alternative market scenarios: Case of the Sparta aquifer
John Hoehn, Deaton (MI)		Valuing Ecolabels: Is There a Market Price Differential for Credence Goods?"
3:30-4:30		W1133 Business Meeting

What Have We Learned from 20 Years of Farmland Amenity Valuation Research?

John C. Bergstrom, University of Georgia
Richard C. Ready, The Pennsylvania State University

Abstract

Assessment of previous farmland amenity valuation studies over the past 20 years provide evidence that these values are sensitive to size, regional scarcity, alternative development, public accessibility, productivity quality, human food plants, active farming, and intensive agriculture. Inconclusive evidence is provided with respect to the effects of distance, agricultural land use, unique landscape features, property rights and nonfarmland amenity substitutes. Implications and guidance of these results for land use policy including farmland protection strategies and priorities are discussed.

Research Conducted under W1133 Objective #4. Estimate the economic values of agricultural land preservation and open space

Based on Presentation and Proceedings Paper. Workshop on What the Public Values About Farm and Ranch Land, Baltimore, MD, November, 2003. Comments on earlier drafts of this presentation and paper by Donald M. McLeod, University of Wyoming and Mary Ahearn, USDA Economic Research Service are gratefully acknowledged.

What Have We Learned from 20 Years of Farmland Amenity Valuation Research?

I. Introduction

Farmland protection became a major public policy issue in the United Stated during the 1970s because of what was perceived to be an alarming, accelerated loss of farmland to urban and other developed uses. Over the past 30 years concern over farmland loss has continued with many state and local governments across the nation implementing farmland protection programs. The federal government also provides support for state and local farmland protection programs through conservation easement funds authorized by the 2002 Farm Bill. Since the early days, farmland protection programs have been justified in the public policy arena on the grounds of protecting market benefits (e.g., market commodity values) and nonmarket benefits (e.g., amenity values). Amenity benefits of farmland protection include public access use values (e.g., farm and ranch tours, local "pick-your-own" fruits and vegetables), use values that do not involve public access (e.g., countryside scenery viewing, prevention of undesirable development) and nonuse values (existence values of wildlife living on farm and ranch land, cultural heritage values, national food security). To learn more about the magnitude and determinants of farmland amenity benefits, economists embarked on a research program starting in the early 1980s to assess these amenity benefits using nonmarket economic valuation techniques.

The purpose of this paper is to review previous farmland amenity valuation studies and assess what these studies have found with respect to the magnitude of farmland amenity value estimates and the factors that determine the magnitude of those value estimates. The next section provides an overview of previous valuation studies including authors, location, farmland valued and methods employed. Following this overview, major empirical findings on the factors that influence farmland amenity values (e.g., willingness to pay) are reviewed, including attributes of the farmland preserved, distance to the farmland, relative scarcity of farmland in the region, and the type of developed use that will occur if farmland is not preserved. Per acre estimates of farmland amenities are then presented and discussed. A summary and conclusions are provided in the final section.

II. Overview of Previous Studies

General background information on previous farmland amenity valuation studies is shown in Table 1. Three different valuation methods have been employed in these studies, contingent valuation (CV), the hedonic price method (HPM), and contingent choice (CC). All of these valuation methods have been thoroughly tested and validated through years of research and are widely accepted by federal, state and local government agencies and the US courts as reliable techniques for estimating nonmarket values such as the amenity benefits of farmland protection (Freeman, 1993; NOAA, 1993). This section provides an overview of these studies, organized by valuation method.

II.1 Contingent Valuation Studies

All of the early farmland amenity valuation studies used contingent valuation (CV) to estimate willingness-to-pay (WTP) for the amenity benefits of farmland protection at the local town or county level. Contingent valuation is a stated preference valuation technique that asks respondents their WTP in a survey setting to preserve farmland from development. The studies that have used this method describe to the respondent the amount of farmland that will be preserved, how preservation will be accomplished, and usually the type of development that will occur if the farmland is not preserved. Within each study, the description of the quantity, attributes, or location of the farmland may be varied across respondents, allowing tests of the influence of these factors on WTP.

In some previous farmland amenity CV studies, individuals were asked to indicate their willingness to pay (WTP) to preserve farmland by "filling in the blank" with a dollar amount (open-ended CV question). In other previous farmland amenity CV studies, individuals were asked to indicate ("Yes" or "No" response) whether they would be willing to pay a given dollar amount to preserve farmland (dichotomous-choice CV question). Other previous studies asked individuals to indicate their WTP to protect farmland by marking an amount shown on a payment card listing a range of dollar amounts (payment card).

States represented in these studies conducted in the 1980s and 1990s include Massachusetts (Halstead, 1984), South Carolina (Bergstrom et al., 1985), Alaska (Beasley et al., 1986), New Brunswick, Canada (Bowker and Didychuck, 1994), Colorado (Rosenberger and Walsh, 1997), Kentucky (Ready et al., 1997) and Illinois (Kreiger, 1999). Studies conducted in the early 2000s added and Wyoming (McLeod et al., 2002) and Colorado (Bittner et al., 2003) to the list of states where CV has been used to estimate the total economic value (use and nonuse values) of farmland protection. Halstead, 1984 valued the protection of farmland of generic quality used for general or mixed agriculture located near a respondent's home in several Massachusetts towns. He measured household WTP to protect this farmland from low, medium and high intensity development using iterative bidding CV questions. Bergstrom et al., 1985 valued the protection of prime quality farmland used for general or mixed agriculture located throughout Greenville County, South Carolina. This study measured household WTP to protect different levels of farmland acres from high intensity development using payment card CV questions. Beasley et al., 1986 valued the protection of prime quality farmland used for general or mixed agriculture in the Matanuska-Susitna Borough, Alaska from medium and high intensity development. Household WTP was measured in this study using iterative bidding CV questions.

Protection of farmland of generic quality used for general or mixed agriculture in the Moncton regions of Kent, Albert and Westmorland counties in New Brunswick, Canada was valued by Bowker and Didychuck, 1994. They measured household WTP to protect different levels of farmland acres using payment card CV questions. Ready et al., 1997 valued the protection of different numbers and acres of horse farms and associated prime farmland in Kentucky counties. Alternative development of these horse farms in the absence of protection was not specified. Household WTP was measured in this study using single-bounded dichotomous choice CV questions. Rosenberger and Walsh, 1997 valued protection of farmland of generic quality used for general or mixed agriculture from medium and high intensity development in Routt County, Colorado. In this study, household WTP to protect various levels of farmland acres was measured using payment card CV questions.

Single-bounded dichotomous choice CV questions were used by Krieger, 1999 to estimate household WTP to protect farmland of generic quality used for general or mixed agriculture in a respondent's home county in Illinois. He did not specify expected alternative development in the absence of protection. McLeod et al., 2002 and Bittner et al., 2003 used open-ended CV questions to estimate household WTP to protect farmland of generic quality used for general or mixed agriculture in Sheridan County, Wyoming and Moffat County, Colorado, respectively. Expected alternative development in the absence of protection was not specified in either of these studies.

II.2 Hedonic Price Method Studies

In the late 1990s, economists started using the hedonic price method to measure the contribution of farmland amenity benefits to the selling price of residential land. The hedonic price method (HPM) is a revealed preference valuation technique which uses property value data to estimate statistical models that relate the price or WTP for land to attributes of the land itself and contextual factors. For example, previous HPM studies have measured the effects of nearby agricultural land on the price or WTP for residential land. HPM studies have been used to measure the effects of open space and scenic views on price or WTP for agricultural land.

States represented by the HPM studies include Kentucky (Ready et al., 1997), New York (Johnson et al., 2001), Maryland (Irwin, 2002), and Pennsylvania (Ready and Abdalla, 2003). These studies have used local, regional, statewide and national data sets and the HPM to estimate farmland amenity use values reflected by the contribution of farmland to WTP for residential property. Most HPM studies estimated the impact of farmland on residential properties located in close proximity. An exception was the Bastian et al., 2002 study which estimated the impact of aesthetic amenities on agricultural land values in Wyoming.

Johnson et al., 2001 used a local property value data to estimate the contribution of adjacent farmland of generic quality used for generic or mixed agriculture to household WTP for residential property in Suffolk County, New York. Irwin, 2002 used a regional property value data set to estimate the effects of nearby (within 400 meters) developable pastureland of generic quality on household WTP for residential property in Anne Arundel, Howard, Calvert and Charles counties, Maryland. She measured the value of this pastureland relative to several alternative land uses including forestland, low and high intensity development, privately owned conservation land and publicly owned nonmilitary land. Ready and Abdalla, 2003 used a local property value data set to measure the effects of proximity to nearby farmland (within 1600 meters) used for general or mixed agriculture (positive amenities) and farmland used for larger-scale livestock and mushroom production operations (negative amenities) on household WTP for residential property in Berks County, Pennsylvania. In this study, farmland values were measured relative to alternative land uses including forestland, privately owned conservation land and commercial, residential, or industrial development.

In contrast to the studies listed above, which measure the impact of a specific parcel of farmland on residential property values within several hundred meters of the parcel, Ready et al., 1997 used the HPM to estimate the county-wide amenity value of farmland. They estimated a two-market model that measured differences both in house prices and prevailing wage rates, and used their model results to estimate household WTP to preserve horse farms in Kentucky.

II.3 Contingent Choice Studies

In the early 2000s, economists' attention turned more towards using contingent choice (CC) to analyze the relationships between WTP for farmland protection and specific farm and ranch factors that influence WTP including attributes of the land itself and contextual factors such as geographic location. Contingent choice (CC) is a stated preference valuation technique which asks individuals in a survey setting to rank different farmland preservation "packages". These different packages vary in attributes of farmland itself, contextual factors and price or cost of the package. Individual rankings combined with data on farmland attributes, contextual factors and price or cost were then statistically analyzed in previous studies to estimate WTP for farmland preservation and the effects of farmland attributes and contextual factors on estimated WTP.

States represented in these studies include New York (Johnson et al., 2001), Delaware (Duke et al., 2002), Rhode Island (Swallow, 2002), and Georgia, Maine and Ohio (Ozdemir, 2003; Ozdemir et al., 2004). Johnson et al., 2001 measured household WTP to protect adjacent farmland of generic quality use for general or mixed agriculture in Suffolk County, New York. They did not specify alternative development in absence of protection. Duke et al., 2002 valued protection of farmland throughout Delaware of generic quality used for cropland and timberland. Alternative development of farmland in the absence of protection was not specified. Swallow, 2002 measured household WTP to protect farmland of generic quality used for general agriculture and dairy in the local town area of Richmond, Rhode Island. He did not specify alternative development in the absence of protection. A multi-state U.S.D.A. National Research Initiative contingent choice study examined preferences and value for farmland amenities for the US nationally and in the individual states of Georgia, Ohio and Maine (Ahearn et al., 2001; Boyle et al., 2001; Ozdemir et al., 2004). As part of this study, Ozdemir, 2003 measured household WTP to protect prime farmland used to produce human food crops located near urban areas from high intensity development in Maine.

III. Determinants of Estimated Farmland Amenity Values

All of the CV, HPM and CC studies provide insight into factors that influence public preferences and values for farmland amenities as reflected by WTP for farm and ranch land preservation. The effects of farmland attributes, surrounding landscape, and alternative use on WTP for farm and ranch land preservation are discussed in this section and illustrated in Figures 1-9. All of the results discussed in this section are based on intra-study (or within study) comparisons of WTP estimates rather than inter-study (or across study) comparisons.

III.1 Farmland Size and Scarcity Attributes

Economic theory suggests that the total value (total WTP) for farmland protection should increase with the size or quantity of acres protected (Figure 1). Several CV studies (Bergstrom et al., 1985; Bowker and Didychuck, 1995; Rosenberger and Walsh, 1997; Ready et al., 1997) and CC studies (Johnson et al., 2001; Duke et al., 2002; Ozdemir, 2003; Ozdemir et al., 2004) provide strong empirical evidence of this basic relationship, i.e. that WTP to preserve more acreage is larger than WTP to preserve less acreage.

Economic theory also suggests that as a commodity such as farmland becomes less scarce (e.g., more is provided), marginal value (marginal WTP) should decrease, so that total value (total WTP) increases at a decreasing rate (Figure 1). This generates a downward sloping marginal value (marginal WTP) curve for farmland acres protected (Figure 2). Several CV studies (Bergstrom et al., 1985; Bowker and Didychuck, 1995; Rosenberger and Walsh, 1997) provide strong evidence that marginal WTP for farmland protection in a given location does indeed decrease as acreage preserved increases. Also consistent with theoretical expectations, several CV studies (Bergstrom et al., 1985; Bowker and Didychuck, 1995; Rosenberger and Walsh, 1997), CC studies (Johnson et al., 2001; Duke et al., 2002) and HPM studies (Ready et al., 1997) provide strong evidence that WTP for small or incremental changes in farmland acres protected is higher in areas where farmland is more scarce, as illustrated in Figure 2.

III.2 Alternative Land Use Attribute

According to economic theory, values or WTP for a given policy change is a function of the pre-policy and post-policy levels of individual utility determined by the pre-policy and post-policy states of the world. Thus, individual values or WTP for a given level of farmland protection are a function of an individual's utility before and after the farmland protection policy is implemented including the amount and nature of farmland protected in the post-policy world compared to expected land use in the pre-policy world; e.g., the expected alternative land use without the farmland protection policy. We refer to the difference between values or WTP for land in agriculture compared to some alternative use such as commercial development as net values or net WTP for farmland protection.

The derivation of net marginal WTP (net MWTP) for farmland protection is illustrated in Figure 3. The horizontal axis in Figure 3 measures the proportion of land in the community in less-developed uses such as farmland, which is also equal to 1 minus the proportion in developed uses. In areas where farmland is relatively scarce, marginal WTP for farmland (MWTPFarmland) is high. As acres of farmland protected increases (left to right on the horizontal axis in Figure 3) MWTP to protect additional farmland decreases, as was shown in Figure 2.

Higher amounts of farmland imply less developed land. In areas where developed land is scarce (close to the right hand vertical axis), marginal WTP for additional developed land (MWTPDeveloped) could well be positive, reflecting the desire by households for employment and shopping opportunities. As the amount of developed land increases (moving from right to left on the horizontal axis in Figure 3) however, MWTP for additional developed land falls. The negative portion of the MWTPDeveloped curve in Figure 3 would be associated with perceived disamenities from over-development (e.g., congestion, pollution).

In a particular area, the difference between MWTPFarmland and MWTPDeveloped gives an individual's net marginal WTP for farmland protection (Net MWTPFarmland) illustrated by the dashed curve in Figure 3. At the point where MWTPFarmland and MWTPDeveloped (Q^2 acres of farmland protected in Figure 3), Net MWTPFarmland is equal to zero. At the margin where MWTPDeveloped becomes zero (Q^1 acres of farmland protected in Figure 3), Net MWTPFarmland equals MWTPFarmland.

Figure 4 illustrates how alternative development of different intensities may affect an individual's net marginal WTP for farmland protection. From the perspective of an individual household, conventional high-density development (e.g., strip malls, big-box stores) is typically considered less attractive as a neighbor than low-density development (e.g., large lot residential development, cluster-type or conservation subdivisions). In Figure 4, the curve labeled MWTPHigh Intensity Development represents an individual's marginal value or WTP for land used for high density development such as shopping centers and quarter-acre or less lot residential development. The curve labeled MWTPLow Intensity Development represents an individual's marginal value or WTP for land used for low density development such as cluster-type and large-lot residential development that preserves open and green space.

As illustrated in Figure 4, marginal value or WTP for low intensity development land lies above marginal value or WTP for high density development land, indicating that individuals prefer more of this type of development. Consequently, net marginal WTP for farmland protection when the alternative land use is high intensity development ($\text{Net\_MWTPFarmland}^{LD}$) is expected theoretically to be lower than net marginal WTP for farmland protection when the alternative land use is low intensity development ($\text{Net\_MWTPFarmland}^{HD}$). Also, it follows theoretically that WTP for a nonmarginal increment in farmland acres protected is expected to increase as the intensity of alternative development conversion increases as illustrated in Figure 5. Several previous CV studies (Halstead, 1984; Beasley et al., 1986; Rosenberger and Walsh, 1997), HPM studies (Irwin, 2002; Ready and Abdalla, 2003) and CC studies (Ozdemir, 2003; Ozdemir et al., 2004) provide strong empirical evidence that the intensity of alternative development conversion influences WTP for farmland protection in a positive manner.

III.3 Agricultural Land Use and Quality Attributes

Previous quantitative and qualitative studies of public preferences and attitudes towards farmland protection indicate that along with providing open and green space, a clear and strong public motivation for farmland protection is to preserve the agrarian nature of a community including cultural values, heritage values, rural lifestyles and access to fresh, local food supplies which are all dependent on the continued existence of viable farms and farming operations (Bergstrom et al., 1985; Furuseth, 1987; Bowker and Didychuck, 1994; Kline and Wichelns, 1996; Duke and Hyde, 2002). The results of these previous studies suggest that WTP should be greater for farmland that supports active and productive agriculture in addition to open and green space.

A recent multi-state contingent choice study (Ozdemir, 2003; Ozdemir et al., 2004) provides strong evidence that WTP increases with the agricultural productive quality of farmland as illustrated in Figure 6. The productivity of farmland, as measured for example by the presence of prime soils, contributes to the economic viability of farms and farming in a community. Previous qualitative studies suggest that people who support farmland protection enjoy seeing the land support flourishing plant growth (Ahearn et al., 2001; Boyle et al., 2001; Paterson et al., 2005). This enjoyment from seeing healthy things grow may also help to explain why so many people like backyard gardening, visiting natural areas and protecting prime agricultural soils and lands.

The value that people receive from seeing healthy things grow combined with the value they place on preserving agrarian culture, heritage and access to fresh, local food supplies suggests that WTP for farmland used to produce human food crops (e.g., cropland, orchards) may be greater than WTP for timberland or pastureland as illustrated by Figure 7. Previous HPM (Irwin, 2002) and contingent choice studies (Swallow, 2002; Ozdemir, 2003; Ozdemir et al., 2004) provide some empirical evidence of relatively higher preferences and WTP for preserving cropland as compared to timberland and pastureland. These results, however, are more preliminary in nature and are likely sensitive to the specific types of cropland, timberland and pastureland valued. For example, negative preferences for clear-cut timberland and unkept, apparently abandoned fields were observed in the Boyle et al., 2001 qualitative preference study. Other studies in the future may reveal positive preferences for other types of timberland and pastureland or rangeland (e.g., land with unique ecological habitats or scenic beauty).

Although the desire to preserve the various local benefits from active and viable farms and farming in a community is a strong public motivation for farmland protection, evidence from recent CC (Johnson et al., 2001) and HPM (Ready and Abdalla, 2003) studies suggest that farmland that is too actively or intensively farmed may result in net negative values to the general public. For example, suppose a particular tract of land is used to grow crops and raise chickens with a number of high intensive poultry houses.

As illustrated in Figure 8, the cropland on this tract of land may generate positive amenity values (area A) while the poultry houses generate negative amenity values (area B) that swamp the positive values resulting in net negative amenity values from this tract of land.

III.4 Human Use Attributes

People can derive enjoyment from farmland amenities with different levels of access to or use of the land itself. Direct public use gives people the opportunity or right to encroach upon the land for various amenity-related purposes such as pick-your-own fruits and vegetables, agritourism activities (e.g., farm tours, hayrides, corn mazes) and nature-based tourism activities (e.g., hunting, fishing, bird-watching). Aesthetic use gives people the opportunity or right to view, paint or photograph the land from public property (e.g., public road or nearby public land) without encroaching upon the land. Nonuse amenity values are public benefits supported by farmland that are independent of direct public use or aesthetic use. For example, nonuse amenity values would include an individual's WTP to preserve wildlife habitat and species on farmland that he or she cannot visit or even see as in the case of an isolated private tract of land with no public road access or nearby public property. Another value from farmland protection that does not depend on direct or visual access to the land itself is the growth control function of farmland protection (e.g., less traffic congestion).

Previous CV (Bowker and Didychuck, 1995) and CC (Swallow, 2002) studies provide limited evidence that WTP for farmland protection increases with higher levels of public access. These results are consistent with theoretical expectations since increasing public access to farmland increases opportunities for aesthetic use and direct public use benefits. Previous studies, however, have not addressed potential conflicts between different use and nonuse values of farmland protection. For example, excessive direct public use of a tract of farmland for agritourism activities may reduce some aesthetic use and nonuse values of that land.

III.5 Other Attributes

Previous studies provide mixed and inconclusive results with respect to the effects of distance from a household residence to farmland. Johnston et al., (2001), in a CC study, found higher watershed-wide amenity values for farmland than for other types of open space, but found in a HPM study that properties adjacent to farmland were worth less than properties adjacent to other types of open space. Ready and Abdalla (2003) found in a HPM study that eased farmland located within 400 meters of a house has less of a positive effect on house prices than forested land, but that outside of 400 meters the ordering reversed. The authors of these two studies speculate that these differences are driven by localized disamenities associated with active farming (e.g., noise, odors, dust). These studies suggest that households receive high amenity values from farmland in their community, but that they may prefer not to be located immediately adjacent to that land.

Similarly, some CV studies (Halstead, 1984; Bowker and Didychuck, 1994) report limited evidence that the total economic value of farmland protection including use and nonuse values is higher for people who live farther away from farmland. It is difficult, however, to compare these results with the HPM distance effect results since previous HPM studies only capture amenity and disamenity effects associated with farmland located relative close to households (e.g., adjacent or within 2 miles). CV and CC studies capture more geographically dispersed amenity and disamenity effects such as public aesthetic use and nonuse values. Because of the difficulty in controlling for the complex and confounding effects (e.g., separating out scarcity, proximity and disamenity or NIMBY effects), farmland valuation studies do not yet provide a clear picture of how proximity to farmland impacts preferences and WTP for farmland protection.

Another farmland attribute that may influence values (WTP) for farmland protection is land tenure or ownership. Previous CC (Swallow, 2002) and HPM (Ready and Abdalla, 2003) studies provide some evidence that open or green space provided by privately-owned land with conservation easements is less preferred and valuable than open or green space provided by publicly-owned open or green space land. Ready and Abdalla, 2003 also found evidence in their study area suggesting that privately-owned eased farmland is less valuable than privately-owned uneased farmland. In contrast, HPM results reported by Irwin, 2002 suggest that in her study area privately-owned open or green space with a conservation easement on it generates the highest amenity values, followed by publicly-owned open or green space, followed in turn by developable privately-owned open or green space land.

Although largely left out of previous farmland valuation studies to date, broad ecological and environmental attributes may be important determinants of preferences and values for farmland protection. For example, results of a recent CC study (Swallow, 2002) suggest that WTP for farmland protection increases with the ecological uniqueness and ecosystem services provided by the land. His results also suggest that WTP for farmland protection increases with the scenic beauty or quality of the land.

IV. Per Acre Value Comparisons

Estimated values or WTP per acre for farmland amenities adjusted to 2003 dollars are summarized in Table 2. Mean annual household WTP estimated in previous CV studies ranges from $.0002 per acre (South Carolina) to $.0697 per acre (Kentucky) with a mean across all studies of $.0142 per acre. To date, total economic values for farmland protection have been estimated in previous CC studies for the states of Maine, New York and Rhode Island and range from $0.0006 per acre (Maine) to $0.4392 per acre (Rhode Island), with a mean across all studies of $0.1739.

Two HPM studies have estimated models from which per acre farmland amenity values can be estimated. Using the hedonic regression coefficients from Irwin (2002), and the mean residential price from her study area, a conversion of one acre of uneased cropland to low density development would reduce residential property values within 400 meters by $1717.87 on average (in 2003 dollars). A one acre conversion to commercial or industrial use would reduce nearby property values by $5018.49. Using the regression coefficients from Ready and Abdalla (2003) and the average house price in their study area, a conversion of one acre of uneased cropland to lower-density housing would decrease nearby house prices by $35.45 on average, an estimate that is not statistically different from zero. Conversion to industrial land would decrease nearby house prices by $365.80. Undeveloped land and open space is much more scarce in the Irwin study site than in the Ready and Abdalla study site. This difference in scarcity may explain some of the difference in estimates marginal amenity values.

Conceptually, WTP values reported in Table 2 generated from CV and CC studies have different interpretations from those generated by HPM studies. CV studies typically ask respondents to value discrete changes in farmland acres protected, and then estimate total WTP for those discrete changes. We can then estimate WTP per acre as reported in Table 2 by dividing total WTP by the number of farmland acres protected. Previous CC studies ask respondents to rank different discrete "packages" of farmland protection attributes including acreage, and then estimate total WTP for the discrete attribute changes. As in the CV case, we can then estimate WTP per acre as reported in Table 1 by dividing total WTP by the number of farmland acres protected. Hence, the CV and CC values per acre reported in Table 2 are average values per acre. In contrast, HPM studies use property value data showing tradeoffs people make over marginal changes in land attributes (assuming data sets with rich land price and attribute observations), and then estimate marginal values or WTP directly. Hence the HPM values per acre reported in Table 2 are marginal values per acre.

Another difference between the stated preference (CV and CC) and revealed preference (HPM) value estimates reported in Table 2 relates to the scope and spread of economic values captured in the value estimates. With the exception of the study by Ready et al., (1997), the HPM revealed preference data sets and resulting value estimates only reflect use values accruing to private land owners who live relatively close to farmland. These are the households who would be expected to hold the highest amenity values for preservation of the farmland. Previous CC and CV stated preference data sets and resulting value estimates reflect both use and nonuse values to the general public living throughout a local community, region or state. Thus, the CV and CC values reported in Table 2 would generally be aggregated over a much larger group of people or population as compared to the HPM values.

Despite the conceptual differences and wide geographical range of previous studies, the per acre value estimates for farmland amenities reported in Table 2 are quite consistent. The low, high and average per acre values estimated in previous CV and CC studies are very close. The Swallow, 2002 high value estimate of $0.4392 per acre is most likely due to the fact that this is an average value estimate derived from a relatively small amount of farmland protected. In contrast, the Bergstrom et al., 1985 low value estimate of $.0002 per acre is most likely due to the fact that it is an average value estimate derived from a relatively large amount of farmland protected. Even though not directly comparable to the CV and CC estimates because it is a marginal rather an average value, the Ready et al., 1997 county-wide HPM study generated an estimated amenity value of $.0047 per acre, close to the CC and CV low value estimates.

Do the farmland amenity value estimates reported in Table 2 display systematic variation? This question would perhaps best be answered through a quantitative meta-analysis of farmland amenity value estimates. The authors of this paper plan to attempt such a meta-analysis as a next step in the overall assessment of previous farmland amenity valuation studies. The ultimate success of this type of meta-analysis, however, is questionable because of data constraints. For example, if we graph total WTP reported in previous CV studies against total acres valued (Figure 10) positive relationships are observed within studies. However, a clear trend between studies is more difficult to observe because of between-study variability.

Two HPM studies showed that farmland can generate disamenities. Johnston et al., (2001) found that, in Suffolk County, NY, land adjacent to farmland was worth $34,700 less per acre than land not located adjacent to farmland. Ready and Abdalla (2003) found that houses located within one mile of a large-scale animal production facility were worth, on average, $1,857 less than similar houses not located near such farms. These results are consistent with studies measuring negative effects of CAFOs (confined animal feeding operations) on property values (Herriges et al., 2003; Palmquist et al., 1997).

Finally, implications of the units of measurement for the values reported in Table 2 with respect to estimation of aggregate farmland amenity values or benefits should be noted. Estimation of aggregate benefits of farmland amenities for a particular region (e.g., county, state) would involve multiplying the per acre per household estimates reported in Table 2 by both the appropriate number of farmland acres protected and the appropriate number of households in the region. The appropriate number of acres is determined by the type of farmland represented by the estimates reported in Table 2.
For example, Bergstrom et al., (1985) measured the value of amenities for prime farmland in Greenville County, South Carolina. Hence, it would be appropriate to aggregate the farmland amenity value estimate of $.0002 per acre over the total number of acres of prime farmland in Greenville County, say as defined by the U.S.D.A. using soil quality. Ready et al., (1997) measured the value of farmland amenities for a special and unique type of farmland, Kentucky horse farms. Thus, it would appropriate to aggregate their estimate of $.0697 per acre only over horse farms in a region.

The appropriate number of households to use in aggregation is determined by the use and nonuse value aspects of the estimates reported in Table 2. For example, on-site use values of farmland amenities with private access only, such as on-site recreation available only to family and friends of property owners, would apply to a relatively small number of households. On-site use values with public access, such as on-site recreation available to the general public, would apply to a larger number of households. Off-site aesthetic values such as scenic driving and nonuse values such as existence values would apply to the largest number of households since these values are the most spatially dispersed and have “public good” characteristics of nonrivalry and nonexclusiveness.

The Bergstrom et al., (1985) estimates reported in Table 2 represent the total economic value (use and nonuse values) of farmland amenities in Greenville County. Thus, it would be appropriate to aggregate the $.0002 per acre per household estimate over the total number of households in the county. In contrast, the Irwin (2002) estimate of $5,018 per acre per household reported in Table 2 measures use values with private access only and would apply to a relatively small number of households adjacent to or located very close to farmland.

V. Summary and Conclusions

The results of previous farmland amenity valuation studies provide relatively strong evidence that preferences and values are sensitive to size in acreage (+), regional farmland scarcity (+), alternative development intensity (+), public accessibility (+), and productivity (+). There is some evidence that preferences and values are also sensitive to human food plants (+), active farming (+), and intensive agriculture (-). Previous studies provide limited and inconclusive evidence with respect to the effects of distance from residence to farmland, the relative value of pastureland and timberland, the relative value of unique landscape features such as scenic quality, ecosystem services, buildings, and specialty commodities, the effects of alternative property right structures (e.g., land ownership) and the effects of non-farmland amenity substitutes (e.g., public parks).

We conclude that although much has been learned over the past 20 years about farmland amenity values, much more qualitative and quantitative research is needed to better understand the effects of specific farmland attributes on preferences and values for farmland amenity protection. The assessment of previous valuation studies presented in this paper indicates numerous data and knowledge gaps that need to be filled. More research and data are needed to accurately estimate average and marginal values of farmland amenities. Previous studies clearly show that acreage protected is an important factor influencing WTP for farmland protection. Future studies should therefore include acreage protected as a standard design factor. Given the results of previous studies showing the strong influence of alternative land use on WTP for farmland protection, this factor should also be included in future studies as a standard design factor. More research and data are needed to better assess the full range of alternative land uses on WTP for farmland amenities (e.g., different types of high density development including "Smart Growth" development).

More research and data are also needed to better assess how WTP for farmland amenities is influenced by different agricultural uses of the land to be protected including commodities produced and the intensity of production. In particular, what types of agricultural commodities and production intensity levels are associated with farmland disamenities and negative WTP values? Although previous studies indicate that WTP for farmland protection tends to increase with land or soil quality, the reasons why are not clear. More research and data are needed to determine if this positive relationship is due to food supply concerns and (or) the amenity values people receive from preserving healthy ecosystems and the associated "flourishing" plant growth and green space.

The relative importance of use vs. nonuse values of farmland amenities is also not well documented and understood from previous studies. More research and data in particular are needed to assess how important public access is to the general publics' WTP for farmland preservation. From the perspective of private landowners and farmland preservation program managers, providing direct, on-site public access to preserved land may be viewed as undesirable or unacceptable, even if highly valued by the general public who may be paying for preservation. The effects of different types of nonuse motivations and values (e.g., environmental values, growth control effects) on WTP for farmland protection and amenities are also not well understood.

Distance from an individual's residence to farmland is a potentially important determinant of WTP for farmland amenities. However, results of previous studies examining distance effects are mixed and sometimes contradictory. Carefully designed and controlled studies are needed to accurately model and separate out distance effects from other confounding factors influencing WTP for farmland amenities. Factors such as land ownership and tenure, ecological services and scenic quality also need to be better documented and understood through future studies that explicitly include these items as design factors.

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Table 1. Summary of Previous Farmland Protection Valuation Studies

Study	Farmland Valued	Valuation Method
Bastian, *et al*, 2002.	Contribution of scenic views to price per acre of remote agricultural land in Wyoming	HPM
Beasley, *et al*, 1986.	Old Colony and Homestead farmland in the Matanuska-Susitna Borough, Alaska	CV
Bergstrom, *et al*, 1985.	Farmland in Greenville County, South Carolina	CV
Bittner, *et al*, 2003.	Farmland and ranchland in Moffat County, Colorado	CV
Bowker and Didychuk, 1994.	Farmland in the Moncton region of Kent, Albert and Westmorland Counties, New Brunswick, Canada	CV
Duke, *et al*, 2002.	Farms in Delaware	CC
Irwin, 2002.	Value of developable pastureland relative to other surrounding land uses on residential property values in Anne Arundel, Howard, Calvert and Charles Counties, Maryland	HPM
Johnson, *et al*, 2001.	Contribution of adjacent farmland to per acre sales price in Suffolk County, Long Island, New York	HPM/CC
Halstead, 1984.	Farmland near a respondent's home in Towns of East Longmeadow, Greenfield and Deerfield, Massachussetts	CV
Kreiger, 1999.	Farmland in home county; Kane, McHenry or DeKalb, Illinois	CV
Mcleod, *et al*, 2002.	Farmland and ranchland in Sheridan County, Wyoming	CV
Ozdemir, 2003.	Farmland in Maine	CC
Ozdemir *et al*, 2004.	Farmland in the U.S., Georgia, Maine and Ohio	CC
Ready, *et al*, 1997.	Number of horse farms in Kentucky counties	HPM/CV
Rosenberger and Walsh, 1997.	Farmland and ranchland in Routt County, Colorado	CV

Figure 1. Size Attribute

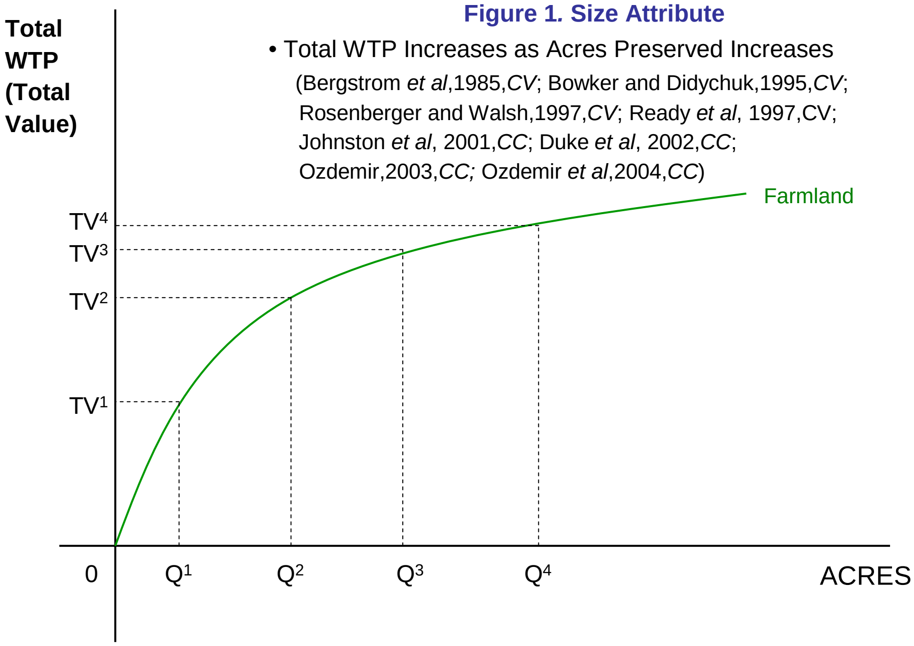


Figure 2. Scarcity Attribute

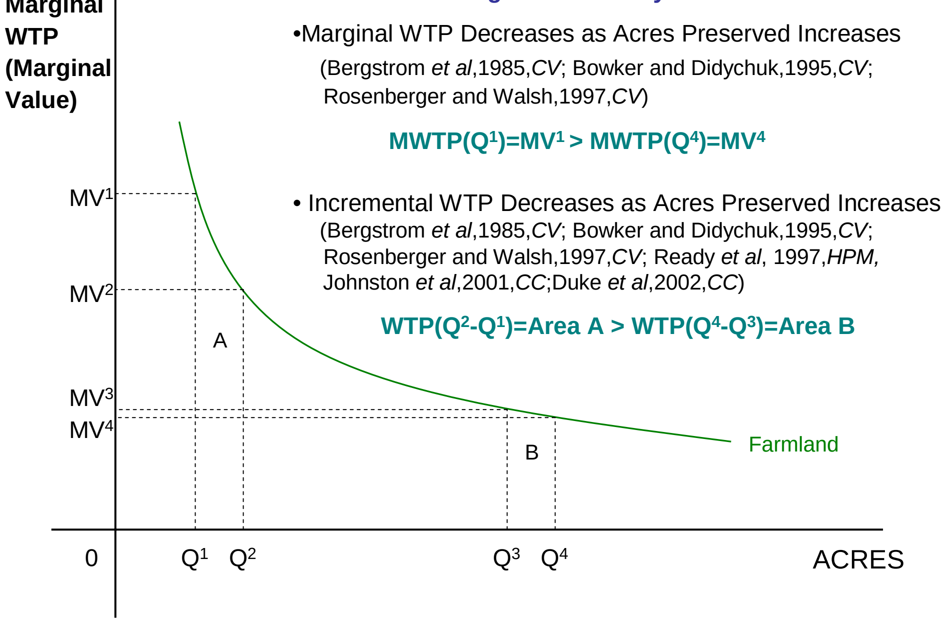


Figure 3. Allocation Between Competing Uses

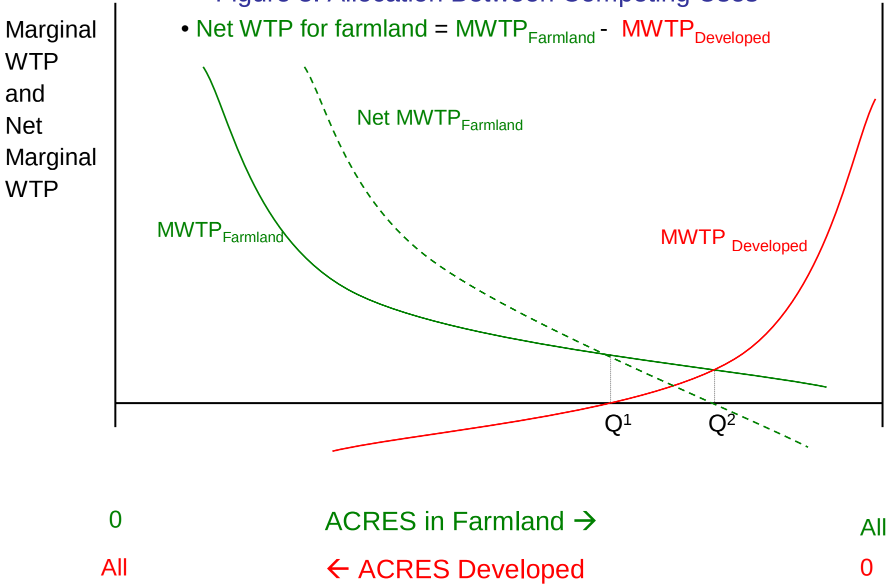
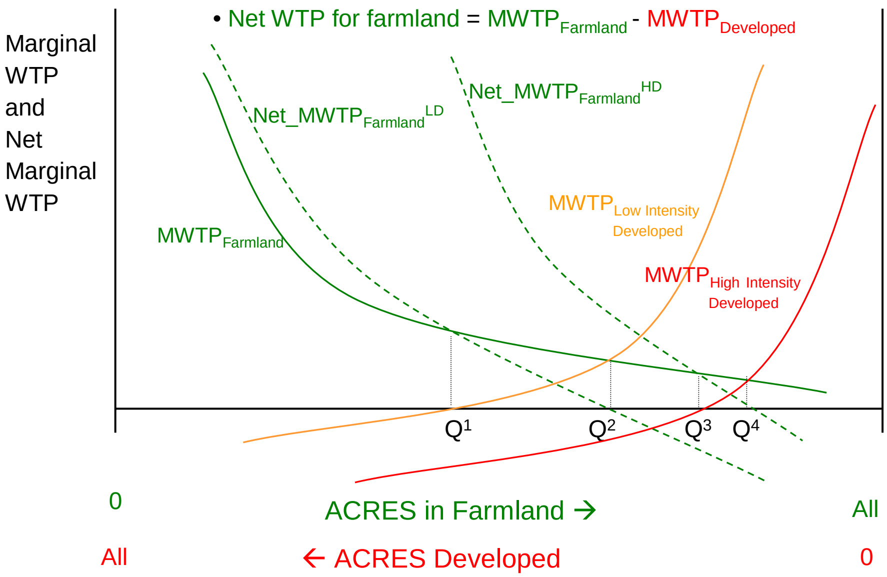


Figure 4. Allocation Between Competing Uses



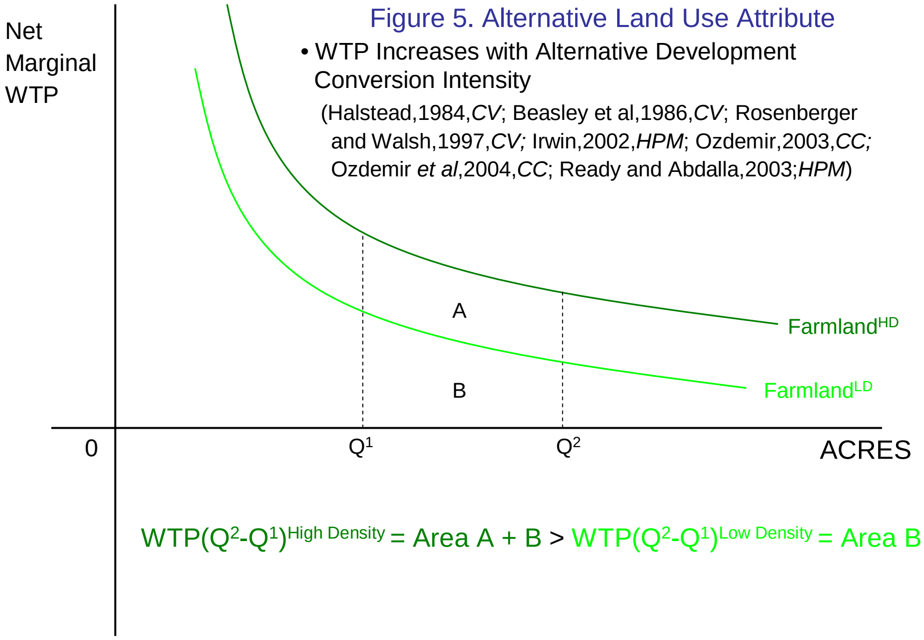


Figure 5. Alternative Land Use Attribute

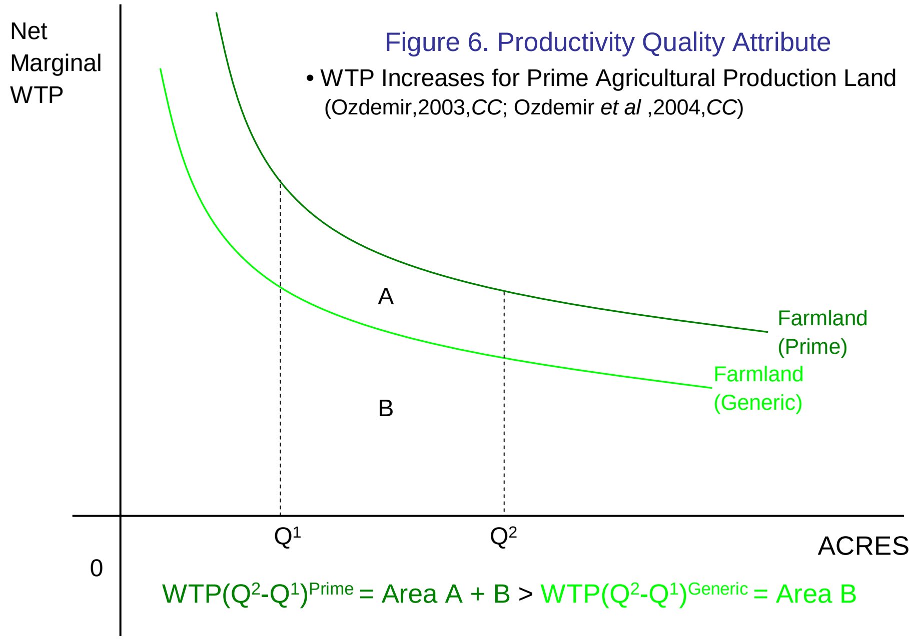


Figure 6. Productivity Quality Attribute
• WTP Increases for Prime Agricultural Production Land
(Ozdemir,2003,CC; Ozdemir et al ,2004,CC)
Net
Marginal
WTP
A
B
Farmland
(Prime)
Farmland
(Generic)
Q1
Q2
ACRES
0
WTP(Q2-Q1)Prime = Area A + B > WTP(Q2-Q1)Generic = Area B

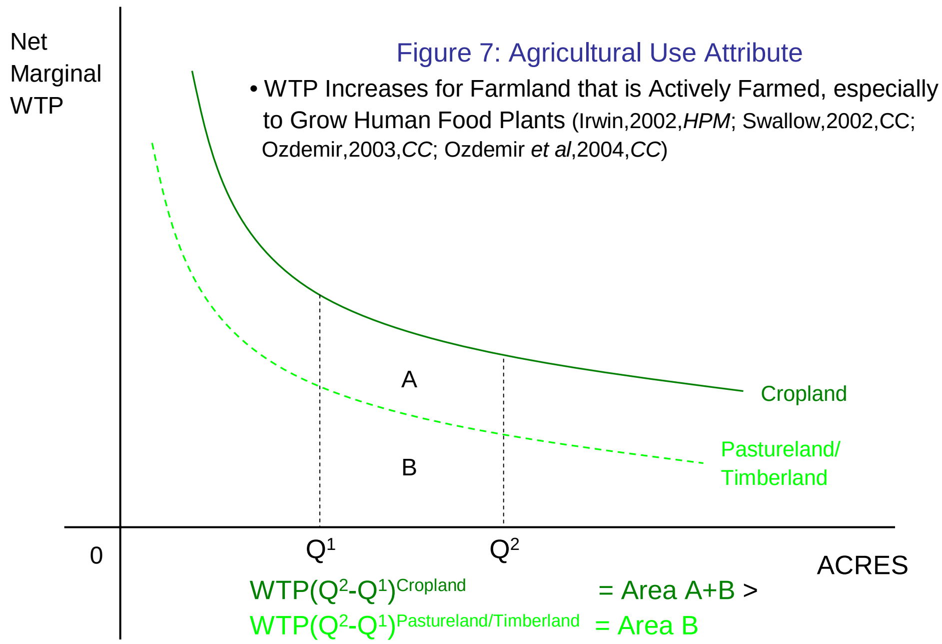
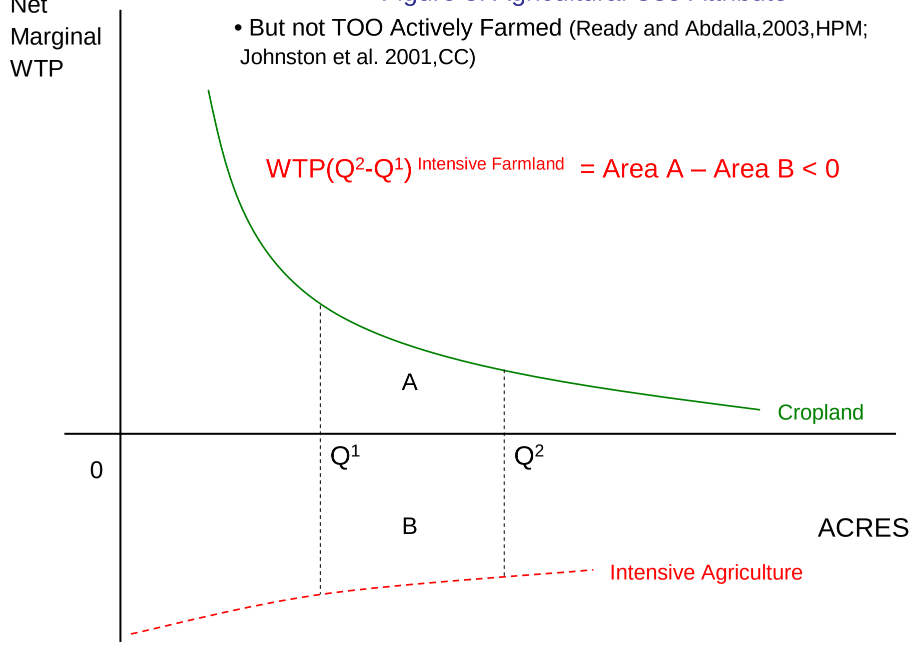


Figure 7: Agricultural Use Attribute

Figure 8: Agricultural Use Attribute



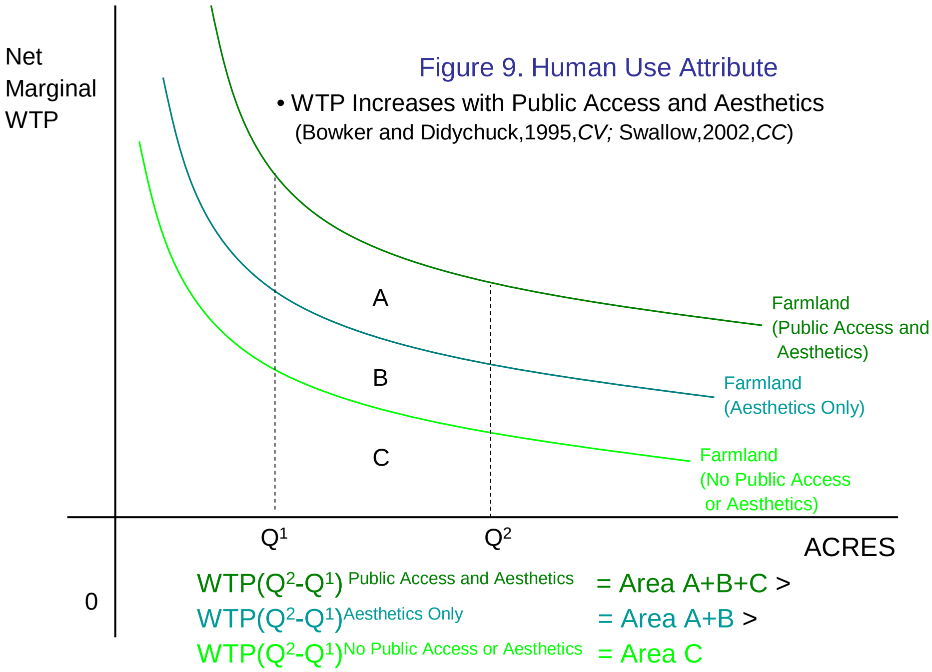
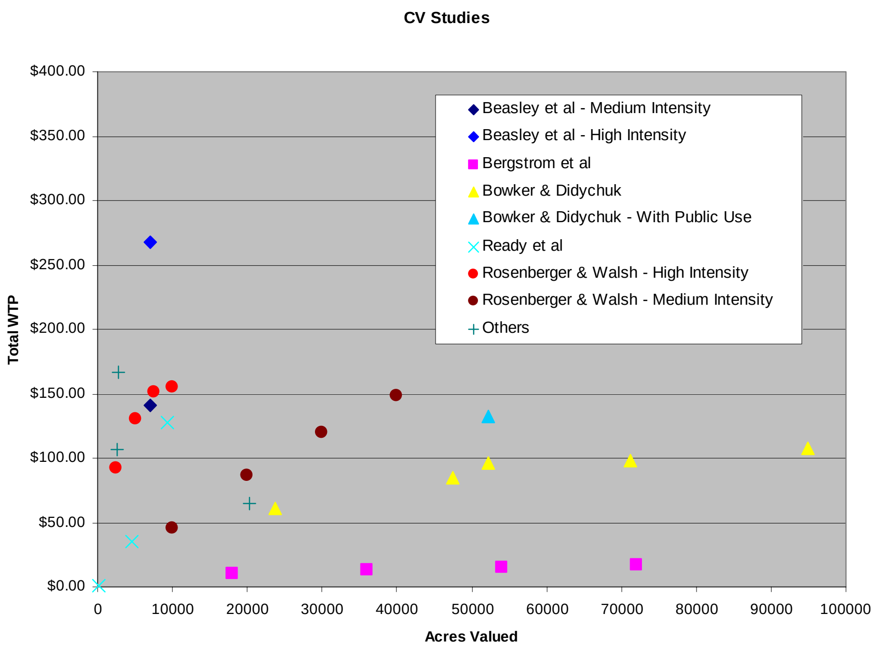

Net
Marginal
WTP
Figure 9. Human Use Attribute
• WTP Increases with Public Access and Aesthetics
(Bowker and Didychuck,1995,*CV;* Swallow,2002,*CC*)
A
B
C
Farmland
(Public Access and
Aesthetics)
Farmland
(Aesthetics Only)
Farmland
(No Public Access
or Aesthetics)
Q^1
Q^2
ACRES
0
$WTP(Q^2-Q^1)^{\text{Public Access and Aesthetics}}$ = Area A+B+C >
$WTP(Q^2-Q^1)^{\text{Aesthetics Only}}$ = Area A+B >
$WTP(Q^2-Q^1)^{\text{No Public Access or Aesthetics}}$ = Area C

Table 2. Estimates of Farmland Amenity Value Per Acre (WTP Per Household)

	Low	Average	High
Contingent Valuation (N=27)	$.0002 (Bergstrom *et al.,* 1985)	$.0142	$.0697 (Ready *et al.,* 1997)
Contingent Choice (N=6)	$.0006 (Ozdemir,2003)	$.1739	$.4392 (Swallow,2002)
Hedonic Price w/o Negatives (n=5)	$35.45 (Ready and Abdalla, 2003)	$1,784.40	$5,018.49 (Irwin, 2002)

Figure 10. Total WTP for Farmland Amenity Protection Graphed Against Total Farmland Acres



Economic Benefits of Large Patches of Tree Canopy: A Second-Stage Hedonic Price Analysis

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Abstract

The benefits from marginal and non-marginal changes in large patches of tree canopy are estimated by applying a first- and second-stage hedonic price model to the sale of single-family residential properties in an urban setting: Portland, Oregon. The first-stage analysis indicates diminishing returns from increasing tree canopy past a certain level. The second-stage analysis, which is based on market segmentation, produces estimated coefficients that are generally consistent across functional forms. Benefit estimates, evaluated at the mean canopy cover, equal between 2.77% and 7.41% of the mean sale price for properties in the study area. A 1-percentage point increase in the average tree canopy cover in the study area is estimated to increase per-property benefits by $208 to $1,452.

I. Introduction

Large contiguous patches of tree canopy are considered to be an important part of an urban environment. In addition to the benefits received by private property owners, such as shade and privacy, these areas provide wildlife habitat, improve air quality, reduce runoff and flooding, lower noise levels, and moderate climate.

The Portland metropolitan area is highly urbanized and development is constrained by an urban growth boundary. Despite these pressures, the percentage of tree canopy, defined as the percentage of an area covered by crowns of trees, increased from 25.1% to 26.3% between 1972-2002 (Poracsky and Lackner 2004). This increase is attributed to a natural environment that is conducive to growing trees, Oregon's land-use laws, Portland's environmental zoning regulations, land purchases by the regional government, and planting efforts by non-profit organizations (Poracsky and Lackner 2004).

Portland's Urban Forestry Management Plan (1995, 2) lists "Maximize and expand the urban forest canopy" as one of its goals. The effect of this objective on the sale price of single-family residential properties is unknown but is important to estimate since the incentives for private property owners to preserve tree canopy may -- or may not -- be consistent with this goal.

This paper estimates the effect of tree canopy located on single-family residential properties, and in the area within 1/4 mile of such properties, on their sale price. For the purposes of this study, "tree canopy" is defined as canopy that provides between 76-100% coverage and encompasses at least one acre. In addition to estimating marginal effects, this paper uses a segmented market approach to estimate non-marginal changes using a second-stage hedonic price model. Benefit estimates are provided for existing levels of tree canopy and for several hypothetical scenarios.

II. Literature

Several studies have examined the relationship between open spaces and the sale price of single-family residential properties in Portland, Oregon (Bolitzer and Netusil 2000; Lutzenhiser and Netusil 2001; Mahan et al. 2000; Netusil 2004a, 2005b). Tree canopy on a property, and in the surrounding neighborhood, is represented by a series of dummy variables in one paper (Netusil 2005a) and captured indirectly as a characteristic of natural area parks and forested wetlands in the other papers.

Multiple hedonic studies have found that property values increase if trees are located on a property (Anderson and Cordell 1988; Dombrow et al. 2000; Morales 1980).

Other hedonic studies have focused on the relationship between property values and forested areas in the surrounding neighborhood.

Tyrvainen (1997) uses apartment sales in Joensuu, Finland to estimate how their sale price is influenced by distance to the nearest wooded recreation area, nearest forested area, and the relative amount of forested areas in the housing district. Sale prices are estimated to increase with proximity to wooded recreation areas and with increases in the amount of forested areas in the housing district. However, the sale price of apartments is found to increase as the distance from a forested area increases. The author attributes this result to the shading effects from dense forests in the study area.

In a related study, Tyrvainen and Miettinen (2000) estimate that a 1 kilometer increase in the distance to the nearest forested area leads to an average 5.9% decrease in the sale price of residential properties in the district of Salo in Finland. Dwellings with a view of forests were found, on average, to be 4.9% more expensive than dwellings with similar characteristics.

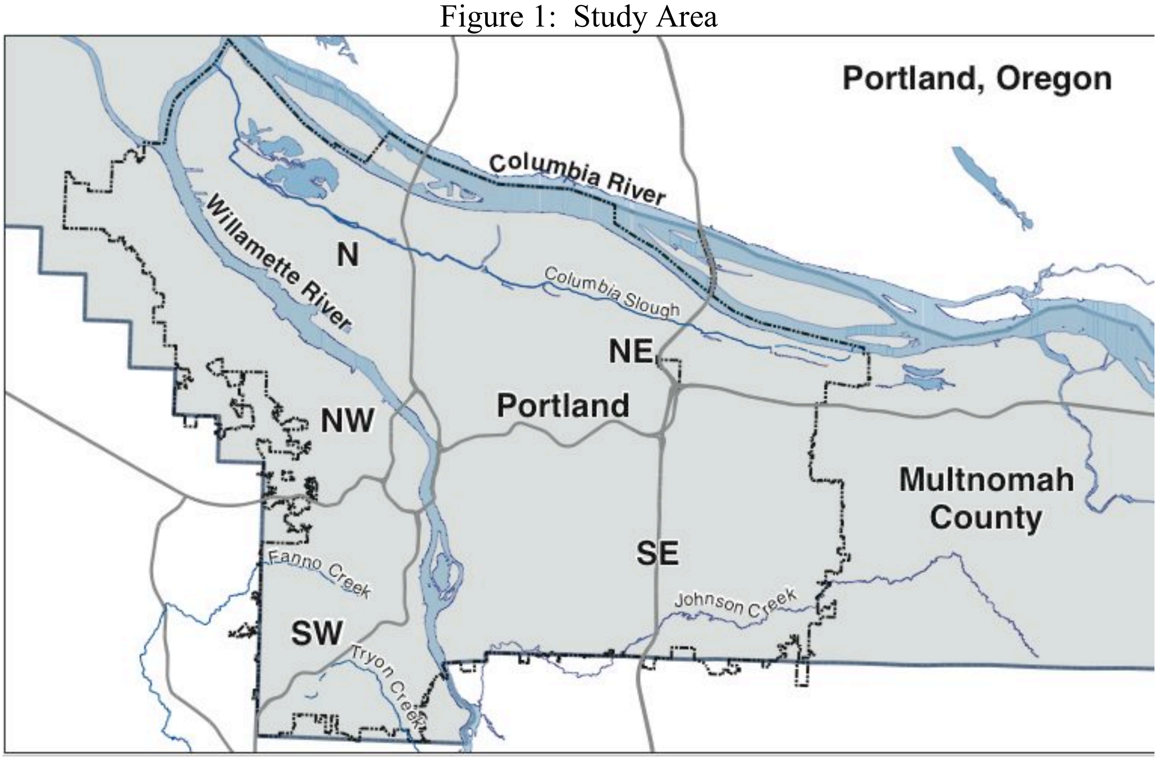
Garrod and Willis (1992) use observations on properties located adjacent to Forestry Commission land across Britain to estimate a first-stage model that includes three tree categories and a second-stage model of the demand for broadleaved woodland. An increase in the proportion of Forestry Commission land with broadleaved trees is estimated to increase a property's sale price, while an increase in mature conifers is found to reduce sale prices. The double-log functional form used in the second-stage model results in an income elasticity estimate for the proportion of broadleaved woodland of 0.82 and an own price elasticity of -1.76.

The only second-stage hedonic model attempted in Portland, Oregon is described in Mahan et al. (2000). While the authors find strong evidence of market segmentation, they were unable to get reliable estimates of the demand curve for size of the nearest wetland.

III. Study Area and Property Characteristics

The study area includes 91,250 acres of Portland, Oregon located within Multnomah County (Figure 1). The study area is highly urbanized with an average lot size of 7,043 square feet. Several water bodies violate one or more water quality standards and Willamette River steelhead and Chinook are listed as threatened under the Endangered Species Act (NMFS 2002).

Figure 1: Study Area



The Willamette River bisects Portland, creating a natural segmentation between the east and west sides. More generally, the city is broken into five areas: North, Northeast, Southeast, Southwest and Northwest.

Between January 1, 1999 and December 31, 2001 there were 30,015 single-family residential property sales in the study area. More detailed information on the data set is contained in Netusil (2005a). Properties on the west side (NW and SW) have a higher mean sale price, are located in census tracts with higher median incomes, and have a higher percentage of tree canopy on the property, and in the area within 1/4 mile of the property, than properties located east of the Willamette River (Table 1).

Table 1: Summary Statistics

	Combined	NW	SW	SE	NE	N
Mean Real Sale Price (2000)	$175,160	$443,588	$255,965	$152,679	$168,894	$125,090
Mean Median Income (Census Tract 2000)	$45,985	$84,834	$63,790	$41,145	$45,216	$37,148
Mean Lot Size (square ft)	7,043	13,626	10,022	6,788	6,310	5,327
Mean Percentage of Tree Canopy on the property	3.48% (14.44)	21.64% (31.26)	16.02% (28.56)	1.22% (7.89)	1.00% (7.22)	0.40% (4.67)
Mean Percentage Tree Canopy within 1/4 mile of properties	7.21% (13.29)	40.26% (20.12) Max: 90	27.03% (17.83) Max: 86	3.86% (7.62) Max: 85	2.53% (4.80) Max: 68	2.66% (3.76) Max: 29
Observations	30,015	767	3,879	11,980	9,597	3,792

Tree canopy within 1/4 mile of a property can be located on privately or publicly owned land. The majority of tree canopy for property sales in the data set is on privately owned land. North Portland is an exception with 1.25% of tree canopy within 1/4 mile of properties located on privately owned land and 1.41% on publicly owned land (Table 2).

Table 2: Tree Canopy within 1/4 mile of Properties

	Percentage of Tree Canopy	Percentage on Private Owned Land	Percentage on Publicly Owned Land
N	2.66%	1.25%	1.41%
NE	2.53%	1.66%	0.97%
SE	3.86%	2.81%	1.05%
SW	27.03%	22.41%	4.63%
NW	40.26%	32.97%	7.29%
Combined	7.21%	5.55%	1.66%

IV. Hedonic Price Method: First and Second Stage Models

The first-stage hedonic price model relates the sale price of properties to their structural, neighborhood amenities, and location characteristics. While estimates for marginal changes in characteristics can be derived from the first stage, the second-stage is needed to estimate the benefits from non-marginal changes.

Rosen (1974) proposed that marginal prices from the first-stage be used in a second-stage model to estimate the demand curve for the attribute of interest. Numerous authors have used Rosen's theoretical framework to estimate a second-stage model by imposing functional form restrictions (Chattopadhyay 1999) or by using a segmented market or a multiple market approach (Garrod and Willis 1992; Mahan et al. 2000; Zabel and Kiel 2000).

Freeman (2003, 371) suggests using segmented markets within a city or across cities to estimate the second-stage hedonic price model. Mahan et al. (2000) found statistical evidence of market segmentation, by area, in Portland, although the authors were not able to successfully estimate a second-stage model.

V. Results

First Stage Hedonic Price Model

Our *a priori* expectation is that tree canopy will have either a positive but diminishing effect on a property's sale price, or will increase a property's sale price to a maximum point past which increases in tree canopy will cause a property's sale price to decline. Two models were developed to explore these expectations; the natural log of a property's real sale price was used as the dependent variable in both models.

In the first model, the percentage of tree canopy on a property, and within 1/4 mile of a property, is represented by a quadratic function, while the natural logs of these variables are used in Model 2. To preserve observations, the minimum amount of tree canopy on each property and within 1/4 mile of each property, was set at 1% for Model 2.

The results from both models are presented in Table 3. The estimated coefficients for the structural, amenity, and location variables are consistent with other studies (Netusil 2005a, 2005b). The estimated coefficients on home characteristics (lot square footage, building square footage, etc.), house style (one story, one story with finished basement, etc.), base zoning (low residential, medium residential, etc.), other amenities within 1/4 mile of the observations (percentage of area with streams, etc.), distance to the central business district, and nearest commercial and industrial districts are not included in Table 3. Full results are available from the authors. In Model 1, the percentage of tree canopy that is estimated to have the largest impact on a property's sale price is approximately 18%. The estimated coefficient on Model 2 is significant and negative, implying that the optimal tree canopy coverage on a property is zero.

Evidence of market segmentation was found by applying an F-test to the coefficients on the area variables (NW, NE, SW, SE). The hypothesis that the estimated coefficients are equal to each other was rejected for both models.

Table 3: Estimated Coefficients and Robust Standard Errors

	Model 1 *Quadratic*	Model 2 *Natural Log*
Northwest	0.787*** (0.0293)	0.829*** (0.033)
Northeast	0.342*** (0.016)	0.338*** (0.016)
Southwest	0.532*** (0.022)	0.552*** (0.0242)
Southeast	0.370*** (0.015)	0.366*** (0.015)
Percentage of Tree Canopy on the Property	0.00046 (0.00035)	
Percentage of Tree Canopy on the Property Squared	-1.28e-05*** (4.42e-06)	
Percentage of Tree Canopy within 1/4 mile of the Property	0.00767*** (0.0018)	
Percentage of Tree Canopy within 1/4 mile of the Property: NW	-0.0140*** (0.00234)	
Percentage of Tree Canopy within 1/4 mile of the Property: NE	-0.0049** (0.0021)	
Percentage of Tree Canopy within 1/4 mile of the Property: SW	-0.0080*** (0.0019)	
Percentage of Tree Canopy within 1/4 mile of the Property: SE	-0.00082 (0.00187)	
Percentage of Tree Canopy within 1/4 mile of the Property Squared	-0.00024** (0.000104)	
Percentage of Tree Canopy within 1/4 mile of the Property Squared: NW	0.000269*** (0.000105)	
Percentage of Tree Canopy within 1/4 mile of the Property Squared: NE	0.000132 (0.000111)	
Percentage of Tree Canopy within 1/4 mile of the Property Squared: SW	0.000248** (0.000104)	
Percentage of Tree Canopy within 1/4 mile of the Property Squared: SE	0.000134 (0.000104)	
Natural Log of Percentage of Lot with Tree Canopy		-0.004977*** (0.001786)
Natural Log of Percentage of Area within 1/4 mile of Property with Tree Canopy		0.018990*** (0.003931)

Natural Log of Percentage of Area within 1/4 mile of Property with Tree Canopy: NW		-0.083126*** (0.012220)
Natural Log of Percentage of Area within 1/4 mile of Property with Tree Canopy: NE		-0.008506* (0.004943)
Natural Log of Percentage of Area within 1/4 mile of Property with Tree Canopy: SW		-0.022236*** (0.006473)
Natural Log of Percentage of Area within 1/4 mile of Property with Tree Canopy: SE		0.005410 (0.004411)
Observations	30,015	30,015
R-squared	0.7553	0.7546
* significant at 10%, ** significant at 5%; *** significant at 1%		

Marginal implicit prices were derived using the results presented in Table 3. The expected relationship between the percentage of tree canopy within 1/4 mile of a property and its sale price occurs in Model 1 for properties in SE, NE and North Portland. Increases in tree canopy up to 16.80% in SW Portland, and 97.36% in NW Portland, are estimated to decrease the sale price of properties located in those areas (Table 4).

The estimated coefficients in Model 2 are consistent with *a priori* expectations for properties in SE, NE and North Portland, but properties in NW and SW Portland are estimated to experience a decline in sale price from increases in tree canopy. Negative marginal implicit prices make intuitive sense since large amounts of dense tree canopy within 1/4 mile of properties in NW and SW Portland may block highly desirable views of mountains, city lights, and the Willamette River.

Table 4: Implicit Prices for tree canopy within 1/4 mile of properties

	Number of Observations	Observations with Negative Implicit Prices *Quadratic*	Maximum or Minimum of Quadratic Function	Observations with Negative Implicit Price *Natural Log*
NW	767	767	97.36% (min)	767
SW	3,879	1,219	16.80% (min)	3,879
SE	11,980	176	33.29% (max)	0
NE	9,597	219	13.31% (max)	0
N	3,792	45	16.22% (max)	0
Total	30,015	2,426		4,646

Second Stage Hedonic Price Model

The marginal implicit prices estimated in the first stage are used as the dependent variable in the second stage models. Since the marginal implicit price of tree canopy and the percentage of tree canopy are determined simultaneously, socioeconomic variables at the census tract level – median age, percentage white, and median income – are used as instruments. Suitable instruments must be exogenous and correlated with the percentage of tree canopy within 1/4 mile of properties, but not correlated with the error term. Socioeconomic variables, such as the instruments used in this study, have been used by other authors to estimate the second-stage hedonic price model (Garrod and Willis 1992; Mahan et al. 2000).

There was no *a priori* expectation about the functional form for the second-stage model, so two models were estimated: linear and double-log. We retained the negative marginal implicit prices estimated in the first-stage models since these appear to be valid estimates for the study area. Other authors have taken a similar approach although some authors have set these prices equal to zero or dropped these observations entirely (Zabel and Kiel 2000).

The results from the second-stage linear models are presented in Table 5. The estimated coefficients on the percentage of tree canopy are negative and significant in both models. Median income has the expected sign and is significant in Model 4, but is insignificant and negative in Model 3.

Table 5: Linear Models: Estimated Coefficients and Robust Standard Errors

	Quadratic First Stage, Linear Second Stage *Model 3*	Log First Stage, Linear Second Stage *Model 4*
Percentage Tree Canopy	-34.97* (0.849)	-92.18* (2.74)
Median Age	-10.43* (1.25)	-34.90* (3.30)
Percentage White	12.43* (0.277)	22.46* (1.00)
Median Income	-0.0001215 (0.00054)	0.0174* (0.002)
Constant	209.64* (32.62)	832.98* (97.24)
R-squared	0.2187	0.1550
Observations	30,015	30,015

Table 6 contains the results from the double-log models. For these models it was assumed that the minimum tree canopy within 1/4 mile of each observation is 1%. The estimated coefficient on tree canopy is negative and significant in both models. The log of median income is positive and significant in Model 5, but the estimated coefficient in Model 6 is negative and significant. These models provide a better fit than the linear models, but all observations in NW and SW Portland are excluded from Model 6 since the properties in these areas have negative marginal implicit prices (Table 4).

Table 6: Double-Log Models: Estimated Coefficients and Robust Standard Errors

	Quadratic First Stage, Log Second Stage *Model 5*	Log First Stage, Log Second Stage *Model 6*
Log Percentage Tree Canopy	-0.80* (0.013)	-0.34* (0.023)
Log Median Age	-1.25* (0.063)	-1.07* (0.058)
Log Percentage White	1.49* (0.236)	1.04* (0.023)
Log Median Income	0.28* (0.032)	-0.31* (0.027)
Constant	1.98* (0.298)	9.98* (0.278)
R-squared	0.2173	0.4910
Observations	27,589	25,369

Benefit Estimates

Benefit estimates for a range of tree canopy levels were obtained using the second-stage results. The benefit estimates for the mean canopy cover (7.21%) within 1/4 mile of properties in the study area represent between 2.77% and 7.41% of the mean sale price of $175,160.

Table 7: Benefit Estimates

	Quadratic First Stage, Linear Second Stage	Log First Stage, Linear Second Stage	Quadratic First Stage, Log Second Stage	Log First Stage, Log Second Stage
2.53% (NE Portland)	$1,908	$5,102	$6,502	$4,269
7.21% (mean for study)	$4,847	$12,986	$7,995	$8,506
8.21%	$5,376	$14,408	$8,203	$9,265
15%	$8,040	$21,630	$9,238	$13,777
25%	$9,029	$24,528	$10,218	$19,283
35%	$6,520	$18,207	$10,920	$24,064

The change in benefits from changes in tree canopy coverage can also be estimated using the second-stage model. An increase in tree canopy cover from 7.21% to 8.21% is estimated to increase benefits by $208 to $1,452 (Table 8). This 1-percentage point change represents an additional 1.35 acres of tree canopy, which corresponds to a per-acre benefit of $154 to $1,076.

Table 8: Benefit Estimates from Changes in Tree Canopy

	Quadratic First Stage, Linear Second Stage	Log First Stage, Linear Second Stage	Quadratic First Stage, Log Second Stage	Log First Stage, Log Second Stage
2.53 to 7.21%	$2,939	$7,884	$1,493	$4,237
7.21 to 8.21%	$529	$1,452	$208	$759
7.21 to 15%	$3,193	$8,644	$1,243	$5,271
Per acre benefit	$392	$1,076	$154	$562

VI. Conclusions

The City of Portland, Oregon is described as a "particularly green and well-treed city" (Poracsky and Lackner 2004,1). The mean percentage of tree canopy within 1/4 mile of properties in the data set is 7.21%, with 5.55% on privately-owned land and 1.66% on publicly-owned land. This average, however, masks large differences in the distribution of tree canopy within the study area.

The estimated coefficients from the first-stage hedonic price model indicate that an increase in tree canopy in areas of the study area with small amounts of tree canopy (N, NE, SE Portland) is expected to increase the sale price of properties. However, in the heavily treed areas of SW and NW Portland, increases in tree canopy are estimated to decrease sale prices. This effect is attributed to the already large percentage of tree canopy in these areas and the potential that highly desirable views will be blocked.

The estimated coefficients on the percentage of tree copy within 1/4 mile of a property are consistently negative and significant across specifications. Although the estimated coefficient on median income was not consistent, the estimated coefficients on median age and percentage white are consistent. Benefit estimates for the mean canopy cover within 1/4 mile of properties in the study area equal 2.77% and 7.41% of the mean sale price of $175,160.

The hedonic price method is only able to capture benefits that are capitalized into the sale price of properties. The attribute that was the focus of this study – tree canopy that provides between 76-100% coverage and encompasses at least one continuous acre – generates many public benefits such as wildlife habitat, improved air quality, reduced runoff and flooding, lower noise levels, and climate moderation.

The small average lot size for residential properties in the study area points to the need for a coordinated effort to maintain and enhance tree canopy. Current regulations in the study area prohibit cutting healthy trees on large lots if doing so would create a "significant negative impact" on the "erosion, soil stability, soil structure, flow of surface waters, water quality, health of adjacent trees and understory plants, or existing windbreaks" and "the character, aesthetics, property values, or property uses of a neighborhood" (City of Portland, Oregon 2005). Our empirical results suggest that these regulations, tree planting programs sponsored by non-profit associations, and efforts by the regional government to educate property owners about the benefits of wildlife habitat in their neighborhood, will maintain, or perhaps enhance, the sale price of single-family residential properties in Portland, Oregon.

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Replication of a Cash and Contingent Valuation Experiment (Preliminary)

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Abstract

This paper presents preliminary findings on a cash and contingent valuation (cv) experiment. The study replicates major elements of an earlier (1990) experiment which solicited hypothetical and actual donations to benefit instream flows for Montana fisheries. The related W-1133 objective is to "estimate the economic benefits of ecosystem management of forests and watersheds". Extensions of the earlier work include: repeat contacts to increase response rate, follow-up of the contingent valuation question to explore respondent certainty, and several question format treatments (payment card, as in the original study, and dichotomous choice). A practical goal of the project is to provide direction to the development of the Montana Streamflow Fund in partnership with Trout Unlimited. The original study was in partnership with the Nature Conservancy. Data collection began in January 2005 and is largely complete; however, the results presented here are preliminary. As in the 1990 survey, the sample populations are subsamples of licensed Montana resident and nonresident anglers. Dillman mailing procedures (five contacts) were used to reach potential respondents. Treatments included a replication of the 1990 payment card (PC) question format (mailed to an initial 1250 resident and 1250 nonresidents respectively) and a dichotomous choice (DC) format (mailed to 1250 nonresidents). Response rates were higher for the PC compared to the DC format (for example, nonresident PC treatments averaged 51.7%, while nonresident DC averaged 44.3%). Response rates were also higher for the cv treatments compared to cash, for example 57.6% for cv nonresident PC and 49.0% for cash nonresident PC. The cash and hypothetical treatments for each question format/subpopulation appear to be similar based on a preliminary comparison of gender, age, income and education. The resident and nonresident angler populations are quite different, with nonresidents tending to be older, richer, more avid and specialized anglers, and more conservation-minded. For example, mean age for resident angler respondents is 47.5 compared to 54.8 for nonresidents, gender proportion, respectively, 25% female versus 13%, median income $40,000 - $60,000 vs $75,000 - $100,000, and percent fly fish only 20.5% versus 66.7%. For the PC treatments, cv donation amounts averaged about double the cash (actual) donation amounts for both subsamples: $5.44 versus $2.80 for residents and $29.28 versus $13.19 for nonresidents. In constant 2005 dollars, the PC values comparing 1990 and 2005 are similar for resident respondents. Preliminary findings on the dichotomous choice format and the certainty followup are not reported in this paper.

Introduction

This paper describes preliminary results from a field experiment designed to compare responses to a contingent valuation instrument to actual cash donations. This study is in part a replication of an earlier experiment (Duffield and Patterson 1991; Duffield 1992; Duffield and Patterson 1992) aimed at measuring values for provision of a public good. The resource in the 1990 survey was increased streamflow in several potentially important spawning tributaries for two endangered fisheries: a fluvial population of Arctic Grayling and a population of Yellowstone cutthroat trout.

A limitation of the 1990 study was that the two treatments of most interest were implemented as one time mailings to simulate typical fund-raising solicitations. Both of the latter went out under The Nature Conservancy letterhead and were designed to be very similar in content and wording. As a result of the single mail contact, the response rates were relatively low to these treatments, particularly for the cash response (Table 1). There was a third treatment (contingent valuation) that paralleled the first two, but went out under University of Montana letterhead and included repeat mail contacts (a total of four) and achieved high response rates (74% and 77% for resident and nonresident anglers respectively). The University of Montana treatment was used to characterize the population and provide a contrast between a "typical" academic contingent valuation and the other treatments.

The objectives in replicating the 1990 survey in 2005 included achieving higher response rates in the comparable cash and contingent valuation treatments to provide a better measure of potential differences in real and hypothetical economic commitments for this resource and setting.

It was also anticipated that the replication over the span of 15 years would provide an opportunity to measure changes in values, and insights into what, if any, measures of attitudes, preferences, or socio-economic status and characteristics might explain any changes found. (Parenthetically, this aspect of the work relates to a separate multiyear project that may be of interest to readers. The Montana Challenge (http://fwp.state.mt.us/tmc/reports/ecovalues.html), directed by Daniel McCollum at the USDA Rocky Mountain Experiment Stations is a state-level case study examining changes in attitudes and values relating to wildlife from a number of social science perspectives. The web citation provides reports including demographics, nonmarket values, recreation, and a content analysis of newspaper articles.)

The remainder of this paper includes a brief summary of literature and methods, followed by a description of the preliminary results.

Literature and Methods

The comparison of real economic commitments with contingent valuation responses had its beginning in the work of Bohm (1972) and Bishop and Heberlein (1979). There have since been a number of laboratory and field experiments. Studies specifically investigating donation payment mechanisms include Duffield and Patterson 1991, Navrud 1992, Seip and Strand 1992, Brown et al. 1996, Champ et al. 1997, Byrnes et al. 1999, Champ and Bishop 2001, and Champ and Bishop 2004.

From a theoretical standpoint, a central feature of the current and 1990 study is that many of the services provided by the resource in question are not excludable. It is anticipated that existence and bequest motives (Krutilla 1967) relating to instream flow in these streams and the associated passive use are significant relative to direct use. In fact it is not very likely that any given angler respondent will ever fish any of the several small streams described in the 1990 and 2005 studies, or experience significantly improved angling in the larger rivers fed by these small tributaries. Nonetheless, direct use may still be an important motive. In any case, the specific payment vehicle used here is anticipated to capture both passive and direct use in a total valuation framework (Randall and Stoll 1983). The choice to make a donation can be modeled in the context of an indirect utility function framework (e.g. Boyle and Bishop 1987). The willingness to pay (donate) amount that will just make an individual ambivalent between the current level of services and one with adequate streamflow defines a Hicksian compensating variation welfare measure. Cameron and Huppert (1991) provide an empirical model for estimating WTP from payment card interval data. Similarly, parametric or nonparametric methods can be applied for the dichotomous choice models (Hanemann 1989; Kriström 1990; Poe et al. 2005).

The current 2005 study includes payment card treatments for both resident and nonresident Montana licensed anglers that were conducted in cooperation with Trout

Unlimited. This provides a replication of the earlier payment card treatments done in cooperation with The Nature Conservancy. Table 1 summarizes and compares study methods between 1990 and 2005. The 1990 University of Montana treatments were not replicated

Extensions to the 1990 study include a question on respondent certainty as a follow-up to the contingent valuation responses (following Champ and Bishop 2001), and testing responses across several question formats. As noted, the latter included payment card formats for both resident and nonresident subsamples (providing the replication to 1990), as well a dichotomous choice treatment for a second nonresident subsample. Table 3 summarizes the allocation of the total initial mailing list (of 3,750 anglers) across the various treatments. Based on the pretest and 1990 study, cash treatments were oversampled relative to contingent valuation in anticipation of lower relative response rates.

An important change in survey methods for the payment card treatments was to use Dillman method repeat mail contacts. The 2005 study included five contacts: an intial letter, first survey mailing, reminder postcard, second survey mailing, and a third survey mailing.

The basic structure (and most of the original questions) of the 1990 survey instrument was retained for 2005. The sequence was as follows: initial set of questions on angling use, questions designed to measure attitudes and preferences, valuation question sequence, and questions addressing respondent socioeconomic characteristics. The decision was made to use the same set of payment card amounts as in 1990 (10, 25, 50, 100, 250, other).

The revised instrument was pretested in fall of 2004 with a mailing to a sample of 300 anglers. One important finding from the pretest was that the subsample of the 2003-2004 nonresident season angler license list made available to the researchers by Montana Fish, Wildlife and Parks included nonresidents who held season licenses by virtue of a "combination" elk and/or deer hunting license that included season fishing. The latter group had very low response rates to the 2005 pretest, and had not been included in the 1990 sample frame. For the main 2005 survey, this group was also excluded from the nonresident season license subsample.

The initial contact letter for the 2005 survey was mailed on January 21. The reminder postcard went out February 8, the first survey package January 27- 31, second survey package on February 25, and third survey package on April 13.

The following discussion of results summarizes responses received and identification of undeliverable mail returns as of May 27, 2005. Preliminary results for the uncertainty followup and dichotomous choice questions are not reported here.

Preliminary Findings

Tables 2 and 3 summarize the 1990 and 2005 response rates. Not surprisingly, using five mail contacts in 2005 (compared to one in 1990) significantly improved response rates. The overall response rate is 47%. The cash response rates were higher than anticipated and average about 85% of the corresponding contingent valuation treatment response rate. The dichotomous choice response rates were also systematically lower (and also in about an 85% ratio) compared to the corresponding nonresident payment card response. Sample sizes for each treatment are close to the study goal of about 200 in each cell for the contingent valuation treatments and well in excess of that number for the cash treatments (Table 3).

Table 4 provides some detail on the declining marginal effect of subsequent respondent contacts on response rates. There is considerable consistency across treatments. Figure 1 shows a plot of five-day moving average responses per day for residents and nonresidents. The three spikes in response rates correspond (with a five or so day lag reflecting mail delivery time) to the mailings of the initial survey package plus reminder postcard and the next two survey mailings. Note that well after each mailing, a low level of response continues.

Table 5 summarizes selected respondent characteristics by subsample. Age, percent female, median education, and median income level are similar across cash and contingent valuation subsamples within each treatment. Table 5 also shows characteristics measures aggregated for residents and nonresidents. Preliminarily, it appears that nonresident anglers are older, less likely to be female, better educated, and richer than resident anglers.

Table 6 summarizes other respondent characteristics by residency including measures of angling use, angling specialization, angling avidity, recreational property ownership in Montana, importance of adequate streamflows, and measure of environmental and wildlife-related attitudes and preferences. It appears that nonresidents are more avid, more specialized, and have preferences more favorable to conservation initiatives. One notable result is that 20.5% of residents but 67% of nonresident anglers fly fish only.

Both resident and nonresident anglers favor rainbow and brown trout fisheries over native cutthroat and bull trout fisheries as far as a priority for improved streamflow. Nonresidents are more certain about their preferences on this allocation issue.

Turning to the preliminary valuation findings, only results for the payment card treatments are summarized here. Additionally, all reported values are simple means of the respondent indicated contingent valuation or actual donation amounts, not WTP values. These simple means are the correct approach for identifying the actual average amount of money raised in the cash transaction treatments.

Tables 8 and 9 summarize for the 1990 study the mean donations per respondent and per delivered mailing, as well as the relative frequency distribution of contributions across payment card bid amounts. On a per respondent basis, the ratio of the cash to hypothetical mean donation amount was 0.48 for residents and 0.73 for nonresidents. The ratios on a per delivered basis are much lower, reflecting the disparity in response rates between the cash and contingent valuation treatments (Table 8).

Table 10 provides relative frequency and mean donation per respondent for the 2005 payment card treatments. Here the ratio of cash to contingent valuation is 0.52 for residents (similar to 1990) and 0.45 for nonresidents (much lower than in 1990). The cash donation amounts for nonresidents are approximately six times higher than those for residents in 1990 and five times higher in 2005.

Table 11 compares the 1990 and 2005 donations in current (survey year) dollars, while Table 12 provides a constant 2005 dollar comparison (correction based on the CPI-U average for November-December 1990 versus February-March 2005).

Based on the constant dollar comparison (Table 12), the resident cash and the resident and nonresident contingent valuation donation means differ by 15 to 20 percent across the 15 year period. The cash nonresident values declined by almost 40%.

Figure 2 is a plot of cash payment card mean contribution (11-day moving average) for both residents and nonresidents. The pattern for residents shows a strong downward trend in mean cash donations over time. It also appears to be roughly parallel to, but much lower than, the nonresident, and goes to zero shortly after the second survey mailing. The nonresident is more variable, but also appears to show a gradual decline in mean donations, but donations do not go to zero over the period plotted

By contrast, in Figure 3, the contingent valuation means for both groups show no obvious downward trend. (Certainly there is greater variability in the means shown late in the survey period as marginal samples are declining (Table 4).)

Discussion

The preliminary results presented hear are just that, preliminary! Obviously they have not yet been subject to any rigorous statistical analysis or modeling. Nonetheless there appears to be some interesting consistency with the 1990 payment card format findings.

The simple mean cash transaction measures tend to be around 50 percent or better of the contingent donation measures. The large differences in values across the two angler populations (resident and nonresident) are replicated. The direction of the differences is also consistent with what one would expect from economic theory given differences in some potential covariates for WTP models (income, avidity, etc.).

It is obvious that there is strong selection bias reflected in the pattern of mean cash donations over time. For residents, cash contributors show up early then disappear altogether by the last wave of respondents. Nonresident cash contributors also are a lower and lower share of the response over time. By contrast there appears to be a more stable persistence of contingent donations over time. These two patterns are consistent with a decline in the cash/contingent donation ratio across waves, and may partly explain the 2005 results relative to 1990 (Tables 11 and 12).

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Table 1. Comparison of Study Methods: 1990 and 2005 Studies

Study characteristic	1990 Study	2005 Study
Resource examined	Instream Flows / Threatened Fisheries	Instream Flows / Montana Fisheries
Cooperating group	The Nature Conservancy	Trout Unlimited
CV Question format	Payment Card	Payment Card and Dichotomous Choice
Surveys mailed	7,662	3,750
Survey contacts	One	Five
Sample Frame	Licensed anglers	Licensed anglers

Table 2. 1990 Study Response Rate Statistics

Statistic	Residents		Nonresidents	
	Cash	Hypothetical	Cash	Hypothetical
Surveys Mailed	2,622	1,166	2,682	1,192
Undeliverable	344	153	310	138
Potential respondents	2,278	1,013	2,372	1,054
Useable returns	205	193	306	288
Response Rate	9.0%	19.1%	12.9%	27.3%

Table 3. Response Rate Characteristics, 2005 Survey

Sample	Surveys mailed	Bad Addresses	Delivered	Surveys returned	Response rate
Resident Payment Card					
- Cash sample	850	53	797	350	43.9%
- Hypothetical sample	400	24	376	181	48.1%
Subtotal-Resident PC	1250	77	1173	531	45.3%
Nonresident Payment Card					
- Cash sample	850	79	771	378	49.0%
- Hypothetical Sample	400	46	354	204	57.6%
Subtotal-Nonresident PC	1250	125	1125	582	51.7%
Nonresident Dichotomous Choice					
- Cash sample	850	110	740	311	42.0%
- Hypothetical sample	400	47	353	173	49.0%
Subtotal-Nonresident DC	1250	157	1093	484	44.3%
Entire Resident sample	1250	77	1173	531	45.3%
Entire Nonresident sample	2500	282	2218	1066	48.1%
Entire Sample	3750	359	3391	1597	47.1%

Table 4. Marginal Effect of Subsequent Respondent Contacts on Response Rates			
Sample	**Wave 1 Response**	**Wave 2 Marginal Response**	**Wave 3 Marginal Response**
Resident Payment Card			
- Cash sample	24.0%	14.3%	4.9%
- Hypothetical sample	27.1%	13.0%	6.9%
Nonresident Payment Card			
- Cash sample	28.3%	16.1%	5.4%
- Hypothetical Sample	37.6%	14.7%	6.5%
Nonresident Dichotomous Choice			
- Cash sample	20.1%	16.4%	5.5%
- Hypothetical sample	30.9%	12.5%	5.7%
Entire Sample	26.6%	14.9%	5.6%

Table 5. Respondent Characteristics, by subsample				
Sample	**Mean Age**	**Percent Female**	**Median Education**	**Median Income level**
Resident Payment Card				
- Cash sample	47.9	24.2	Some college	40 to 60
- Hypothetical sample	46.7	25.0	Some college	40 to 60
All Resident PC	47.5	24.5	Some college	40 to 60
Nonresident Payment Card				
- Cash sample	55.2	14.1	Finished college	60 to 75
- Hypothetical Sample	54.1	15.4	Finished college	75 to 100
All Nonresident PC	54.8	14.6	Finished college	60 to 75
Nonresident Dichotomous Choice				
- Cash sample	53.9	13.4	Finished college	75 to 100
- Hypothetical sample	55.2	11.5	Finished college	75 to 100
All Nonresident DC	54.7	12.2	Finished college	75 to 100

Table 6. Selected Respondent Characteristics, by Residency

Characteristic	Residents	Nonresidents
Percent of respondents who fished 25 days or more in Montana in 2004	8.1%	10.3%
Percent who only fly fish	20.5%	66.7%
Percent who say fishing is their favorite outdoor recreational activity	11.4%	35.9%
Percent who own or lease recreational property in Montana	14.1%	24.5%
Percent who say that adequate streamflows are "very important" for the future of Montana fisheries.	74.6%	87.5%
Respondents who said they knew either "a fair amount" or "a great deal" about existing conservation trust fund efforts	41.6%	53.2%
Respondents who "strongly agree" with the statement "I'm glad there is wilderness in Montana even if I never get to see it."	51.6%	63.7%
Respondents who agreed with the statement "I feel I should be doing more for Montana's rivers and streams."	38.5%	45.5%
Respondents who agreed with the statement "Private conservation organizations should play a major role in protecting our environmental resources."	54.8%	75.4%
Respondents who strongly disagreed with the statement "I think most Montana rivers already have enough water in them to be a healthy resource."	22.4%	17.9%
Respondents who strongly agreed with the statement "Rivers have spiritual or sacred value for me."	11.0%	18.1%
Respondents who agreed with the statement "I would be willing to contribute money or time to help Montana rivers even if I could never visit them."	25.5%	. 39.3%

Table 7. Respondent Opinions on Fisheries and Streamflows, by Residency.		
Characteristic	**Residents**	**Nonresidents**
Respondents who think rainbows and brown trout fisheries should be a priority for improved streamflow	33.3%	38.7%
Respondents who think native cutthroat and bull trout fisheries should be a priority for improved streamflow	22.5%	28.4%
Respondents not sure how best to prioritize improved streamflows	37.6%	26.4%
Respondents who ranked Arctic grayling as a lowest priority for streamflow improvement	24.2%	30.4%

Table 8. 1990 Study Mean Donation Amounts				
Statistic	**Residents**		**Nonresidents**	
	Cash	**Hypothetical**	**Cash**	**Hypothetical**
Donation per respondent	2.24	4.64	12.60	17.36
Cash/Hypo ratio	0.48		0.73	
Donation per delivered survey	0.20	0.88	1.63	4.74
Cash/Hypo ratio	0.23		0.34	

Table 9. 1990 Frequency Distribution of Contributions (% of all contributions)				
Bid	**Residents**		**Nonresidents**	
	Cash	**Hypothetical**	**Cash**	**Hypothetical**
$10	54%	75%	41%	39%
$25	42	18	35	36
$50	4	7	17	17
$100	0	0	6	8
$250	0	0	1	1
Average contribution	$17.69	$14.92	$28.43	$31.85
Average per respondent	$2.24	$4.64	$12.60	$17.36

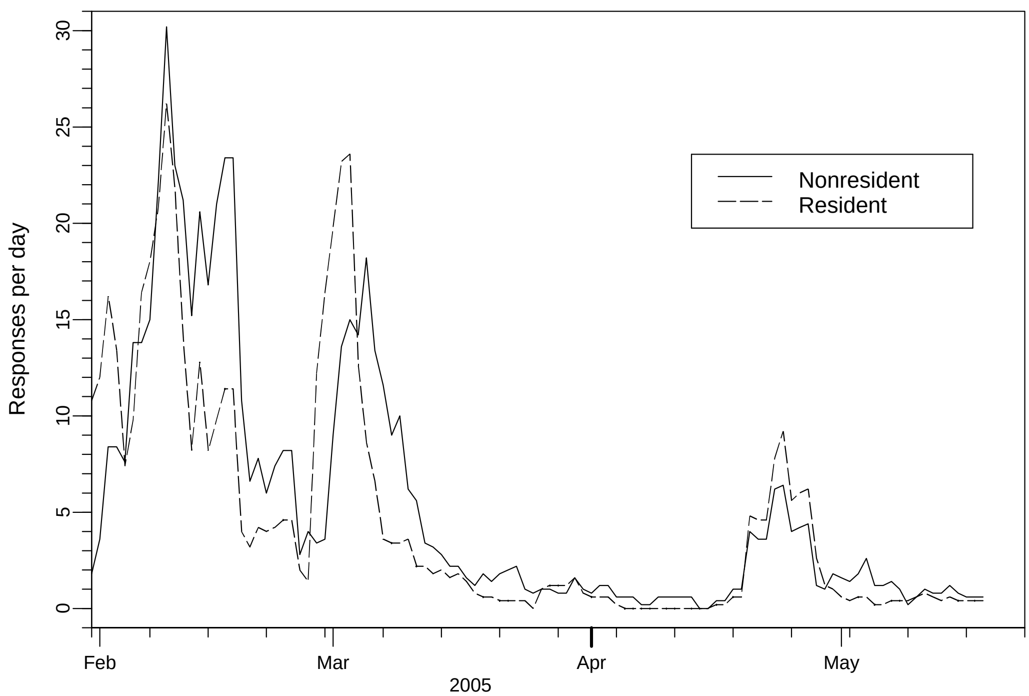
Table 10. Relative frequency distribution (in percent) for amount contributed, payment card				
	Resident		Nonresident	
Amount($)	**Cash**	**Hypo**	**Cash**	**Hypo**
0	89.8	73.3	69.4	48.1
1		1.1		
10	5.0	15.9	8.4	7.2
15			0.3	
20	0.6		1.0	1.0
25	3.5	6.3	9.2	20.2
50	0.3	2.3	6.3	11.5
100	0.6	1.1	4.7	9.1
200	0.3			
250			0.8	2.4
500				0.5
n	343	176	382	208
mean	$2.80	$5.44	$13.19	$29.28

Table 11. 1990 and 2005 Mean Payment Card Donation (current dollars)				
Study/statistic	**Resident**		**Nonresident**	
	Cash	**Hypothetical**	**Cash**	**Hypothetical**
1990 study	2.24	4.64	12.60	17.36
Ratio	0.48		0.73	
2005 study	2.80	5.44	13.19	29.28
Ratio	0.52		0.45	

Table 12. 1990 and 2005 Mean Payment Card Donation (constant 2005 dollars)				
Study/statistic	**Resident**		**Nonresident**	
	Cash	**Hypothetical**	**Cash**	**Hypothetical**
1990 study	3.22	6.68	18.13	24.98
Ratio	0.48		0.73	
2005 study	2.80	5.44	13.19	29.28
Ratio	0.52		0.45	

Figures 1 & 2.

Payment card responses per day, 5 -day moving average



Cash payment card mean contribution, 11 -day moving average

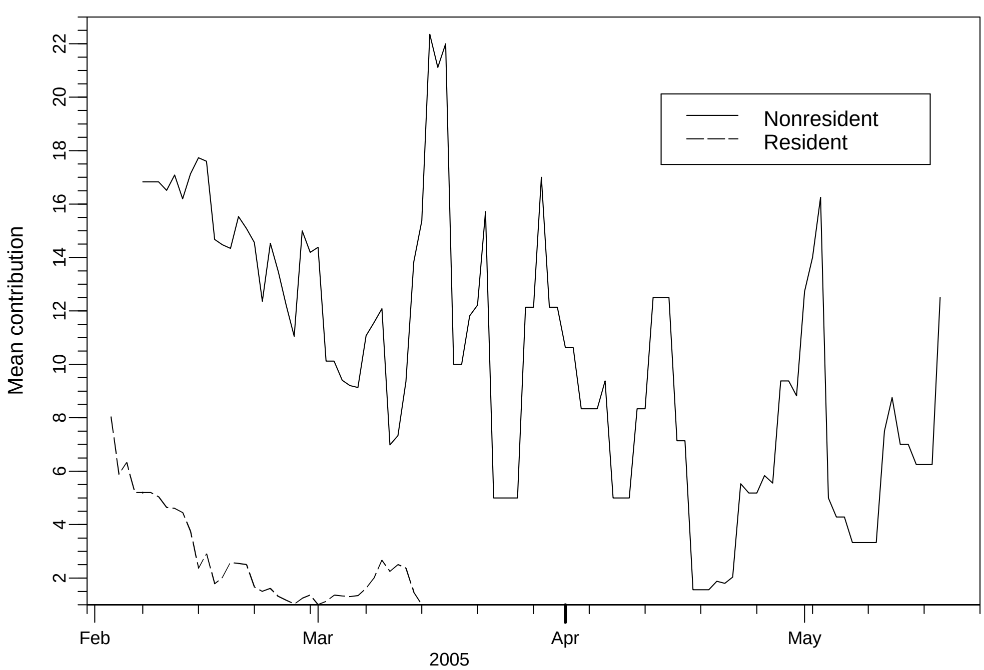
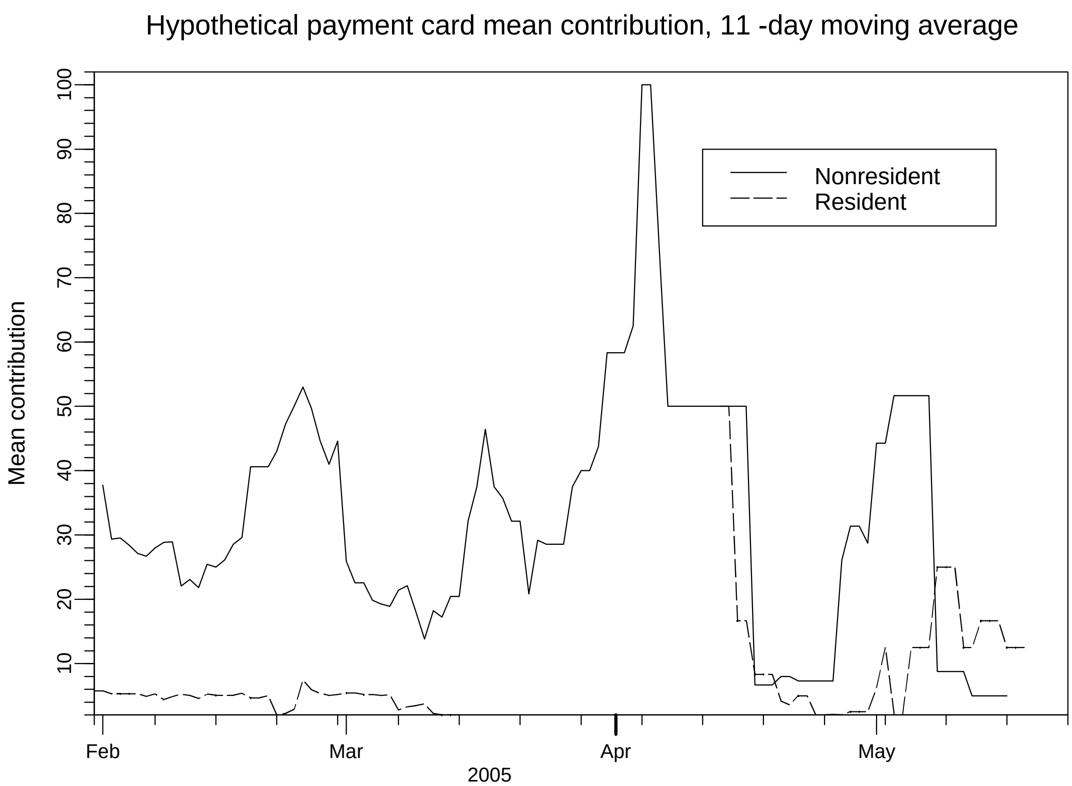


Figure 3.


Hypothetical payment card mean contribution, 11 -day moving average
Mean contribution
100
90
80
70
60
50
40
30
20
10
Nonresident
Resident
Feb
Mar
Apr
May
2005

Is Hypothetical Bias Universal? Validating Stated Preference Responses Using Binding Public Referenda

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Abstract

This paper compares discrete choice contingent valuation responses to aggregated votes in a subsequent binding public referendum. This criterion validity test is distinguished from prior work by (1) an identical quasi-public good and information content in both hypothetical and actual contexts; (2) a familiar and salient good that would be provided by a trusted local institution; (3) hypothetical responses derived from a genuine contingent choice context. The research presented here is also distinguished by its simplicity—the hypothetical and actual choice contexts are exactly parallel and respondents are drawn from an identical known population. Also in contrast to prior research, the present study finds no evidence of hypothetical bias. Point estimates of implied hypothetical and actual WTP differ by less than 10%, and hypothesis tests cannot reject the equivalence of hypothetical and actual behavior. Study results provide a number of compelling possibilities for the potential amelioration of hypothetical bias.

This research contributes to the fourth objective of the W-1133 regional project (estimate the economic values of agricultural land preservation and open space), as it addresses a critical methodological issue affecting a primary means of assessing land preservation and open space values. Economic values of agricultural land preservation and open space are often estimated using stated preference (SP) methods. However, past research has shown that values estimated using such methods are often subject to significant hypothetical bias. This paper suggests that hypothetical bias is not universal in such valuation efforts, and discusses potential means to ameliorate such bias in SP surveys—including surveys applied to the estimation of land preservation and open space values.

Introduction

Prior assessments have demonstrated often substantial hypothetical bias in stated preference willingness to pay (WTP) estimates, calling into question the appropriateness of such estimates for welfare evaluation (Arrow et al. 1993). Reviews provided by Murphy and Stevens (2004) and List and Gallett (2001) illustrate the ubiquity of research addressing the presence of—and potential calibrations for—hypothetical bias in stated preference valuation. While not all research finds clear evidence of hypothetical bias (e.g., Smith and Mansfield 1998; Vossler and Kerkvliet 2003; Champ and Bishop 2001; Johannesson 1997), and some finds that hypothetical bias may be ameliorated using cheap-talk, certainty adjustments, or other mechanisms (Champ et al. 1997; Champ et al. 2004; Cummings and Taylor 1999; Loomis et al. 1996), the preponderance of evidence concludes that there are often significant differences between stated (hypothetical) and actual market behavior (e.g., Murphy and Stevens 2004; List and Gallett 2001).

While hypotheses regarding hypothetical bias may be tested using assessments of either convergent or criterion validity, criterion validity tests are generally preferred in cases where appropriate criterion values exist (Bateman et al. 2002). As noted by Carson et al. (1986), criterion validity tests typically require comparisons between contingent (hypothetical) markets and markets that require some type of real payment. However, notwithstanding the common and perhaps mistaken (Murphy and Stevens 2004; Harrison 2002) presumption that markets requiring real payments necessarily reveal criterion values (i.e., actual WTP), markets used in purported criterion validity tests most often incorporate simulated or experimental elements as a means to permit comparisons with hypothetical markets (Murphy and Stevens 2004).

While such simulated markets may in some instances allow the elicitation of unbiased WTP estimates, they are often conducted in institutional settings unfamiliar to respondents. Such settings may generate novel or unusual behavior, confusion, distrust, or other behaviors that may lead to misstatements of true WTP. For such reasons Bateman et al. (2002) and others argue that comparisons involving WTP estimates elicited through simulated or experimental markets rarely qualify as true tests of criterion validity. The most common alternative—the use of individual or group donation mechanisms to validate hypothetical WTP (e.g., Champ et al. 1997; Champ and Bishop 2001; Seip and Strand 1992; Foster et al. 1997; Spencer et al. 1998)—may suffer from confounding effects of free-riding and the associated lack of incentive compatibility (Bateman et al. 2002; Champ and Bishop 2001). As a result, it not clear that such assessments provide appropriate criterion values to which hypothetical WTP may be compared.

Compared to assessments of hypothetical bias using simulated markets or donation mechanisms, a relatively small number of studies have attempted to validate hypothetical survey responses using criterion values inferred from binding referenda or public votes (Bateman et al. 2002). Recent studies include Schläpfer et al.'s (2004) comparison of contingent valuation (CVM) responses and binding referendum responses for similar but not identical landscape protection programs. Others, including Carson et al. (1986), Champ and Brown (1997) and Vossler and Kerkvliet (2003) compare measures of intended voting behavior to actual referendum results. (For example, Vossler and Kerkvliet (2003, p. 633) state that "it is likely that many of [their] respondents were aware of the upcoming vote and many may have studied the issue and decided how to vote.") However, despite a variety of past comparisons of hypothetical and actual voting behavior, the authors are aware of no published comparisons of responses in genuine stated preference survey contexts (cf. Schläpfer et al. 2004, p. 4) and exactly parallel binding referendum votes for identical environmental programs.

This study compares hypothetical, discrete choice CVM responses to aggregated votes in a subsequent, official and binding public referendum, where identical goods are considered in both the hypothetical and actual choice contexts. The good in question is the provision of a public water supply to the community of North Scituate, Rhode Island. Comparison of behavior in these parallel hypothetical and real choice contexts provides a criterion validity test that does not incorporate the unfamiliar elements and/or incentive compatibility concerns that may be associated with comparisons of hypothetical and real WTP using simulated markets or donation mechanisms.

The comparison of hypothetical choices and binding votes presented here is distinguished from prior work by three primary factors: (1) an identical quasi-public good and information content in both hypothetical and actual contexts; (2) a familiar and salient good provided by a trusted local institution; (3) hypothetical responses derived from a genuine contingent valuation context. The research presented here is also distinguished by its simplicity—the hypothetical and actual choice contexts are exactly parallel, and respondents are drawn from the same known population. No re-coding or transformation of survey responses is required, no cheap-talk or similar mechanisms are applied, and a straightforward "one vote per survey" format eliminates the need to adjust for correlation among responses by individual respondents or to allow for sequence effects.

This study is also distinguished by results that show no statistical evidence of hypothetical bias. While actual and intended voting behavior have often been shown to comport quite closely (e.g., Vossler and Kerkvliet 2003), the authors are aware of no prior work that shows similar correspondence between binding votes and hypothetical choices in genuine stated preference contexts. Moreover, these findings contradict the preponderance of evidence from simulated markets, which shows clear evidence of hypothetical biases across a range of stated preference approaches (Murphy and Stevens 2004). Contrary findings from the present study provide evidence that hypothetical bias is not indeed universal, and hint at potential avenues for the amelioration of such biases in future work.

Comparing Hypothetical Choices and Actual Votes

Numerous authors, including most recently Murphy and Stevens (2004), have outlined conceptual issues underlying the presence of hypothetical biases in stated preference responses and associated WTP estimates. These discussions reflect issues well-known in the literature, and are not reprised here. Rather, we emphasize that which may be learned from a direct comparison of hypothetical choice behavior in a genuine contingent choice survey context and a directly analogous, officially sanctioned and binding vote.

For purposes of the present analysis, we define hypothetical bias as one of two interrelated conditions: (1) a case in which sample mean or median WTP estimated using a stated preference survey instrument may be shown to differ systematically from that estimated using actual markets or behavior, and/or (2) a case in which the percentage or likelihood of 'yes' (or approval) votes associated with a specific and identical public or quasi-public good, at a given and identical household cost, differs systematically between a hypothetical choice and actual voting context. We further constrain our definition of hypothetical bias with an additional condition that the actual behavior occur in a familiar and trusted environment or institution, to avoid potential biases in WTP that may result from the eliciting of behavior in unfamiliar or simulated market contexts.

Conditions for Appropriate Comparison of Hypothetical Choices and Referendum Votes

Champ and Bishop (2001, p. 385) note that past attempts to validate stated preference responses using referendum behavior have "have been met with serious limitations," related to a typical lack of parallelism between hypothetical and referendum choice contexts. More recently, Schläpfer et al. (2004) note three conditions relevant to criterion validity tests involving hypothetical choices and actual votes that are often violated. (Schläpfer et al. (2004) also mention a fourth issue, relevant only where within-subject comparisons are made. Since the present assessment does not make within-subject comparisons, this issue is not relevant here.) The first involves the *types of referenda* that are appropriate for tests of criterion validity. Whereas many referenda involve programs whose costs to the household are unspecified or otherwise unclear, direct comparison to stated preference formats requires a voting choice that may be placed in the "same utility maximization framework as the CV responses" (Schläpfer et al. 2004, p. 4). Respondents in the real voting context must consider a choice involving the provision of a known good, with the expected increase in household costs clearly specified.

The second condition relates to the distinction between *genuine* stated preference survey contexts, and surveys (or pre-election polls) in which respondents are asked about planned or intended votes. As stated by Schläpfer et al. (2004, p. 4), "it appears to be impossible to put respondents in the mindset of a hypothetical choice on the basis of controlled survey information when they are, at the same time, making a real voting choice that is influenced by information from a variety of sources." Based on this argument, Schläpfer et al. (2004, p. 4-5) recommend that assessments of criterion validity involve stated preference surveys conducted "*before* the actual referendum proposition becomes the subject of public debate."

The third condition involves common differences between elicitation and information formats in stated preference surveys and binding referenda. For example, where tax consequences and public good outcomes are rarely precisely specified in public referenda, they are typically specified in detail by stated preference surveys (Schläpfer et al. 2004). In contrast, the most appropriate comparison of hypothetical versus real choices involves close correspondence between the elicitation and information formats of the two choice contexts, inasmuch as is possible given that one choice is hypothetical.

A fourth condition, and one *not* emphasized by Schläpfer et al. (2004), is that tests of criterion validity should ideally involve identical goods in both hypothetical and actual contexts. Past validity tests involving referenda or donation mechanisms have often incorporated non-trivial differences between goods considered in the hypothetical and actual contexts. For example, Schläpfer et al. (2004) report on a study in which the good considered in the hypothetical good was a "regional landscape conservation program," while the good considered in the referendum was an "increase of cantonal fund for nature and heritage protection." While such distinctions might be considered trivial, it is also possible that they might have significant implications for willingness to pay and findings of hypothetical bias.

The North Scituate Water Supply Study

Although tests of criterion validity need not satisfy all of the conditions characterized above, significant departures from these conditions may render conclusions regarding hypothetical bias of questionable validity. Based on these conditions, the North Scituate Water Supply Study provides a nearly ideal situation to assess criterion validity using actual voting behavior. The study is characterized by: (1) an actual voting choice that may be placed in the same utility maximization context as stated preference responses, (2) a stated preference survey implemented before the public referendum was approved or scheduled, (3) a referendum that precisely specified household tax and quasi-public good outcomes with an elicitation and information content similar to that of the hypothetical survey, and (4) hypothetical and actual choice contexts addressing an identical quasi-public goods.

The study was conducted to assist the Town of Scituate Water Study Committee in assessing public support for provision of public water supply to the Village of North Scituate. The project would have installed and operated infrastructure necessary to provide public water to approximately 500 homes within the Village of North Scituate. Based on State of Rhode Island regulatory requirements, implementation of the proposed water project would have required a majority vote of affected property owners in an officially sanctioned referendum. The Water Supply Committee funded the contingent choice survey as a practical means to gauge public willingness to pay for public water, prior to incurring the significant cost required to sanction, promote, schedule, and implement the actual referendum (Johnston 2001).

While the contingent choice survey cover letter and instrument noted the possibility of a public vote as a “next step” in the process, this was the first indication that any official referendum might be forthcoming. As the survey was designed as a means to assess public preferences—before the official vote was approved or scheduled—it provides a nearly ideal context in which to assess the validity of hypothetical survey responses in a genuine stated preference context. The Appendix provides the exact text incorporated in the survey cover letter, in which the rationale for the survey was described to respondents.

The Survey Instrument

The contingent choice survey was designed in collaboration with the Water Supply Committee, and was iteratively pretested and revised based on meetings with the Committee and water supply experts, focus groups with local residents, and individual pretests including verbal protocol analysis (Schkade and Payne 1994). The Committee provided engineering plans for a proposed water project and estimated costs based on consultations with water systems experts. These plans and estimates were used as the basis for *both* the contingent choice survey and the subsequent binding referendum.

Prior to presenting the contingent choice question, the survey (and an accompanying fact sheet) provided detailed information concerning public water and the proposed water project. As described to both survey respondents and referendum voters, the water supply project is best characterized as a quasi-public good. The Committee initially envisioned a project in which individual homeowners could “opt-out” of the system—making it more akin to a private good. At the time of the study, however, it remained uncertain whether connection to the system would be mandatory (Long 2001).

Hence, to reduce the potential for incentive non-compatibility (Carson et al. 1999), the contingent choice survey presented the choice as involving mandatory payment and water service. In addition, the project would have resulted in other changes characteristic of a public good, including the opening of new areas to potential development (areas unsuitable for private wells), and the nuisance associated with the installation of water supply lines.

The hypothetical choice question asked respondents to vote for or against the proposed water project, given a specified quarterly household water bill that would cover all installation, operation, and maintenance costs. Because costs were not known with 100% certainty, the Committee estimated a realistic range of costs, based on data received from neighboring water districts and engineering cost estimates (Maguire Group Inc. 2000). In order to forecast voting behaviors at different cost levels within this range, five different survey versions were produced, each with a different projected cost. The five quarterly cost levels were \$125, \$175, \$250, \$325, and \$425. Respondents were informed that "because costs are not known with 100% certainty, the Water Study Committee has estimated a realistic range of costs. Some receiving this survey will see costs on the high end of this range. Some will see costs on the low end of this range." This statement was included in order to provide a straightforward explanation for the varying cost levels incorporated in versions of the survey received by different households.

After detailing the water supply project and its costs, the dichotomous choice question was worded as follows:

For this final question, please assume that your household's average **quarterly bill (paid every three months, or four times per year)** would be **$___.** Considering the costs and benefits of the proposed public water supply, how would you vote?

- ❑ YES—I would vote in favor of the public water supply in my area. I understand that my household would pay approximately **$___ per quarter** in new district water bills.
- ❑ NO—I would vote against the public water supply in my area. I understand that my household would continue to pay the costs of operating and maintaining our private well.

The Data and Empirical Model

The North Scituate Water Supply Survey was implemented as a mail survey, following a variant of the tailored survey design method of Dillman (2000). As only quarterly cost varied across survey versions the experimental design was straightforward, with a roughly equal number of surveys incorporating each of the five cost levels (i.e., $125, $175, $250, $325, and $425). Other attributes of the project remained constant over all survey versions. In addition to the contingent choice question, survey responses provided information concerning respondents' satisfaction with the water from their private wells, the ability of their wells to provide an adequate quantity of water year-round, the household's use of water filters and/or bottled water, and other elements of potential relevance.

Surveys were distributed to all homeowners in the region that would be affected by the proposed water supply project. In total, 435 surveys were mailed on July 2, 2001. Of these, 341 surveys were returned, for a final response rate of 78%. Three-hundred surveys were returned based on a preview letter, an initial survey mailing and a reminder letter. An additional 41 were returned subsequent to a final reminder postcard sent on

July 28. This distinction is noted as it appears that there is a systematic difference between responses received before and after the reminder postcard. Of all returned surveys, 314 provide sufficient information for inclusion in the empirical model of stated preference (hypothetical) responses.

The North Scituate Water Supply Referendum

Subsequent to the implementation of the survey (and indeed informed by survey results), an binding referendum to authorize the water supply project was sanctioned and scheduled by the Town of Scituate. The referendum concerned "whether to establish an independent water district…[with an]…approximate cost per year to the people receiving the service [of] $1000." It was emphasized that prior to the completion of the project (a multiple year task), subsequent votes would likely be necessary to address specific issues. Regarding the issue of mandatory versus voluntary participation in the public water system, once established, it was emphasized that mandatory connection with the system "was a possibility" (Long 2001).

The referendum was held during a Special Financial Town Meeting on November 13, 2001 (Long 2001). The water supply project was identical to that considered in the hypothetical survey instrument implemented approximately four months prior. Description of the water supply project in the public referendum was drawn from the same information found in the hypothetical survey instrument, and specified an anticipated household cost of $1000 per year, or $250 per quarter—the median value presented in hypothetical survey versions. Those invited to the Town Meeting were the same homeowners to whom the survey instrument had been mailed.

Aggregate data for the November 13, 2001 referendum (actual votes) were obtained from official minutes of the Special Financial Town Meeting (Long 2001). (All those eligible to vote in the Town Meeting had already received the prior survey describing the water supply project.) After the provision of a matching verbal description of the project, and a limited question-and-answer session, the vote was initiated at 8:45pm. The final ballot results, at an anticipated household cost of $250 per quarter, were 122 in favor and 145 opposed, for a 45.7% approval.

The Empirical Model

As each respondent considered only a single contingent choice question, the data may be analyzed using a standard random utility model (Hanemann 1984; McConnell 1990), with all observations considered independently and identically distributed (*iid*). The model presumes that respondents choose whether to vote for mandatory public water supply based on the difference in utility resulting from public water supply and that resulting from retaining private (well) supply. This difference may be represented by

$$dU = U_p(\mathbf{W_p}, Y-C_p, \mathbf{D}) - U_w(\mathbf{W_w}, Y, \mathbf{D}) \quad (1)$$

where dU represents the utility difference associated with public water supply, $U_p(\cdot)$ represents utility realized from the provision of public water, and $U_w(\cdot)$ represents utility realized from the retention of private water. Utility from public water is assumed to be determined by the attributes of the public water supply (vector $\mathbf{W_p}$, assumed fixed across all households), the household's demographic attributes (vector $\mathbf{D}$), and household income (Y) minus the additional cost of public water (C_p). Utility from private water supply is determined by the attributes of the household's well-water supply (vector $\mathbf{W_w}$, which may vary across households), the household's demographic attributes (vector $\mathbf{D}$), and household income (Y).

The random utility model presumes that utility $U(\cdot)$ may be divided into empirically measurable (observable) and stochastic (unobservable) components, such that

$$
\begin{aligned}
dU &= v_p(\boldsymbol{W_p}, Y\text{-}C_p, \boldsymbol{D}) - v_w(\mathbf{W_w}, Y, \boldsymbol{D}) - [\varepsilon_w - \varepsilon_p] \\
&= dv - \theta. \qquad (2)
\end{aligned}
$$

Here, $v_p(\cdot)$ and $v_w(\cdot)$ represent the empirically measurable components of utility associated with public and well water supply, respectively. The terms ε_p and ε_w represent the associated stochastic, or unobservable components. Assuming the standard linear approximation for $v_p(\cdot)$ and $v_w(\cdot)$ common in random utility models, and that $\boldsymbol{W_p}$ is fixed and constant across all observations, dv may be represented by a reduced-form econometric specification

$$
dv = \beta_0 + \boldsymbol{\beta_1}(\mathbf{W_w}) + \beta_2(C_p) + \boldsymbol{\beta_3}(\mathbf{D}). \qquad (3)
$$

Given (1)-(3), if one assumes that θ follows a logistic distribution, one may model the probability of choosing public water using the familiar logit model, with the standard likelihood function provided by Maddala (1983) and many others. As each survey incorporates only a single choice question, each response is treated as independently and identically distributed (*iid*) for purposes of estimation. Following the model of (1)-(3) above, variables included in the statistical model characterize such features as the cost of public water supply, the attributes of each household's existing private well-water supply, and other household attributes. Table 1 characterizes independent variables included in one or more variants of the statistical model of hypothetical choice responses.

Results from this model are compared to aggregated results from the binding referendum. To provide the most conservative test of criterion validity—here the equivalence between hypothetical choices and binding votes—the results of the binding vote are treated as non-stochastic (i.e., a fixed point of 0.457). While one might also treat referendum results as the result of a stochastic process, the resulting variance would increase the ease with which one might reject the null hypothesis of zero hypothetical bias.

Model Results

Results of the logit model are presented in table 2. Model one is the final, unrestricted specification. The model is statistically significant at $p<0.0001$ (likelihood ratio $\chi^2 = 88.898$, df = 6), and correctly predicts 77.2% of observed choices. All independent variables in the final model are statistically significant at $p<0.10$, with most significant at $p<0.01$. Model two represents a restricted specification from which two variables (*late*; *late*×*cost*) have been excluded. As indicated by variable descriptions in table 1, these variables allow estimated parameters for the equation intercept and program cost to vary systematically according to whether the survey was received after a final reminder postcard was mailed (July 28, 2001).

A likelihood ratio test of restrictions in model two rejects the null hypothesis of zero joint influence ($\chi^2 = 12.322$, df = 2, p=0.002). Hence, we conclude that there are systematic differences between the preferences of those who returned surveys after July 28 and those who returned surveys between July 2 and July 28. Of particular relevance here, results suggest that late respondents were much less influenced by the household cost of the project (*cost*), as indicated by the near-zero sum of (*cost* + *late*×*cost*). While the explanation for this finding is unknown, it suggests that the timing of survey responses may influence the potential for hypothetical bias, as in this case it influences the responsiveness of choices to program cost. Given statistical significance of the restrictions implicit in model two (see above), model one is selected as the final model for assessments of criterion validity.

Assessments of Criterion Validity and Hypothetical Bias

As referendum results are only available as an aggregate sum, comparisons of individual responses are not possible. Hence, all results are based on aggregate responses to in both hypothetical and binding choice contexts, preventing a detailed assessment of nonresponse such as that of Vossler and Kerkvliet (2003). Nonetheless, while the specific identities and demographic attributes of the referendum respondents are unknown, both the survey and referendum captured a relatively large percentage of the households in the affected region (78% and 61% of the 435 households, respectively).

Unlike assessments of hypothetical biases in simulated or experimental markets—in which complete demand or preference equations may be estimated—here a complete preference function may only be estimated for hypothetical responses. As noted above, referendum results are characterized only by a single point: 45.69% approval of the proposed water supply project at an estimated household cost of $250 per quarter. This limits the extent of comparisons that may be made between hypothetical and binding responses. Nonetheless, even within these limitations, one may assess differences between responses in the two choice contexts.

The most direct comparison involves the probability of supporting the proposed water supply project (or, alternatively, the percentage of representative respondents who would support the project). The proportion of votes supporting the water supply project is known in the referendum—0.4569 at $250/quarter. An analogous proportion may be estimated based on stated preference model results from table 2, characterizing hypothetical choices. Given a $250/quarter cost, and mean values for other model variables (table 1), the proportion of support ('yes' votes) predicted by the logit model is 0.4978. Based on model results, a Wald test (Greene 2003) fails to reject the equality of the hypothetical (estimated) and actual proportions of supporting votes (χ^2=0.04, df = 1, prob = 0.8474). An analogous result holds if one conducts a comparable hypothesis test using standard errors for the predicted (hypothetical) probabilities, following the resampling approach of Krinsky and Robb (1986). The latter test is conducted for comparison. We randomly draw 10,000 sets of coefficient estimates from the estimated distribution of parameters obtained from maximum likelihood estimation. Probability estimates (i.e., probability of a 'yes' vote) are calculated for each draw, resulting in an empirical distribution of probability from which the estimated standard error is calculated. Based on this estimated standard error (0.0419), a t-test fails to reject the equality of the hypothetical (estimated) and actual probabilities (p=0.25). In sum, statistical comparisons of hypothetical choices and binding votes provide no evidence of hypothetical bias in the probability of supporting the provision of identical quasi-public goods, at identical household costs. These results are summarized in table 3.

An even stronger refutation of hypothetical bias emerges if one only considers surveys received on-time (i.e., the variable *late* is set equal to 0). Given a $250/quarter cost, and mean values for other model variables (table 1), the proportion of support predicted by a logit model excluding late surveys is 0.4796. Based on model results, a

Wald test (χ^2=0.02, df = 1, prob = 0.9153) fails to reject the equality of the hypothetical (estimated) and actual proportions of supporting votes.

One may also assess criterion validity in terms of implied WTP. Traditionally, one assesses criterion validity based on standard estimates of either mean or median WTP. Here, however, standard WTP estimates may not be derived from binding referendum results. Rather, as noted above, one only observes a single point estimate. This point estimate indicates that 45.7% of respondents vote 'yes' at a $250/quarter cost. The appropriate WTP comparison, then, is the estimated *hypothetical* cost level at which survey respondents would provide an identical level of support (i.e., 45.7%). Given model results, this may be calculated as

$$WTP_{0.457} = \frac{\hat{\beta}_0 + (\hat{\beta}_{bottled} \times bottled) + (\hat{\beta}_{supply} \times supply) + (\hat{\beta}_{h\_size} \times h\_size) + (\hat{\beta}_{late} \times late) + 0.1727}{-\hat{\beta}_{\cos t} - \hat{\beta}_{cost \times late} \times late}$$

(4)

where independent variables (*bottled*, *supply*, *h_size*, *late*) are set to mean sample values, corresponding parameter estimates are given by $\hat{\beta}_i$ ($\hat{\beta}_0$ is the equation intercept), and the constant 0.1727 represents the value of *dv* in (3) that leads to 45.7% support based on the logistic probability function. It is easily shown that (4) follows directly from the specification of *dv* in (3) and the logistic probability function of the logit model.

Based on (4), 45.7% support for the water supply project is projected at a quarterly cost of $268.01. This represents a 7.2% increase over the $250/quarter cost at which actual 45.7% approval was found—a small difference in point-estimate WTP associated with 45.7% support. A Wald test (χ^2=0.04, df = 1, prob = 0.8505) fails to reject the equality of these hypothetical (estimated) and actual WTP estimates. Hence, mirroring results found above, assessment of WTP finds no evidence of statistically significant hypothetical bias in a direct comparison of identical hypothetical and binding choices. This stands in clear contrast to prior work showing that hypothetical values are typically 1.5 to 3 times greater than actual market values (e.g., Loomis et al. 1996; Murphy and Stevens 2004; List and Gallet 2001).

Also as above, hypothetical and binding results comport even more closely if one omits late survey responses. When *late*=0, 45.7% support for the water supply project is projected at a quarterly cost of $258.59. Again, Wald test results (χ^2=0.01, df = 1, prob = 0.9162) fail to reject the equality of hypothetical (estimated) and actual estimates. Analogous hypothesis tests using resampling methods (Krinsky and Robb 1986) generate qualitatively identical results.

Implications and Discussion

Results found here mirror those of Vossler and Kerkvliet (2003), Vossler et al. (2003), Champ and Brown (1997), and others who contrast intended voting behavior (or CVM votes in contexts where an upcoming referendum was anticipated) with binding referendum votes, and find close correspondence between hypothetical and binding responses. However, to our knowledge this is the first assessment in which hypothetical responses in a genuine CVM context have been compared to binding referendum results for identical programs, and in which there is no evidence of significant hypothetical bias. This results begs the question as to why hypothetical bias is not present here, despite overwhelming evidence of hypothetical bias in simulated (i.e., experimental) markets (Murphy and Stevens 2004).

Although the present data do not allow unambiguous determination of the reason(s) why hypothetical bias is not significant here, there are a variety of potential explanations that correspond to prior findings in the literature. These might include: 1] the salience and familiarity of the good in question and equivalence of information content in hypothetical and binding choice contexts, 2] the explicit linkage between the CVM survey and an official government process, including notification that an official vote might be forthcoming, 3] random chance.

Salience and Familiarity of the Good and Equivalence of Information Content

According to Arrow et al. (1993, p. 4605), "[i]f CV surveys are to elicit useful information about willingness to pay, respondents must understand exactly what it is they are being asked to value." The survey and focus group literature suggests that first hand experience with natural resources may influence values and survey responses (Cameron and Englin 1997; Johnston et al. 1995). The literature also argues that familiarity with goods and/or behavior tends to create closer correspondence between behavioral intentions and actual behavior (Mitchell and Carson 1989, p. 186). As stated by Blamey et al. (2001, p. 128), "familiarity may be beneficial in terms of the validity and reliability of results." Here, the survey presents a quasi-public good that is highly familiar and salient to many respondents. Moreover, many respondents will have had direct experience with the attributes of this good—public water supply—in other homes or businesses. This stands in contrast to goods often valued using stated preference methods, which may be unfamiliar and with which respondents may have little direct experience.

It has also been established that information provision can influence WTP estimates derived from stated preference survey instruments (e.g., Bergstrom and Stoll 1989; Bergstrom et al. 1989; Hoehn and Randall 2002). Moreover, it is common for information provision in stated preference survey instruments to differ substantially from that in public referenda (Champ and Bishop 2001; Schläpfer et al. 2004). Here, the information content underlying hypothetical and binding choices is identical. Indeed, all households in the affected neighborhood were provided with extensive and accurate information regarding the proposed water supply project as part of the survey. Information provided during the public meeting was also drawn from the informational materials developed for the survey. Hence, the level and type of information underlying the hypothetical and binding choices in this case are highly similar—if not identical. Based on empirical results found here and prior results from the literature, it is possible—perhaps even likely—that the familiarity and salience of the good in question, combined with extensive and equivalent information provided in both choice contexts, may have contributed to a closer correspondence between hypothetical and actual responses.

Explicit Linkage Between the CVM Survey and an Official Government Process

The contingent choice survey described here is relatively unusual in that it was implemented as part of an official government consideration of a specific and known public project. Also, while the decision to hold the public referendum had not been made at the time of survey implementation, the possibility of a forthcoming officially sanctioned referendum was mentioned as part of the survey materials (see Appendix). Hence, while the survey may not be appropriately characterized as a pre-election poll (c.f., Schläpfer et al., 2004), the association of the survey with an official process and the possibility of a subsequent referendum may have placed respondents in a mindset closer to that which would apply during a binding vote.

As noted by Schläpfer et al.(2004, p. 4), "[i]t appears to be impossible to put respondents in the mindset of a hypothetical choice … when they are, around the same time, making a real voting choice." While this statement is presented as a critique of validity tests based on surveys conducted *after* a referendum had been announced and scheduled, it might also be interpreted as a potential means to reduce hypothetical biases in genuine CVM surveys. That is, the simple mention that a CVM survey has been commissioned by a government agency, and that a binding referendum may be forthcoming, might be sufficient to place most respondents in a mindset equivalent to that which would occur during an analogous binding vote. While survey results cannot confirm such a supposition, it is consistent with the both results found here and the close correspondence between binding votes and responses in CVM surveys conducted after public referenda had been announced and promoted (e.g., Vossler and Kerkvliet 2003).

Hypothetical Bias and Random Chance

Despite the clear refutation of hypothetical bias found in the present case, it is impossible to rule out the possibility that these results are due to random chance. Indeed, the nature of statistical inference implies the possibility—albeit improbable—that type II statistical errors will occur, in which the null hypothesis of zero hypothetical bias cannot be rejected, even though such biases are in fact present. Moreover, the lack of experimental control over the exact respondents comprising the hypothetical and binding referendum samples implies that the two samples are different, even though drawn from an identical population.

Despite these possibilities, we find no compelling evidence that results found here are due to either type II statistical errors or potential differences between the two samples. For example, with regard to sample differences, we note that survey respondents comprise 78% of the entire population affected by the proposed policy, while the sample of voters comprises 61% of the identical population. While differences between the two respondent samples cannot be conclusively disproved, neither is there evidence of substantial nonresponse in either instance. Moreover, there is no evidence that incentives for response (or nonresponse) differ between the hypothetical and binding choice contexts. Hence, while we note the *possibility* that results are due to stochastic elements, we also note that the preponderance of evidence suggests that—in all likelihood—hypothetical bias is indeed negligible in the present case.

Conclusion

This paper compares hypothetical, discrete choice CVM responses to aggregated votes in a subsequent, official and binding public referendum, where identical goods are considered in both the hypothetical and actual choice contexts. In contrast to prior stated preference validity tests conducted using simulated markets, here we find no evidence of statistically significant hypothetical bias. Even on a point-estimate basis, implied hypothetical and actual WTP differ by less than 10%—a result of some significance given that may past assessments of CVM have shown mean hypothetical values "are about 2.5 to 3 times greater than actual values." (Murphy and Stevens 2004). While reasons for the lack of hypothetical bias cannot be unambiguously established in the present case—attributes of the study provide a number of compelling possibilities for the potential amelioration of hypothetical biases.

Among the possibilities suggested by the present study are that reductions in hypothetical biases may be related to the salience and familiarity of the good in question and equivalence of information content in hypothetical and binding choice contexts, and an explicit linkage between the survey and an official government process, including notification that an official vote may be forthcoming. Additional research is required, however, to establish which, if either of these factors might provide a practical means to reduce or eliminate hypothetical biases in broader CVM research. In contrast, subsequent research might also find that the present results are due primarily to random chance, and that these results, while promising, hold little promise for improvements to CVM methods in general.

Empirical results shown here may offer more in terms of compelling questions and possibilities than unambiguous proof that hypothetical biases may be overcome in broader stated preference research. While the relatively simple, unambiguous results provided by the present research might be considered compelling evidence that hypothetical bias can be avoided, the lack of data for individual respondents also leaves open the possibility—even if remote—that results reflect other influences such as differing rates of nonresponse. Such possibilities notwithstanding, model results at a minimum suggest that hypothetical bias is not universal, and that researchers should neither abandon the search for means to ameliorate hypothetical biases, nor should accept such biases as a foregone conclusion.

Appendix: Text of Selected Survey Materials

The following appendix provides the text incorporated in the survey cover letter, in which the rationale for the survey was described to respondents.

Text of the Cover Letter

"I am writing to ask for your input on an important decision that affects your household—the potential creation of a water district to provide public water to the Village of North Scituate and points North along Route 116. The Town of Scituate Water Study Committee has prepared this survey to assess public support or opposition to this project. You have received this survey because your home is in the region under consideration for public water.

The proposed water district will not proceed without the majority support of property owners who live within the boundaries of the proposed district. This survey is the first step in determining whether such support exists. Depending on survey results, the next step would be a public information forum, followed by an official vote of affected homeowners in November, 2001. Only homeowners within the proposed water district would be allowed to vote for or against the project.

Included in this package are a one-page survey and a brief fact sheet providing some important information regarding the proposed water district. It is important that we hear from all residents who may be affected by the proposed water supply project. Your answers to this survey are strictly confidential and anonymous. If you have any questions or concerns regarding the survey, please don't hesitate to contact The Town of Scituate Water Supply Board at _________. We hope that you will take the time to complete this important survey."

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Table 1. Model Variables and Summary Statistics

Variable	Definition	Mean	Std. Dev.
Bottled	Binary variable indicting that the household uses bottled water for drinking (1 = yes, 0 = no).	0.1404	0.3479
Supply	Binary variable identifying households whose well provides an adequate quantity of water during all months of the year (1 = yes, 0 = no).	0.8788	0.3269
H_Size	Number of persons living in the household.	2.9266	2.2594
Late	Binary variable identifying surveys received "late," or after July 28.	0.1257	0.3320
Cost	Estimated quarterly household cost of the proposed water supply project, including all installation, maintenance, and operation costs.	248.0994	101.9605
Cost×Late	Quadratic interaction between *Cost* and *Late*.	32.7485	95.4149

Table 2. Maximum Likelihood Logit Results

	Unrestricted Model			Restricted Model		
Variable	Coefficient	Std. Err.	Prob>|z|	Coefficient	Std. Err.	Prob>|z|
Intercept	5.0533	0.8717	<0.001	4.2656	0.8009	<0.001
Bottled	0.9017	0.4140	0.029	0.9467	0.4073	0.020
Supply	-3.5329	0.6746	<0.001	-3.1893	0.6477	<0.001
H_Size	0.1701	0.0909	0.061	0.1472	0.0870	0.091
Late	-2.4447	0.9446	0.010	--	--	--
Late×Cost	0.0121	0.0036	0.001	--	--	--
Cost	-0.0106	0.0017	<0.001	-0.0080	0.0015	<0.001
-2LnL χ^2: model (df = 6)	88.8981		<0.001	76.5759		<0.001
-2LnL χ^2: for restrictions (df = 2)				12.3222		0.002
Pseudo R^2	0.2109			0.1817		
N (obs.)	304			304		
N per completed survey	1			1		

Table 3. Assessments of Hypothetical Bias: Empirical Results

	Full Model (Includes Late Surveys)	Full Model (*Late*=0)
Probability of 'Yes' Vote at $250/Quarter Cost		
Contingent Choice (hypothetical)	0.4978	0.4796
Referendum (actual)	0.4569	0.4569
Point Estimate Difference	0.0409	0.0227
Wald χ^2 for H_0: [Hypothetical = Actual Probability]	0.04	0.02
Prob > χ^2 (df=1)	0.8474	0.9153
WTP Associated with 45.7% 'Yes' Votes		
Contingent Choice (hypothetical)	$268.01	$258.59
Referendum (actual)	$250.00	$250.00
Point Estimate Difference	$18.01	$8.59
Wald χ^2 for H_0: [Hypothetical = Actual WTP]	0.04	0.01
Prob > χ^2 (df=1)	0.8505	0.9162

Rural Economies in Transition: Duration Models of Eastern Wilderness Designation

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ABSTRACT

This paper reports the results of an analysis that directly contributes to one of the Western Regional Research Group W-1133's official objectives: "Estimating the economic benefit of ecosystem management of forests and watersheds". This project also meets the spirit of W-1133 by combining expertise across three institutions: Oregon State University, USDA Forest Service and West Virginia University. This paper contributes to a larger project that investigates the role of wilderness designation and other land use types (national forests, national parks and state public lands) on development paths in the Appalachian Region (410 counties across 13 states in the eastern U.S.).

This analysis uses a discrete duration modeling approach to estimate rates of transition for county economies in the Appalachian Region for the period 1969 to 2000. An income indicator was generated that compared the relative dominance of non-labor sources of income to extraction/manufacturing sources of income. A similar ratio was generated that compared the total number of services sector jobs with extraction/manufacturing total jobs. Each county was then evaluated based on whether its income and jobs indicators were dominated by extraction/manufacturing sources (ratio <1 and indicator coded as 0) or were dominated by non-labor income and services jobs (ratio >1 and indicator coded as 1). The indicator variables created a vector of data for each county for each year, indicating if and when it transitioned from extraction/manufacturing to non-labor or services orientations.

When all eligible counties (metropolitan, urban and rural) were included in the model, wilderness counties were shown to have lower baseline income and jobs transition rates than counties without wilderness. Increases in wilderness density were associated with steeper hazard functions; i.e., transition rates increased. This means that wilderness counties, which occur mostly in rural areas, started at a relative disadvantage, but with increasing amounts of wilderness, transitioned at a higher rate. Given the temporal nature of the duration models, we provide evidence that wilderness designation is a contributing factor in the spatial distribution of migration patterns over the last three decades in the Appalachian Region.

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Introduction

One debate regarding the role of wilderness designation focuses on how wilderness affects the structure and function of local economies. Earlier analyses of aggregate-level data demonstrate (1) significant and positive associations between wilderness and economic indicators of growth in population, jobs, income and services sectors; and (2) a lack of negative associations between wilderness and economic indicators of growth in resource extraction-dependent sectors in the Appalachian Region (see Rosenberger, English and Sperow 2004a and 2004b). This analysis applies a duration modeling framework to measure the effect of wilderness (and other land) designations on the rate at which county economies are shifting away from dependence on resource extraction, primary production and manufacturing to one based on amenities, services, and non-labor income.

Lorah (2000) suggested that environmental amenities may act as catalysts in the transformation of rural economies. This transformation is away from resource extractive industries to relatively diversified economies that attract tourists, small businesses and retirees due to high levels of natural amenities. Wilderness is one such amenity. In his analysis, Lorah (2000) estimated correlation coefficients between the date of transition and the percent of a county's land base in either wilderness or in wilderness, national parks, national monuments, and wilderness study areas. His study area consisted of all rural counties in the Western U.S. His indicator variable for classifying counties as 'amenity' versus 'extraction' was the ratio of non-labor income from dividends, interest and real estate (DIRE) to total income from resource extraction (agriculture, forestry and mining) sectors. If the ratio was greater than one, then the county was classified as amenity (non-labor income from DIRE surpassed extraction income); otherwise it was classified as an extraction economy. This ratio was calculated for all years from

1969 to 1996. He recorded the year in which the ratio became greater than one, which serves as the transition year.

Lorah (2000) compared the year of transition with the percent of county area in wilderness using correlation coefficients. He found a negative and significant correlation coefficient; increasing quantities of wilderness were associated with earlier transitioning of rural economies. If the study area was further restricted to rural counties not adjacent to metropolitan counties, the same association became stronger. And when additional types of amenity lands were included (e.g., national parks, national monuments, and wilderness study areas), the associations were about the same as with wilderness alone. Lorah (2000) concluded from his analysis that "environmental amenities play a role in shaping the economic structure of rural counties. Where environmental amenities such as wilderness exist, local economies are more likely to have moved beyond a narrow reliance on extraction. Counties without the benefit of environmental amenities are at a competitive disadvantage in attracting tourists, immigrants, and employers." (234).

However, correlation coefficients identify associations in the data, but do not imply any form of causality. If we are to argue wilderness is a catalyst (causes or speeds up) in the transition of local economies from one state to another, then we need to apply a framework that measures causality. This analysis applies a modeling framework that comes closer to measuring causal relationships between wilderness designation and the temporal transition of local economies in the Appalachian Region.

Theoretical Discrete Duration Models

Models based on longitudinal (cross-sectional over time) data have been developed and applied by a variety of disciplines. These types of models are known as duration models, event history models, survival models, and failure-time or reliability models. These models are concerned with measuring temporal patterns and causes of change and have been applied by economists in investigating length of unemployment spells (Meyer 1990), durations of strikes (Kennan 1985; Gunderson and Melino), job search and migration patterns (Detang-Dessendre and Molho 1999), etc. Other applications have looked at the timing of policy adoption (Kerr and Newell 2003; McCammon 1998; Berry and Berry 1990), political changes (Gasiorowski 1995) and length of peace spells (Beck et al. 1998; Box-Steffensmeier and Zorn 2001). More recently, duration models have been extended to modeling land use changes and adding a spatial dimension to the underlying modeling framework (Waldorf 2003; Hite et al. 2003; Irwin and Bockstael 2002; Vance and Geoghegan 2002; Coomes et al. 2000).

This study's longitudinal data consists of historical county-level economic data for all counties in the Appalachian Region (n = 410 counties; t = 32 years from 1969-2000). This study measures the rate of transition for counties from one state to another state. The first transition indicator focuses on the source of income similar to Lorah's (2000) analysis. The ratios of non-labor income (DIRE plus government transfer payments for retirement benefits) to income from the mining, manufacturing and agriculture, forestry and fisheries sectors are calculated. Two states are defined based on the income indicator: (1) a county is dependent on extraction/manufacturing if the income ratio is less than one; and (2) a county is dependent on non-labor income if the income ratio is greater than one. The second indicator focuses on jobs. The ratios of service-sector jobs to extraction/manufacturing (agriculture, forestry and fisheries services plus mining plus manufacturing) jobs are calculated. Two states are defined based on the job indicator: (3) a county is dependent on production/manufacturing if the job ratio is less than one; and (4) a county is dependent on services if the job ratio is greater than one. Our interest is on the transition from Income State (1) to Income State (2), and Job State (3) to Job State (4). Each year of data is coded as either zero (Income State (1) or Job State (3)) or one (Income State (2) or Job State (4)). Therefore, our dependent variables of analysis are binary coded data.

Standard regression or maximum likelihood estimators are not appropriate for duration data because of two problems: right-censoring and time-varying covariates (Allison 1984; Box-Steffensmeier and Jones 1997, 2004). There are three possible cases for any county in the dataset. In Case One, a county has transitioned from one state to another prior to data collection (all annual observations would be "ones"). These data are considered to be left-censored, contain very little information for measuring transition rates, and are typically dropped from the dataset. In Case Two, a county starts in one state and transitions to the other state during the study period (i.e., a series of zeros followed by a series of ones signifying the year of transition). In Case Three, a county never transitions from the initial state (all zeros). This is the case of right-censoring; we do not know when (or if) it will transition to the latter state in the future.

Time-varying covariates are an additional issue addressed by duration modeling. Regression models treat all exogenous variables as fixed; however, time-varying covariates are not fixed over time. Many characteristics can change over a longitudinal study period, such as a person's age, marital status, household size, or annual income, or in the case of a county, annual population, income, land allocations, etc. Both right-censoring and time-varying covariates are important issues to be resolved by a duration model.

Fortunately, duration models that deal with discrete-time data can easily account for both right-censoring and time-varying covariates (Allison 1984; Beck et al. 1998; Box-Steffensmeier and Jones 2004). Discrete time data are a series of binary outcomes (zeros and ones) recording whether or not an event occurred at a point in time. Our data are also discrete (not continuous) since observations are recorded on an annual basis.

There are three elementary concepts to duration models: the survivor function, the occurrence of an event, and the hazard rate (Box-Steffensmeier 1997). The probability function f(t) for a discrete random variable *T* defined at point t_i is

$$f(t) = \Pr(T = t_i).$$

There can be several 'transitions' from one state to the next across all observations in the dataset in any given year. Let *j* denote a transition time, then a survivor function S(t) for the discrete random variable *T* is defined as

$$S(t) = \Pr(T \geq t_i) = \sum_{j \geq i} f(t_j).$$

The hazard rate h(t), or risk of an event occurring, is the ratio of the probability of transition to the probability of surviving (not transitioning):

$$h(t) = \frac{f(t)}{S(t)}.$$

The hazard probability is the conditional probability of transition given survival:

$$h(t) = \Pr(T = t_i \mid T \geq t_i).$$

In the case of right-censored observations, the event never occurs so the observations contribute full information (i.e., a vector of zeros). Box-Steffensmeier and Jones (2004) demonstrate that the likelihood function for this type of dataset is

$$L = \prod_{i=1}^{n} \{f(t)\}^{y_{it}} \{S(t)\}^{1-y_{it}}$$

where y_{it} denotes the binary dependent variable for observation i coded as either 1 if the event occurred or 0 if it did not occur, and it is recorded for each time period t. In this case, each county is permitted to transition only once (no multiple events).

Two primary types of functions are used to estimate models for discrete duration data. If we let λ_i denote the probability of an event's occurrence, $\lambda_i = \Pr(y_{it} = 1)$, and the probability of a non-occurrence as $\Pr(y_{it} = 0) = 1 - \lambda_i$, then we need to specify a distribution for the following model:

$$\lambda_{it} = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki}$$

where x is a covariate and β are parameters to be estimated. A commonly used function for this model is the logit function:

$$\log\left(\frac{\lambda_i}{1-\lambda_i}\right) = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki}.$$

The logit coefficients are directly interpretable: if $\beta_k > 0$, the log of the odds ratio is increasing as the covariate increases. The predicted probability of an event occurring is recoverable by:

$$\hat{\lambda}_i = \frac{e^{\beta' x}}{1 + e^{\beta' x}}.$$

An alternative form is the complementary log-log or extreme value distribution:

$$\log[-\log(1-\lambda_i)] = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_k x_{ki}.$$

Estimated parameters from this model are interpreted in a similar fashion as the logit model. The predicted probability of an event occurring is recoverable from the extreme value model by:

$$\lambda_i = 1 - \exp[-\exp(\beta' x)].$$

Assumptions about the distribution of the hazard rate over time can have significant implications for duration model outcomes. When working with continuous time data, it is recommended to use a Cox semi-parametric method that makes no assumption on the shape of the underlying hazard function (Tuma 1994; Box-Steffensmeier and Jones 2004). However, the logit model is close to a parametric exponential model, implying the underlying hazard rate is flat or constant over time. The assumption of a constant hazard rate most often does not fit the distribution of empirical data. The extreme value or complementary log-log model most closely resembles a Weibull distribution of parametric models for continuous time duration data. Weibull distributions are asymmetric, slowly departing from $\lambda_i = 0$ and quickly approaching $\lambda_i = 1$. When there are relatively few transitions in the data (i.e., "1's"), logit and extreme value model estimates can differ substantially (Box-Steffensmeier and Jones 2004).

There are simple methods of accounting for duration dependence and recovering the baseline hazard rates in discrete time duration data. These methods include: (a) specifying temporal dummy variables; or (b) specifying some functional form (linear, natural logarithm, polynomial) of the duration length for each observation (Box-Steffensmeier and Jones 2004; Beck et al. 1998). Choices are an empirical matter and can be tested by using standard likelihood ratio tests.

Data

Data used in this analysis are derived from a variety of sources. Variable names and descriptions are listed in Table 1. The dependent variables (ratios of income sources and job sectors) are calculated from US Department of Commerce, Economics and Statistics

Administration, Bureau of Economic Analysis, *Regional Economic Information System* (REIS*) cd, 1969-2000* data, which provides annual observations. Several explanatory variables, including total population, total employment, per capita personal income (in constant dollars – 2000) are also derived from the REIS cd. Wilderness is calculated as the proportion of federally-designated wilderness in a 15-mile radius from county centroid using GIS and Conservation Biology Institute, *CBI/WWF Protected Areas Database, Second Edition, November 2001, data cd:* (http://www.consbio.org/cbi/pubs/cdroms.htm) (see Rosenberger, English and Sperow 2004a for a description of the method used to calculate this land variable). Several dummy variables that identify the presence of a city with more than 100,000 in total population, adjacency to an urban county, and rural-urban-metropolitan classifications are derived from US Department of Agriculture, Economic Research Service's databases. In particular, city is derived from the Urban Influence Codes, and urban adjacency and rural-urban-metro classifications are derived from the Rural/Urban Continuum Codes (aka Beale Codes). The presence of an airport is derived from Environmental Systems Research Institute, Inc., *ESRI Data and Maps CD 2: United States, 1999*.

Estimated Duration Models

The binary coded dependent variable identifies whether a county in a given year has transitioned from extraction/manufacturing income and job dependence relative to non-labor income and services jobs, respectively, to dependence on non-labor income and services jobs relative to extraction/manufacturing (1 = if the ratio is greater than one signifying the event has occurred or 0 = the event has not yet occurred). Table 2 provides the number of counties for each duration (number of years) before a county has transitioned in either the income ratio or the jobs ratio. Duration periods range from zero years (the county transitioned prior to the analysis period; i.e., the county's ratio for either income or jobs was already greater than one in 1969) to 32 years (the county has yet to transition from the initial state to the next state). Figures 1 and 2 provide the Kaplan-Meier non-parametric hazard function and survivor function for the income indicator, respectively. Figures 3 and 4 provide the Kaplan-Meier non-parametric hazard function and survivor function for the jobs indicator, respectively. The survivor functions for both indicators are declining over time. However, also note that the income indicator has a steeper slope than the jobs indicator, and there is a significantly larger proportion of the jobs indicator surviving to the end of the analysis period (37% vs. 4%, respectively).

Four sets of duration models are estimated, including income transitions for all eligible metropolitan, urban and rural counties (Model A) and for eligible urban and rural counties (Model B); and jobs transitions for all eligible metropolitan, urban and rural counties (Model C) and for eligible urban and rural counties (Model D).

The original dataset includes observations on 410 counties for 32 years, or 13,120 county-years of observations. Two sub-matrices of the data are used for both sets of models – all eligible counties (less left-censored counties) and all urban and rural eligible counties (identified as Beale code 4-9). Left censored counties (coded as all 1's across the analysis period) are dropped from the dataset in order to estimate semi-parametric and parametric models that include covariate effects and account for duration dependency among the baseline hazard rates. For the income indicator, 137 counties (or 33%) had transitioned to non-labor income prior to 1969. For the job indicator, 33 counties (or 8%) had transitioned to services jobs prior to 1969.

Discrete duration models also suffer from an identification problem. The identification problem occurs when dealing with temporal data and causal relationships between observations in any given year. If population is measured in the same year as the transition indicator, did the population change occur before or after the transition? This is also known as the simultaneity problem. A simple solution is to lag all continuously defined variables, such as population, employment, and per capital personal income. Therefore, the year 1969 data are dropped from the datasets to account for the lagged explanatory variables. The datasets were further reduced by dropping all county-year observations beyond the point of transition (i.e., all 1's subsequent to the first transition point are redundant and provide no additional information).

Table 3 shows the distribution of county types across the full dataset and Models A, B, C, and D. The characteristics are recorded as of year 2000. A greater number of counties had transitioned to non-labor income than services jobs. There are fewer counties of all types (metropolitan, urban and rural) for the income transition data. The patterns of urban adjacency, city and airport between Models A and B and Models C and D are similar. Table 4 shows the distribution and quantity of wilderness acres across Models A, B, C, and D.

The estimated discrete duration models based on an extreme value (complementary log-log) distribution are reported in Table 5 for the income transition indicator and Table 6 for the jobs transition indicator. Standard errors of the covariate estimates are corrected for latent heteroskedasticity using a sandwich estimator with assumed weights equal to one. Likelihood ratio tests suggest that the extreme value link is preferred over the logit link for the data. Likelihood ratio tests also suggest that duration dependency is an important factor to account for, and the parsimonious natural logarithm of duration-years is preferred over a temporal dummy variable specification or other forms of duration-years specification (linear, polynomial).

The extreme value binary models measure the change in the probability of an event occurring. In this context, we are measuring the probability of experiencing a transition from one economic state to another using an income indicator and a jobs indicator. Since our "hazard" is the transition from one state to another, a *positively signed* covariate *increases* the risk of transition (temporally comes sooner), while a *negatively signed* covariate *decreases* the risk of transition (temporally comes later). However, the magnitudes of covariate effects are not directly interpretable (Vance and Goeghegan 2002). Therefore, percentage changes in the transition rates will also be discussed.

The estimated sub-models are very similar across different specifications of the land use variables. The only statistically insignificant variables in each of the models included the presence of a *CITY* or an *AIRPORT* and the dummy variable for wilderness in Model A and *RURAL* counties in Model D.

Transition from the state of extraction/manufacturing income dominance over non-labor sources of income to non-labor income dominating extraction/manufacturing income in a county is increased by higher population densities ($D(POP_{-1})$), adjacency to urban areas (*ADJURB*), the presence of a city with a population greater than 100,000 (*CITY*), higher per capita personal income ($PCPSINC_{-1}$), rural counties (*RURAL*), and generally the presence of an airport (*AIRPORT*) when metropolitan counties are included in the analysis (Model A – Table 5). However, when the analysis is reduced to urban and rural counties (Model B – Table 5), the results change significantly. Higher population densities, rural counties, and generally higher per capita incomes still increase income transition rates for the income indicator. For urban and rural counties, adjacency to urban counties, the presence of a city or an airport reduces the timing of income transition.

Transition from the state of extraction/manufacturing jobs dominance over service sector jobs to service sector jobs dominating extraction/manufacturing jobs in a county is increased by the presence of a city with a population greater than 100,000 (*CITY*) and decreased for counties adjacent to urban areas (*ADJURB*) (Table 6). However, the other variables have mixed results. Increases in employment densities ($D(EMP_{-1})$) generally reduce the transition rate except when all federal lands and metropolitan counties are included (Model C3), in which case the jobs transition rate increases. The presence of an airport (*AIRPORT*) increases or decreases jobs transition rates, depending on the particular land use specification. Rural counties (*RURAL*) were found to transition later in the jobs indicator.

The primary focus of this analysis is on designated wilderness areas. Generally, the sign of this land use variable is consistent whether the analysis includes metropolitan counties or not (Tables 5 and 6). Counties with some wilderness (*DUMWA15*) generally had lower baseline transition rates in the income indicator when compared to urban and rural counties (Model B – Table 5; Models C and D – Table 6). The more wilderness in a given county was associated with increasing transition rates for both income and jobs indicators (*D(QWA15T)*).

Table 7 provides the percentage changes in the income and jobs indicators' transition rates for all models. Percentage changes for continuously defined variables (population density, per capita personal income, and temporally measured wilderness densities) are calculated for a 10 percent increase in the variable from its mean value. Percentage changes for dummy variables are calculated as with and without the feature.

A 10 percent increase in lagged population density ($D(POP_{-1})$) increases the income transition rates from nearly seven percent when metropolitan counties are included to over 40 percent when considering only urban and rural counties (Models A and B, respectively). A A 10 percent increase in per capita income ($PCPSINC_{-1}$) does not substantially increase income transition rates. A 10 percent increase in lagged employment density ($D(EMP_{-1})$) does not increase jobs transition rates (Models C and D). Counties that are adjacent to urban areas (*ADJURB*) have a 22 percent increase in income transition rates as compared to non-adjacent counties when metropolitan counties are included, but have a -43 percent and -40 to -70 percent decrease in income and jobs transition rates, respectively, when urban and rural counties are isolated. Counties with a city greater than 100,000 in population (*CITY*) have about a -18 percent decrease in income transition rates when the analysis is restricted to urban and rural counties (Model B), but a 58 percent increase in jobs transition rates regardless of sample restrictions (Models C and D). Counties with an airport (*AIRPORT*) have a -48 percent decrease in income transition rates for nonmetropolitan counties, but a 39 to 58 percent increase in jobs transition rates regardless of sample restrictions (Models C and D). Rural counties (*RURAL*) have a 16-50 percent increase in income transition rates for all counties and nonmetropolitan counties, respectively (Models A and B), while jobs transition rates are 58 percent lower for all counties (Model C).

A 10 percent increase in the density of wilderness acres (*D(QWA15T)* results in increases in income and jobs transition rates: 0.5 to 2 percent for income transition rates in all counties vs. nonmetropolitan counties, respectively, and 0.5 to 1 percent increase in jobs transition rates in nonmetropolitan counties vs. all counties, respectively (Models D and C). Wilderness counties (*DUMWA15*) in general had lower baseline transition rates than non-wilderness counties, ranging from 46 to 70 percent lower for both income and jobs transitions.

Conclusions

Several duration models were estimated to measure changes in the hazard rate of transitioning from one economic state to another for the Appalachian Region from 1969 to 2000.

An income indicator was generated that compared the relative dominance of non-labor sources of income to extraction/manufacturing sources of income. A similar ratio was generated that compared the total number of services sector jobs with extraction/manufacturing total jobs. Each county was then evaluated based on whether its income and jobs indicators were dominated by extraction/manufacturing sources (ratio <1 and indicator coded as 0) or were dominated by non-labor income and services jobs (ratio >1 and indicator coded as 1). The indicator variables created a vector of data for each county for each year, indicating if and when it transitioned from extraction/manufacturing to non-labor or services orientations.

When all eligible counties (metropolitan, urban and rural) were included in the model, wilderness counties were shown to have lower baseline income and jobs transition rates than counties without wilderness. Increases in wilderness density were associated with steeper hazard functions; i.e., transition rates increased. This means that wilderness counties, which occur mostly in rural areas, started at a relative disadvantage, but with increasing amounts of wilderness, transitioned at a higher rate.

Wilderness is not the only land use that may contribute to migration patterns that affect rural counties' transitions to the new economy. Other land use types provide amenity benefits that have been proven to contribute to in-migration of jobs and people, including national forests, national parks, and state lands. These other land use types were evaluated in this project, with results provided in Rosenberger, English and Sperow (2004c). However, wilderness effects were statistically significant and of the same sign whether the effect of these other land use types are accounted for or not. Given the temporal nature of the duration models, we provide evidence that wilderness designation is a causal factor in the spatial distribution of migration patterns over the last three decades.

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Table 1. Variable Definitions for Wilderness Duration Models

Variable	Definition
YRINC	0,1: Unearned income > extraction income
YRS_INC	# of years before income transition
YRJOBS	0,1: Services jobs > extraction jobs
YRS_JOBS	# of years before jobs transition
$D(POP)_{-1}$	Lagged annual density of total county population
$D(EMP)_{-1}$	Lagged annual density of total county employment
$PCPSINC_{-1}$	Lagged annual per capita personal income (2000 dollars)
D(QWA15T)	Density of total wilderness acres per year
DUMWA15	0,1: County has wilderness acreas
ADJURB	0,1: County is adjacent to an urban county
CITY	0,1: County has city with population > 25,000
AIRPORT	0,1: County has a commercial airport
RURAL	0,1: County is rural

Table 2. Transition Rates in the Appalachian Region, 1969-2000 (n = 410).

Duration (years)	Income Indicator[a]				Jobs Indicator[b]			
	# Counties	Percent	Hazard Rate[c]	Survivor Rate[d]	# Counties	Percent	Hazard Rate[c]	Survivor Rate[d]
0	137	33.41	---	---	33	8.05	---	---
1	9	2.20	0.03	0.96	1	0.24	0.01	0.99
2	13	3.17	0.05	0.92	5	1.22	0.01	0.98
3	4	0.98	0.02	0.90	1	0.24	0.01	0.98
4	10	2.44	0.04	0.86	5	1.22	0.01	0.97
5	17	4.15	0.08	0.80	2	0.49	0.01	0.96
6	22	5.37	0.11	0.71	4	0.98	0.01	0.95
7	1	0.24	0.01	0.70	2	0.49	0.01	0.95
8	2	0.49	0.01	0.70	0	0.00	0.00	0.95
9	3	0.73	0.02	0.68	2	0.49	0.01	0.94
10	9	2.20	0.04	0.65	4	0.98	0.01	0.93
11	24	5.85	0.15	0.55	5	1.22	0.01	0.92
12	27	6.59	0.20	0.44	4	0.98	0.01	0.91
13	21	5.12	0.19	0.36	11	2.68	0.03	0.88
14	16	3.90	0.17	0.30	12	2.93	0.04	0.84
15	6	1.46	0.07	0.28	5	1.22	0.02	0.83
16	8	1.95	0.10	0.25	14	3.41	0.05	0.79
17	8	1.95	0.11	0.22	17	4.15	0.06	0.74
18	1	0.24	0.01	0.22	8	1.95	0.03	0.72
19	6	1.46	0.09	0.20	8	1.95	0.03	0.70
20	7	1.71	0.12	0.18	4	0.98	0.02	0.69
21	6	1.46	0.11	0.16	16	3.90	0.06	0.64
22	2	0.49	0.04	0.15	8	1.95	0.03	0.62
23	2	0.49	0.04	0.14	14	3.41	0.06	0.58
24	6	1.46	0.14	0.12	7	1.71	0.03	0.56
25	3	0.73	0.08	0.11	3	0.73	0.01	0.56
26	7	1.71	0.21	0.09	10	2.44	0.05	0.53
27	5	1.22	0.18	0.07	13	3.17	0.07	0.49
28	5	1.22	0.22	0.06	9	2.20	0.05	0.47
29	1	0.24	0.04	0.06	14	3.41	0.08	0.43
30	1	0.24	0.05	0.05	9	2.20	0.06	0.41
31	6	1.46	0.40	0.03	7	1.71	0.04	0.39
32	15	3.66	---	---	153	37.32	---	---

[a]Income transition indicator = non-labor income > extraction income.
[b]Jobs transition indicator = services jobs > extraction + manufacturing jobs.
[c]Hazard rate = # transitioned in year t / # at risk in year t.
[d]Survivor rate = cumulative proportion surviving to j = (1-hazard $rate_{j-1}$)*proportion $surviving_j$.

Table 3. Summary Characteristics by Model Type, Appalachian Region, 2000

Variable (# of Counties)	All Counties[a]	Income Indicator		Jobs Indicator	
		Model A[b]	Model B[c]	Model C[d]	Model D[e]
# Counties	410	273	171	377	245
Metropolitan	140	102	0	132	0
Urban	186	132	132	166	166
Rural	84	39	39	79	79
Urban Adjacency	122	88	49	116	62
City	104	68	68	92	92
Airport	150	124	73	140	84

[a]All counties in Appalachian Region.
[b]Model A excludes all left-censored counties for income indicator.
[c]Model B excludes all left-censored counties for income indicator plus metropolitan counties.
[d]Model C excludes all left-censored counties for jobs indicator.
[e]Model D excludes all left-censored counties for jobs indicator plus metropolitan counties.

Table 4. Summary Statistics for Wilderness Acres within a 15-Mile Radius of County Centroid[a], Appalachian Region.

Model	# Counties (%)	Mean Acres	Std. Error	Min Acres	Max Acres
A[b]	45 (16)	12,151	12,342	312	47,510
B[c]	33 (19)	12,830	13,514	312	47,510
C[d]	69 (18)	11,327	11,100	136	47,510
D[e]	54 (22)	11,694	11,870	136	47,510

[a]452,389 total acres in a circle with a 15-mile radius.
[b]Model A excludes all left-censored counties for income indicator, n=273.
[c]Model B excludes all left-censored counties for income indicator plus metropolitan counties, n=171.
[d]Model C excludes all left-censored counties for jobs indicator, n=377.
[e]Model D excludes all left-censored counties for jobs indicator plus metropolitan counties, n=245.

Table 5. Income Transition Duration Extreme Value Models, Appalachian Region, 1969-2000.

Variable	MODEL A		MODEL B	
	Coefficient	Std. Error[c]	Coefficient	Std. Error[c]
$lnD(POP)_{-1}$	0.783	0.095	3.590	0.162
ADJURB	1.170	0.184	-1.863	0.215
CITY	-0.045	0.238	-1.417	0.246
AIRPORT	-0.259	0.188	-1.920	0.212
RURAL	1.989	0.298	5.765	0.333
$PCPSINC_{-1}$	0.360E-03	0.270E-04	0.001	0.284E-04
D(QWA15T)	54.591	9.479	184.289	10.072
DUMWA15	0.362	0.269	-4.760	0.365
ln(YRS_INC)	-4.042	0.138	-8.024	0.190
N (county-years)	3753		2733	
Log Likelihood	-908.12		-654.65	

[a] Model A excludes all left-censored counties for income indicator, n=273.
[b] Model B excludes all left-censored counties for income indicator plus metropolitan counties, n=171.
[c]Standard errors reported are based on an asymptotic covariance matrix adjusted for latent heteroskedasticity using a sandwich estimator with weights equal to one.
Dependent variable is YRINC.

Table 6. Jobs Transition Duration Extreme Value Models, Appalachian Region, 1969-2000.

Variable	MODEL C		MODEL D	
	Coefficient	Std. Error[c]	Coefficient	Std. Error[c]
$lnD(EMP)_{-1}$[a]	-5.110	0.083	-6.138	0.127
ADJURB	-4.495	0.071	-1.753	0.072
CITY	19.949	0.102	31.968	0.115
AIRPORT	9.208	0.087	2.210	0.087
RURAL	-4.258	0.115	-0.099	0.155
D(QWA15T)[b]	604.824	4.878	610.228	4.833
DUMWA15	-8.431	0.096	-5.761	0.102
ln(YRS_JOB)	-23.992	0.080	-28.821	0.126
N (county-years)	9100		7050	
Log Likelihood	-1117.18		-777.42	

[a]Model C excludes all left-censored counties for jobs indicator, n=377.
[b] Model D excludes all left-censored counties for jobs indicator plus metropolitan counties, n=245.
[c]Standard errors reported are based on an asymptotic covariance matrix adjusted for latent heteroskedasticity using a sandwich estimator with weights equal to one.
Dependent variable is YRJOBS.

Table 7. Percentage Change[a] in Transition Rate, Income Transition Models A and B, and Jobs Transition Models C and D.

Variable	Model A	Model B	Model C	Model D
$\ln D(POP)_{-1}$	6.95	40.79	na	na
$\ln D(EMP)_{-1}$	na	na	0[c]	0[c]
ADJURB	22.26	-43.13	-70.85	-39.88
CITY	----[b]	-18.50	58.20	58.20
AIRPORT	----[b]	-47.50	58.20	39.21
RURAL	15.76	50.24	-57.52	----[b]
$PCPSINC_{-1}$	0[c]	0[c]	na	na
D(QWA15T)	0.48	1.57	0.97	0.43
DUMWA15	----	-45.90	-69.78	-58.80

[a]Percentage changes in transition rate were calculated as follows:

Dummy Variables: $\%\Delta = 100 * \frac{\left(\lambda_i \mid_{x_i=1} - \lambda_i \mid_{x_i=0}\right)}{\lambda_i \mid_{x_i=0}}$, and

Continuous Variables: $\%\Delta = 100 * \frac{\left(\lambda_i \mid_{(\bar{x}+10\%)} - \lambda_i \mid_{\bar{x}}\right)}{\lambda_i \mid_{\bar{x}}}$.

[b]---- refers to insignificant estimate in extreme value model.
[c]Zero percentage changes are sufficiently close to zero to be labeled as such.
na = not applicable.

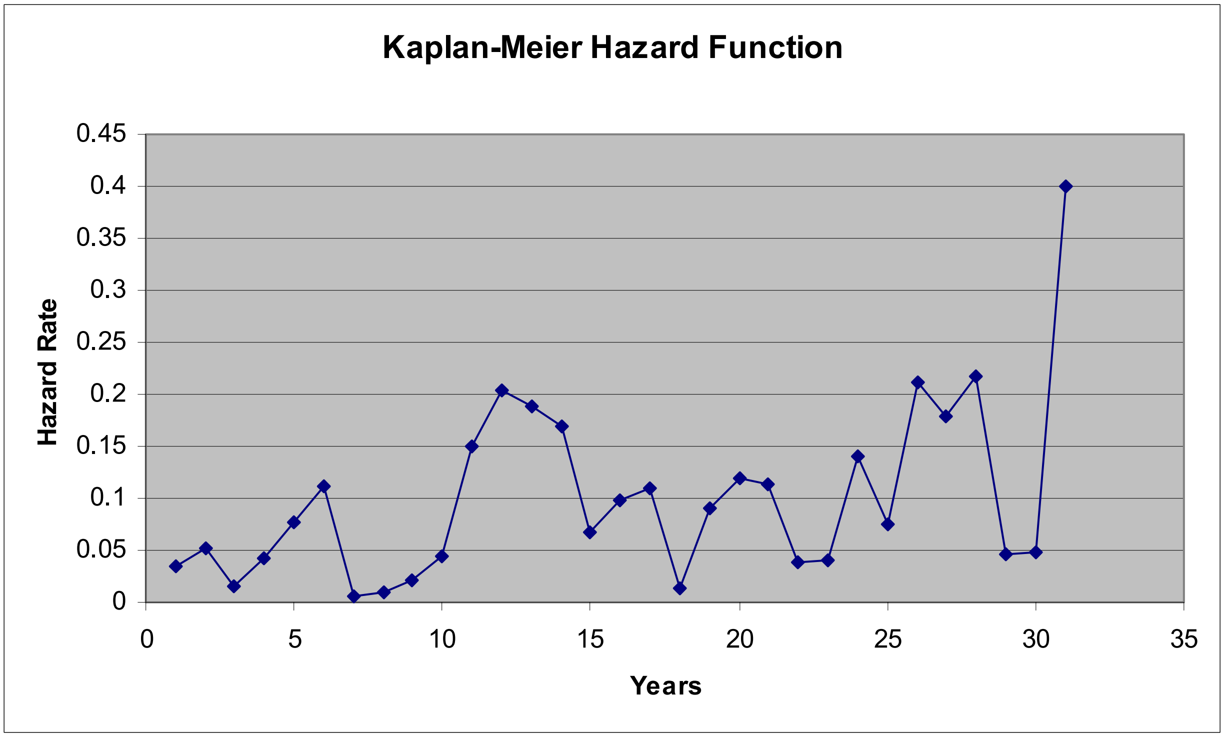

Figure 1. Income transition indicator hazard function.

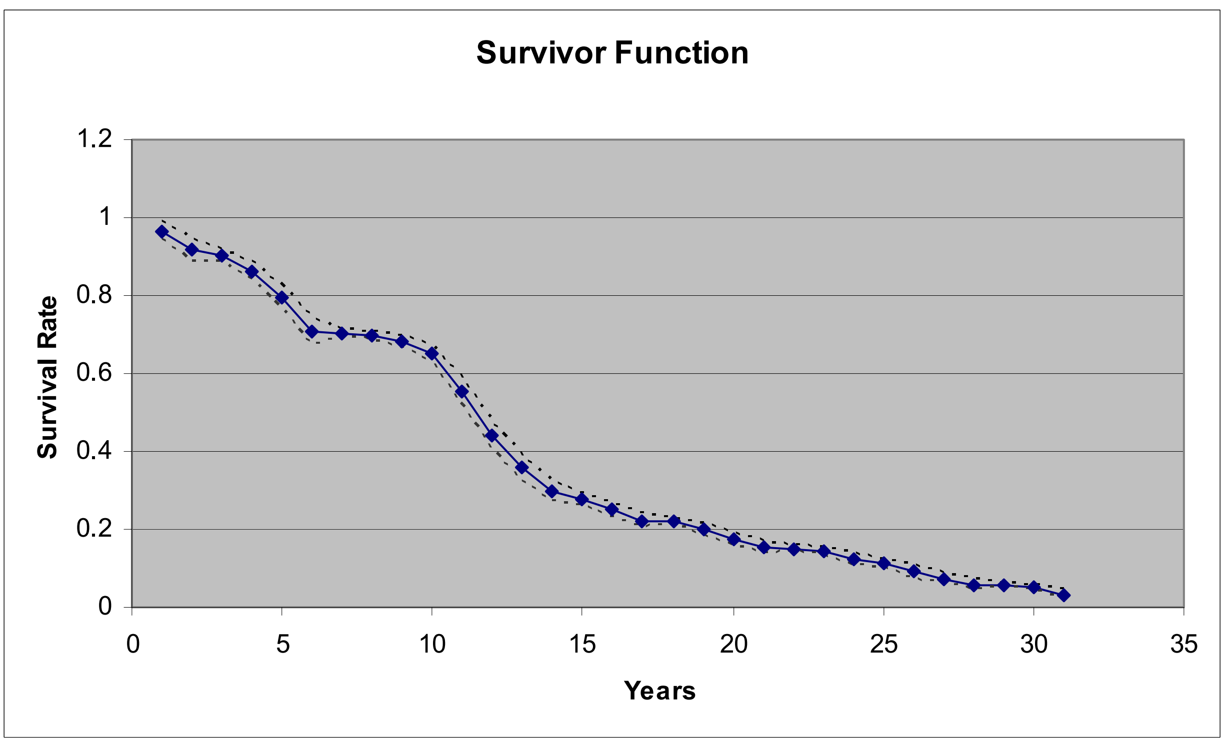

Figure 2. Income transition indicator survivor function.

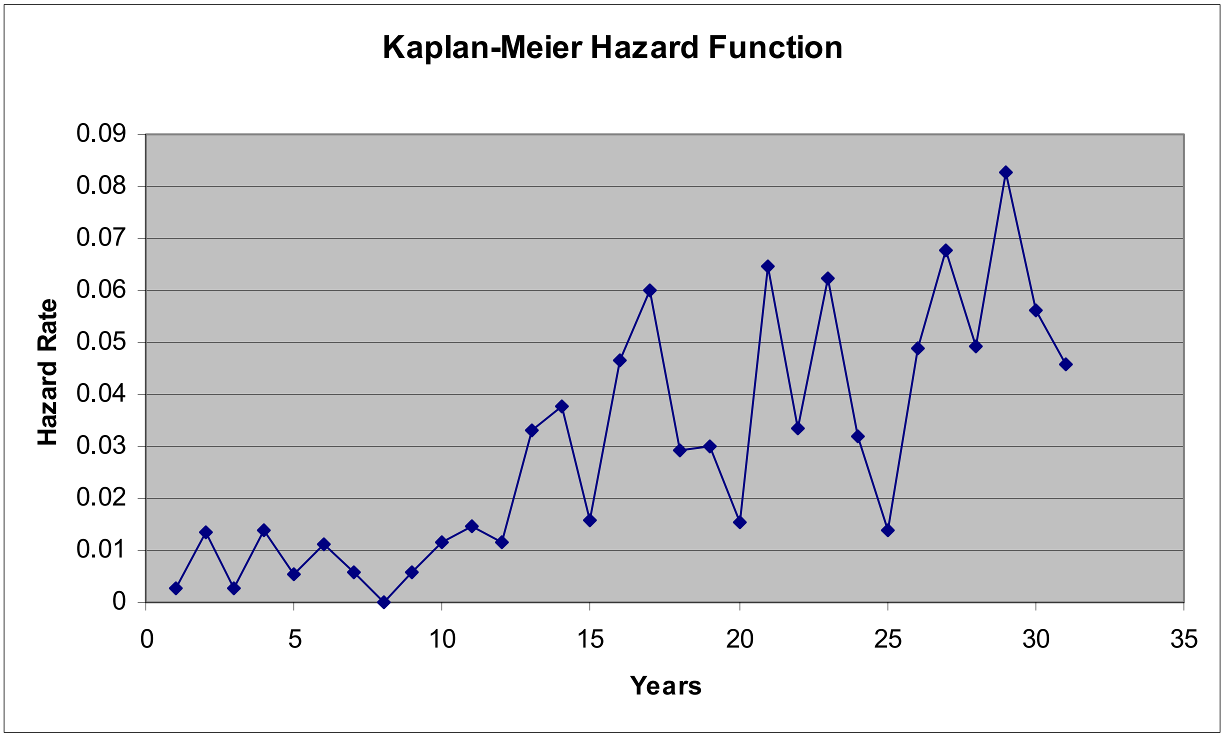

Figure 3. Jobs transition indicator hazard function.

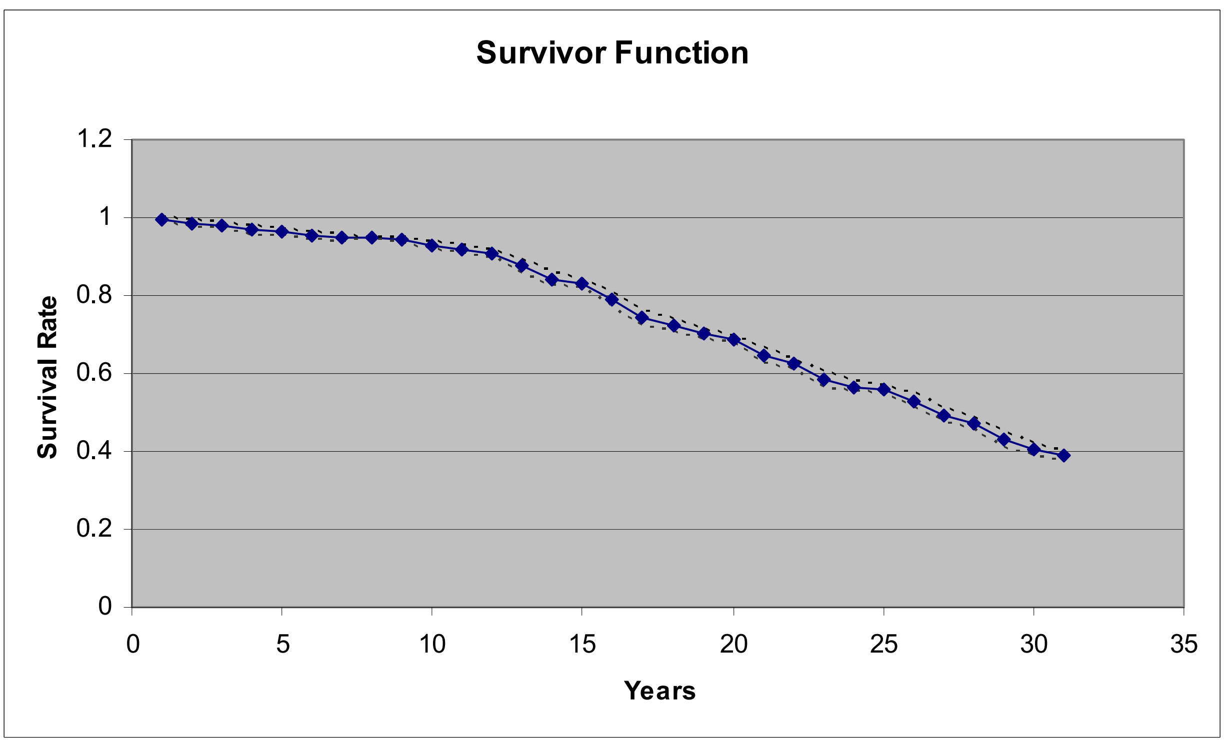

Figure 4. Jobs transition indicator survivor function.

Socio-Economic Aspects of Open Space and

Agricultural Land Preservation

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Socio-Economic Aspects of Open Space and Agricultural Land Preservation

In some regions of the United States there is a growing concern with the numbers of strip malls and large-lot residential communities that are creating suburban sprawl. Where land becomes a precious commodity, many decisions about whether to preserve or sell are being made. This study investigates whether the decision to preserve is being made using insufficient criteria – in particular with the omission of socioeconomic aspects. Using county-level data, regression analysis is used to determine whether there are significant relationships between the amount of land preserved and socio-economic indicators. The results indicate that the amount of land preserved as a percentage of total county acreage is positively related to high incomes, high housing values, population growth, farmland prices and the number of farms. In addition the amount of land preserved as a percentage of total county acreage is negatively related to the county unemployment rate, the age of residents, and the percentage of African American residents. These results suggest that the socio-economic impacts associated with land preservation programs should be considered in net preservation benefits calculations. In particular open space and farmland preservation programs, should consider if they pose potential adverse impacts on minority and low-income residents.

I. Introduction

In today's world of rapidly increasing suburbanization, it has become clear that farmland preservation must be given careful consideration or land will continue to be consumed by "Big Box" stores and sprawling housing developments. Over the past three decades local, regional and national governments have become increasingly concerned with land preservation and have used methods such as tax-relief programs, right-to-farm laws, acquisition of development rights, and agricultural zoning to ensure such preservation (Nelson 1992). There have also been significant efforts to establish preservation criteria and determine the public's preferences regarding what land should be preserved. Examples of such criteria include soil type and productivity of the land, sustaining the rural agricultural economy, preserving rural heritage, preserving ecological services, protecting scenic amenities, maintaining recreational opportunities and the proximity to other protected land (Hellerstein et. al. 2002). Some of the goals of the general public in preserving land include protecting groundwater, protecting wildlife habitats, preserving natural places, providing local food, slowing development, and keeping farmland as a way of life (Kline and Wichelns 1996).

Policy criteria which appears to be absent from land preservation policies includes socio-economic criteria in the selection process regarding which land parcels to preserve. Some researchers have concluded that economic segregation is the inevitable result of rapid growth and suburbanization, resulting from competition among communities to create a high quality of life paired with this drive to preserve. Low income workers are forced out of areas with preserved environmental amenities by high income tax-paying residents living in exclusive neighborhoods (Katz 2000). Communities often create their own organizations to achieve these segregation goals, usually by preventing affordable housing from being built and enacting housing standards and zoning restrictions (Downs 1994). Although unintentional, the drive to preserve farmland may actually result in negative socio-economic consequences.

If present, these consequences can result in a significant cost to society that may not be included in net farmland or open space preservation benefits estimates. The purpose of this paper is to investigate possible socio-economic consequences associated with farmland preservation programs and in particular if such programs are discriminating against low income and minority populations. The sections of this paper include a review of the existing literature; an explanation of the data and economic model; presentation of the econometric model; a review of the regression results and, finally, our conclusions and recommendations for further research. The study uses county-level data for 3,104 counties in the forty-eight contiguous United States, to investigate whether significant relationships exist between the percentage of preserved land and socio-economic indicators. The overall objective is to determine if socio-economic information should be incorporated into the criteria regarding the decision to preserve farmland and open space.

II. Review of Literature

Between 1982 and 1997 the National Resources Inventory of the United States Department of Agriculture reported 44 million acres of cropland lost, while developed area increased by 34% (Libby 2002). Although it is widely accepted that the United States is not in danger of a food shortage, open or undeveloped land satisfies many other conditions including habitat for wildlife, existence value, preservation of the rural character of an area, and many other previously noted amenities. However, in an age of expansion and sprawl, the drive to preserve open-space and farmlands has become more intense.

When deciding whether to preserve land, three items are generally considered: how it will affect the economy, how it will affect future development, and if it will maintain environmental quality; water quality in particular. The first question has been studied by Hunt, Kerkvliet and Plantinga (2004). They investigated the relationship between preserving public land and the health of the economy, using employment and net migration as indicators. Their preliminary results show that employment is negatively effected in the immediate term, but returned to normal after approximately five years, while net migration was not significantly effected. Both Downs (2002) and Phillips and Goodstein (2000) studied the effect of the Urban Growth Boundary instituted in Portland, Oregon in 1979, and each found no evidence that the Urban Growth Boundary had a significant upward effect on the housing prices in the area. Beasley, et. al. (1986), Bergstrom, et. al. (1985) and Halstead (1984) all looked at the external benefits of farm and open-space preservation and found that it improves water quality in the area by reducing runoff and associated water pollution that would have been present had the land been developed.

The findings of this type of research are important, however an additional question one could ask relates to how preservation will affect society. This question is the main focus of this paper. There has been very little investigation into this realm, but because sprawl and development planning have such a strong relationship with preservation of open space, the effects of other types of exclusionary land policies on society (such as zoning and density requirements) are closely related to this question.

The main problem lies in the fact that healthy cities must expand in order to remain healthy. In order to judge how dynamic a city is, David Rusk (1999) evaluated cities using his own equation defined as the initial density of the city multiplied by the rate of boundary expansion. Rusk found that dynamic cities did not have sprawl because enough land was acquired with annexation, they had higher job creation and income growth, and were less racially segregated. Static cities did not expand quickly enough and the growing population was forced to the suburbs creating a sprawl effect. Most importantly, static cities are also more racially segregated. Rusk explained that "suburbs invented and perfected the practice of 'exclusionary zoning.'" Examples of this suburban exclusion are two of the first towns to consider land preservation: Darien and New Canaan, Connecticut, which are now some of the most exclusive residential areas of the United States (Katz 2000). From the beginning, both of these towns imposed zoning restrictions, and they made a conscious decision to exclude apartments, condos, and other types of lower-income housing. In addition, these towns planned industrial space, a town center and imposed two-acre minimum lot sizes on the rest of the land. The towns' residents are primarily Caucasian, homes tend to be very expensive, and their viewscape is described as very pretty, with much of their original 4,000 acres of farmland in tact.

Numerous suggestions exist regarding how to end the segregation and discrimination that comes with suburban expansion and development exclusivity. Downs (1994) argues that the typical "American Dream" values the perks of suburban life – owning a house with a spacious lot, owning a car, working in low-rise buildings with free parking, living in small communities with strong local governments and living without seeing poverty. In order to change the way our cities work, end discrimination and segregation and preserve more land, this dream must change. Others argue that suburban growth management and affordable housing without debilitating consequences to the poor is in fact possible. Montgomery County in Maryland purchases Moderately Priced Dwelling Units built in all new subdivisions in exchange for higher density zoning. Montgomery County also set aside 90,000 acres as permanent farmland (Rusk, 1999). However, it is important that these Moderately Priced Dwelling Units remain at reasonable prices after resale, or else be replaced with other similarly priced housing options. Although this program earned a lot of praise at its inception, current news reports unfortunately show that it did not, in fact, keep housing prices low and diversity high. By

2008, median single family home prices are expected to exceed one million dollars. Local county workers, such as the firefighters, are now being forced to live as far away as West Virginia because they aren't able to live where they work (Craig 2005).

The following sections examine quantitatively whether significant evidence exists in terms of adverse socio-economic consequences associated with open-space and farmland preservation at the county level in the United States.

III. Data and Economic Model

County-level data for 3,104 jurisdictions within the 48 contiguous United States was compiled from a number of sources in order to investigate the following equation:

$$PCT\_PRES = f\,(HIGH\_INC,\ HIGH\_HOUS\_VAL,\ UNEMP\_RATE,\ PCT\_BLACK,\ MED\_AGE,\ POP2000,\ CHG\_POP,\ PRICE\_ACRE,\ NUM\_FARMS) \qquad (1)$$

The dependent variable is the percentage of country acreage preserved in easements (*PCT_PRES*). The value of this variable was estimated by summing the easement acreages from the Federal Farm and Ranchland Protection Program (USDA 2003) the total conserved acreages from the National Land Trust census which represents non-profit private land trusts (Land Trust Alliance 2003) [1]. The primary source of the county level socio-economic explanatory variables was the United States 2000 census. These include: the unemployment rate (*UNEMP_RATE*); the percentage of African American county residents (*PCT_BLACK*); median age for county residents (*MED_AGE*); and county population (*POP2000*). A population growth variable (*CHG_POP*) was also included in our model and was calculated as the percentage change in county population from the 1990 to the 2000 census years. Two other variables that were derived from the census data were a high income dummy variable (*HIGH_INC*) and a high median housing value dummy variable (*HIGH_HOUS_VAL*). These two dummy variables are equal to one if the county median values were greater than one standard deviation above the sample mean. The model also includes two agricultural variables from the 2002 agricultural census; county level average per acre value of farmland and the number of farms.

Summary statistics and expected coefficient signs of the variables are included in Table 1. Select map of the variables are included as Figures 1 through 7. The coefficient sign expectations reflect our presumption that as the amount county lands preserved increases, there will be less developable land available and as such the value of the housing stock will be higher, and county incomes will correspondingly be positively related to the percentage of preserved land. In other words because open land is highly valued it is usually seen as an elevator of housing prices (Edelstein 1974 and Can 1990), and thus, wealthier people living in larger, higher priced homes, tend to inhabit areas with preserved open space. We also expect the higher the population and the higher population growth will be positively related to the percentage of county lands preserved, assuming that preserved open space and farmlands are considered an amenity, and thus the more people within a county, the greater the aggregate benefits associated with preserved lands. Correspondingly we expect unemployment rates, the median age of residents and the percentage of minority residents to be inversely related to the percentage of county land preserved, given the negative correlations between these variables and a continuous median income variable. [2] Previous research (Katz 2000, Downs 1994, Rusk 1999) has also shown that open space amenities that create desirable residential areas can have a pushing-out affect on minority populations. With regards to the farmland variables, we expect that the percentage of county land preserved would be positively related to the number of farms, given farm preservation is a goal of farmland protection programs. With respect to farmland prices, we initially expected that prices would be inversely related to the percentage of land protected because preserved or eased farmland values presumably have negligible development value. However Nickerson and Lynch (2001) found that in Maryland there was little statistical evidence that preservation programs significantly decrease the price of farmland.

IV. Econometric Model and Regression Results

Our dataset is not uncommon from many microeconomic datasets where the dependent variable is censored such that a significant fraction of the observations take on a value of zero (Greene 2003). As such the distributional assumption for the model is a truncated distribution where only the portion where the dependent variable (y) exceeds zero is relevant to our analysis. Thus we estimate a censored (Tobit) regression model for our analysis. The econometric model estimated is as follows:

$$\begin{aligned} PCT\_PRES_i = {} & \alpha + \beta_1 HIGH\_INC_i + \beta_2 HIGH\_HOUS\_VAL_i + \beta_3 UNEMP\_RATE_i + \\ & \beta_4 PCT\_BLACK_i + \beta_5\, MED\_AGE_i + \beta_6\, POP2000_i + \beta_7\, CHG\_POP_i + \\ & B_8 PRICE\_ACRE_i + \beta_9\, NUM\_FARMS_i + \varepsilon_i \end{aligned} \tag{2}$$

Where ε_i is assumed to be a normally distributed, random-error component with a mean of zero and a variance of σ^2. The parameters estimated include: α , β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8 and β_9.

Two issues arose with regards to our dataset; that being multicolinearity and heteroskedasticity. Given the cross sectional nature of this data set, we tested for heteroskedasticity using the Breusch-Pagan test. The null hypothesis of homoskedasticity was rejected thus the reported regression results in Table 2 are corrected for heteroskedasticity using White's consistent covariance matrix. Upon analysis of a pair wise correlation matrix, it became evident that multicolinearity existed amongst the variables related to median household income and housing values. The creation of high income and high housing value dummy variables eliminated this concern.
Consistent with any nonlinear regression model, the marginal effects of changes in the explanatory variables do not correspond directly to the maximum likelihood parameter estimates of β_i . The marginal effects for the Tobit model when censoring is at the left, at zero, are calculated as the derivatives for the probabilities as follows:

$$\partial \, \mathrm{E}[y|\mathbf{x}] \, / \partial \, \mathbf{x} = \Phi \, (\beta' \, \mathbf{x}/\sigma) \, \beta \qquad (3)$$

The marginal effects computed at the means are included in Table 2.

The regression results presented in Table 2 were consistent with our expectations. The coefficient estimates associated with the high income and high housing value dummy variables were positive as expected, and significantly different from zero. These results suggest that the higher the percentage of preserved open space and farmland within a county, the higher the median incomes of its residents and the higher the median housing values. With respect to the population and farm variables included in the model, the coefficient estimates were also positive and significantly different from zero. County population and population growth are indicators of suburbanization pressures, and the development activities associated with such growth tend to drive the desire to preserve open space. However as noted above, the larger the percentage of preserved land tends to result in more elitist counties with higher income residents living in higher valued homes. With respect to the number of farms within a county, the higher the percentage of preserved land does appear to be positively influencing the number of farms. However the price per acre of farmland also appears to be driven upward as more land is preserved.

The coefficient estimate for the unemployment rate variable is significantly different from zero and negative as expected. This result is consistent with the high income results above, in that lower unemployment rates are associated with counties with more preserved open space and farmlands. With respect to minority populations and the elderly, the coefficient estimates on the percentage of African American and median age variables are negative and significantly different from zero. These results suggest that counties with higher percentages of preserved land, are less likely to have minority populations and the elderly residing within them.

V. Conclusions

This study indicates that socio-economic aspects such as income level, housing value, and the minority populations should be investigated further and possibly used as criteria when implementing land preservation policies or programs. The relationships found between these socio-economic aspects and the percentage of preserved land suggests that land preservation programs may result in negative consequences for minorities, low-income families and the elderly. This is a cost to society that has not previously been included in net open space and farmland preservation benefits estimates. As more and more counties are being faced with population pressures, and demand for open-space amenities increases, programs to preserve more land should include as socio-economic component it an effort to prevent the creation of elitist or high income and high housing value communities, with no affordable housing for lower and even median income segments of society. This research suggests that net benefit valuation studies of open-space and farmland preservation programs, should take into consideration both the socio-economic consequences as well as the environmental consequences these programs.

End Notes

1. For the private non-profit conserved acreages we assumed that the address location of the individual land trusts corresponds to the county with which the conserved acres they are responsible for are located. The Land Trust Alliance only compiles state level acreages but provided us with the individual land trust names and locations from which we assigned acreages at the county level.

2. The pair-wise correlation coefficients between a median county household income (a continuous variable) and county unemployment rate, percentage of African American residents and median age were -0.35, -0.22 and -0.16, respectively.

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Table 1: Variable Summary Information

Variable Name (Exp. Coef. Sign)	*Mean*	*Standard Deviation*	*Definition*
PCT_PRES	0.532	4.278	Percent of county land preserved calculated as the sum of federal FRLPP and non-profit Land Trusts.
HIGH_INC (+)	0.130	0.336	Dummy variable = 1 if county median income in year 2000 is greater than one standard deviation above the sample mean.
HIGH_HOUS_VAL(+)	0.101	0.302	Dummy variable = 1 if county median house value in year 2000 is greater than one standard deviation above the sample mean.
UNEMP_RATE (-)	6.138	2.713	County annual unemployment rate in year 2000.
PCT_BLACK (-)	8.840	14.573	Percentage of African American residential county population.
MED_AGE (-)	37.379	3.964	County median age in year 2000.
POP2000 (+)	88,661	291,173	County population in year 2000.
CHG_POP (+)	11.121	16.070	Percentage change in county population from 1990 to 2000.
PRICE_ACRE (-/+)	2,259	3,995	County average price per acre of farmland in 2002.
NUM_FARMS (+)	679	542	County average number of farms in 2002.

Table 2: Tobit Regression Results

Variable Name	*Coefficient Estimate*	*Standard Error* [(a)]	*P-Value*	*Marginal Effects*
CONSTANT	-8.4424***	3.1185	0.0068	
HIGH_INC	2.0692**	0.8881	0.0198	0.2553
HIGH_HOUS_VAL	8.9254***	1.4856	0.0000	1.1012
UNEMP_RATE	-0.4168***	0.1380	0.0025	-0.0514
PCT_BLACK	-0.0459*	0.0243	0.0646	-0.0056
MED_AGE	-0.1243*	0.0709	0.0792	-0.0153
POP2000	0.0000004**	0.0000002	0.0257	0.0000005
CHG_POP	0.0370**	0.0187	0.0480	0.0046
PRICE_ACRE	0.0002**	0.0001	0.0499	0.000024
NUM_FARMS	0.0012***	0.0004	0.0047	0.00015
Log-Likelihood	**-2747**			
R-square ANOVA	**0.59**			
R-square Decomposition	**0.48**			
Number of Observations	**3,104**			

(a) White's consistent standard errors.

***, **, *** indicate significance at 0.10, 0.05 and 0.01, respectively.**

Figure 1: Preserved Acres of Land by County

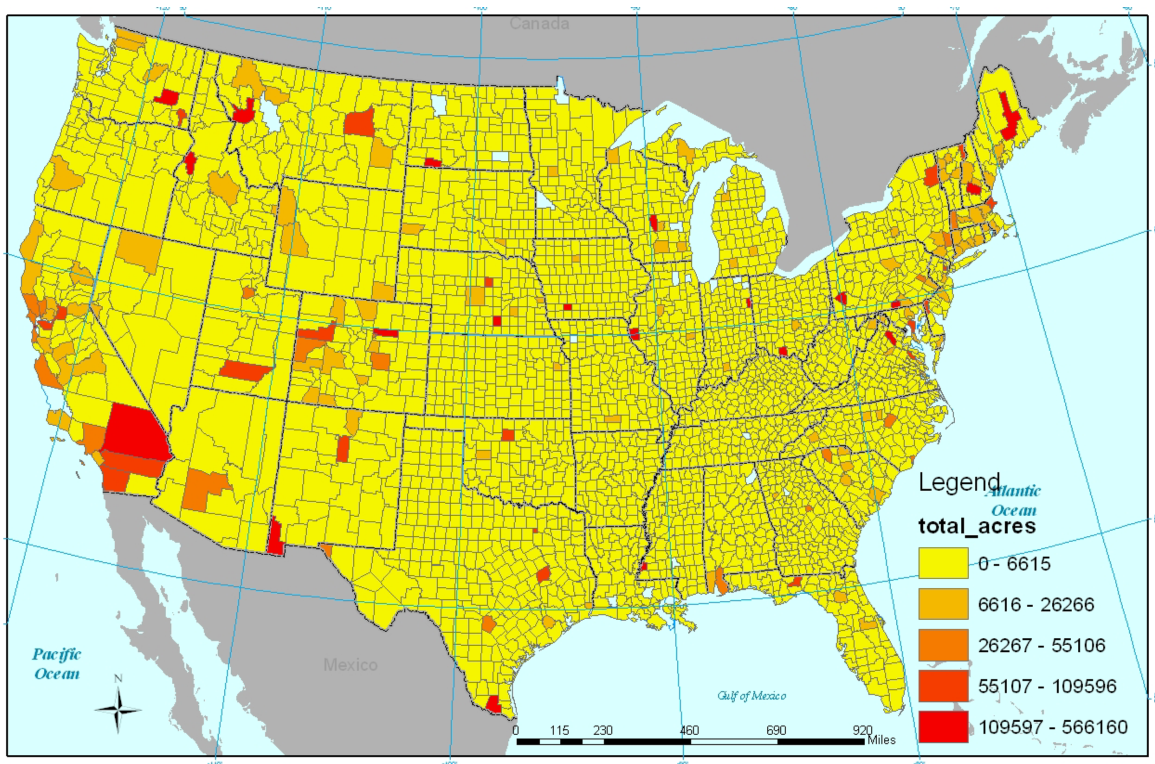


Figure 2: Median Income by County (2000 Census)

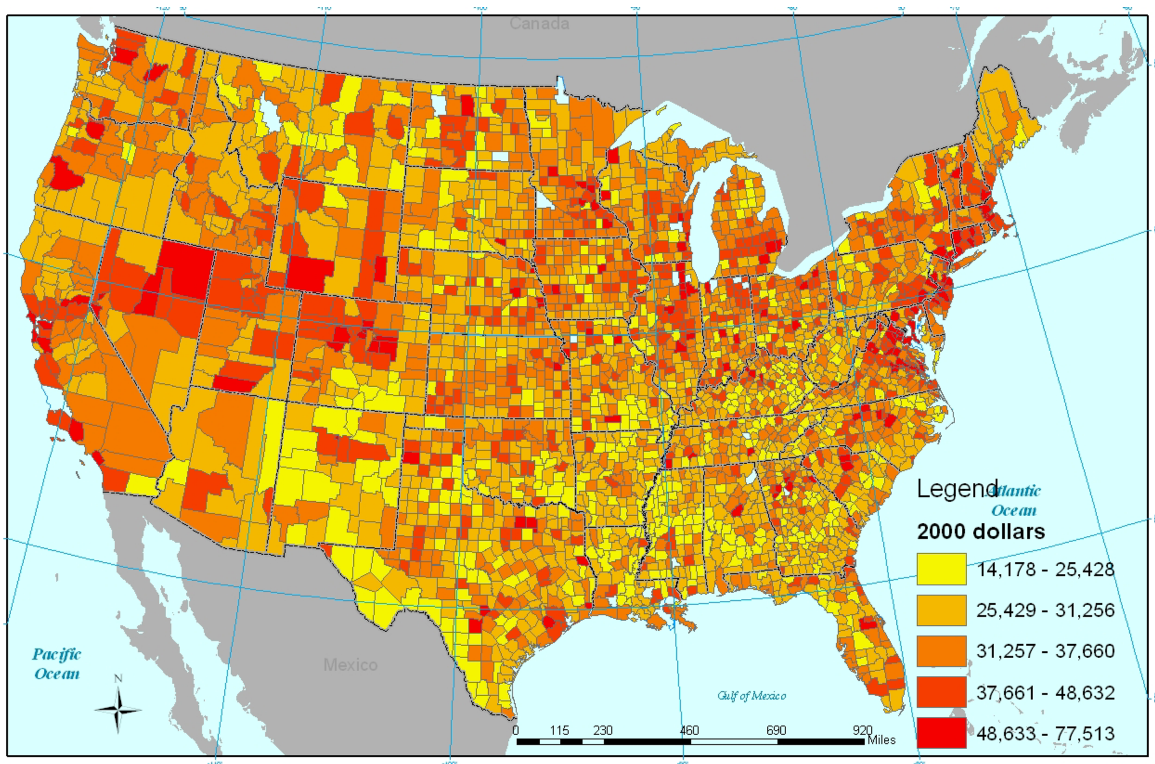


Figure 3: Median House Values by County (2000 Census)

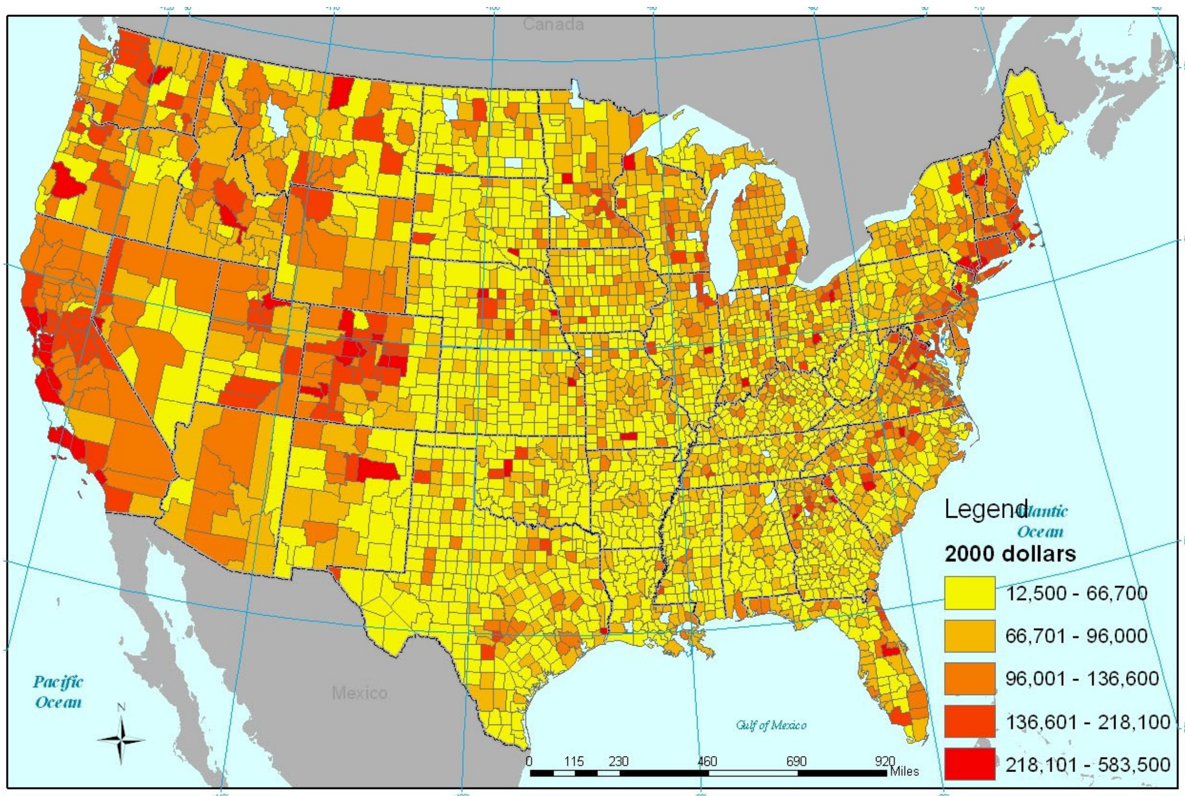


Figure 4: Unemployment Rates by County (2000 Census)

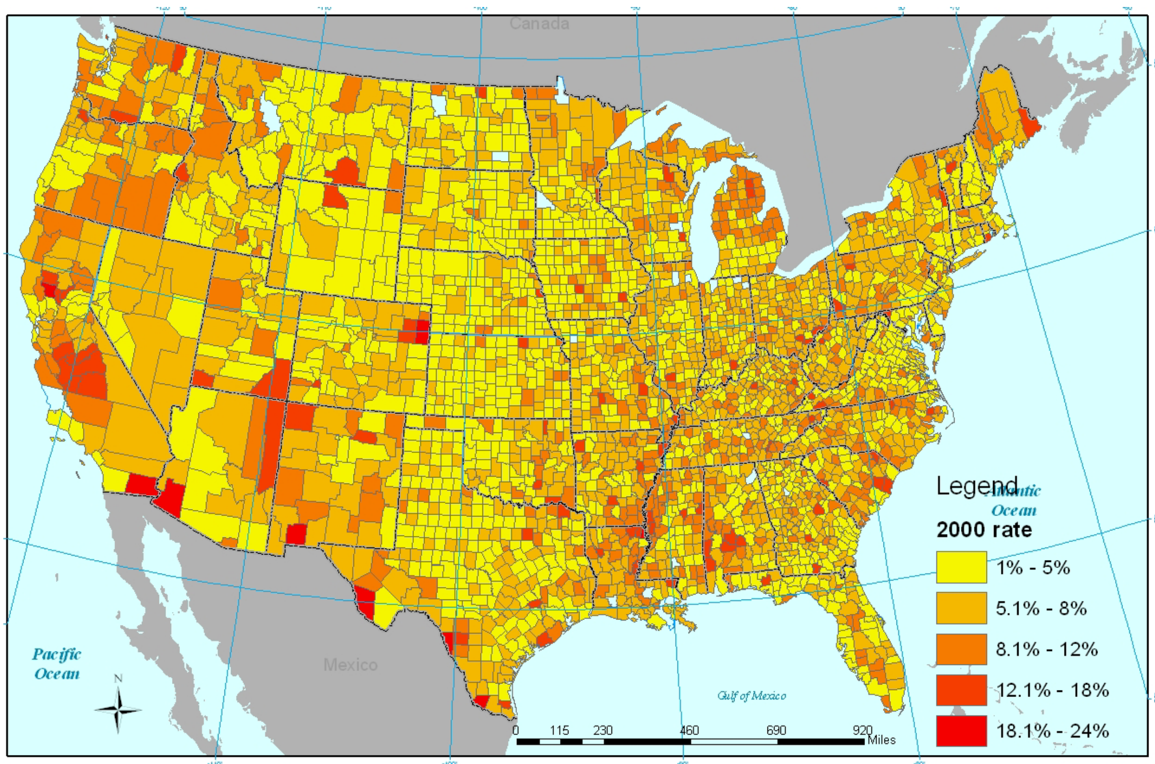


Figure 5: Percentage of Population that is African American (2000 Census)

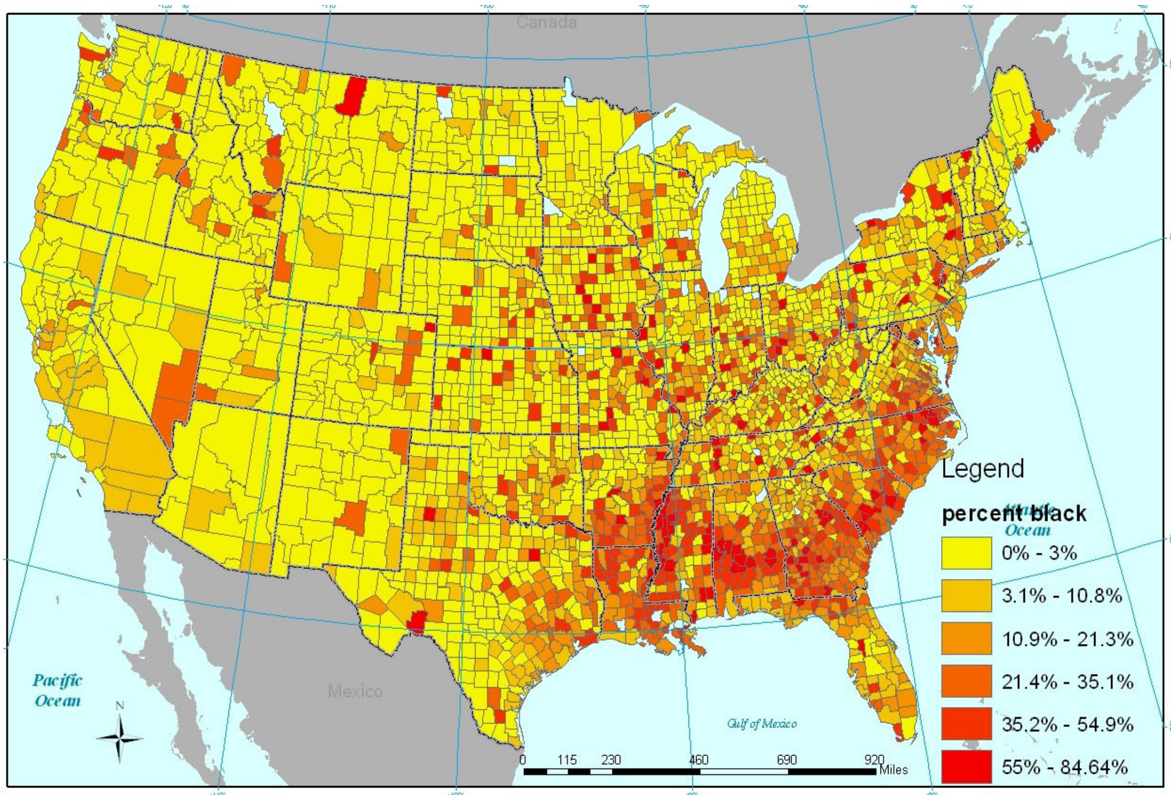


Figure 6: Percentage Change in Population by County from 1990 to 2000

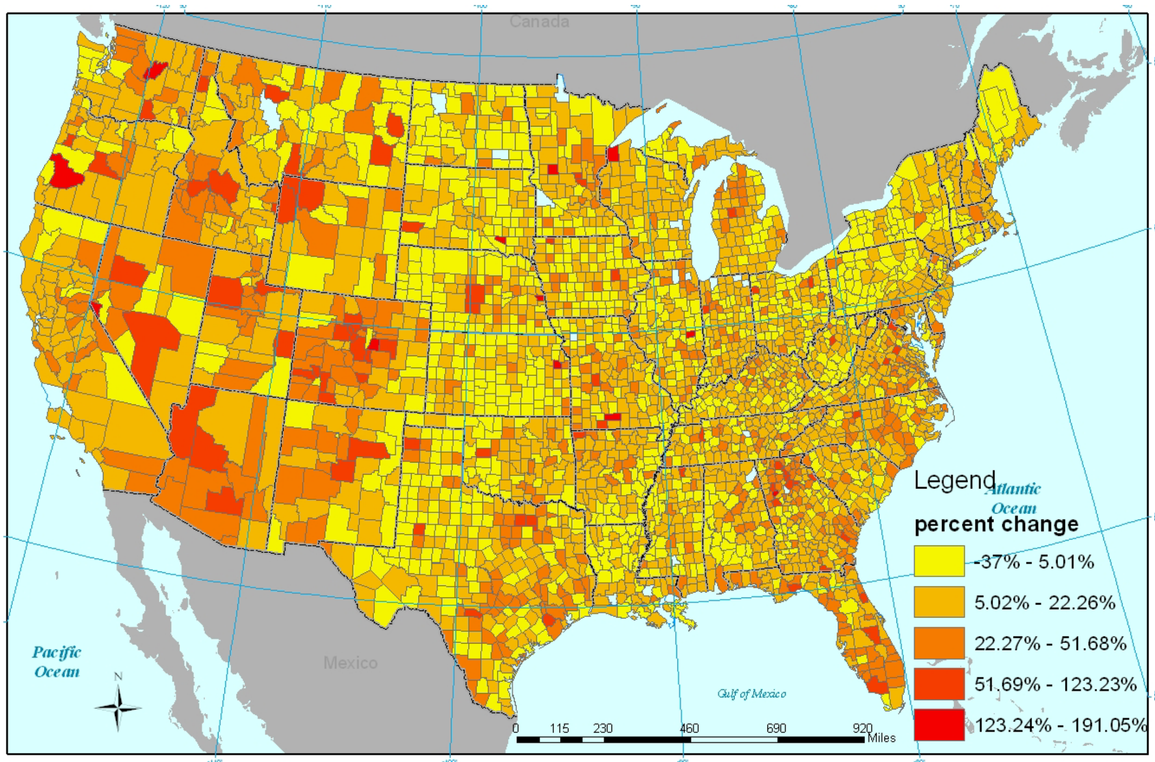
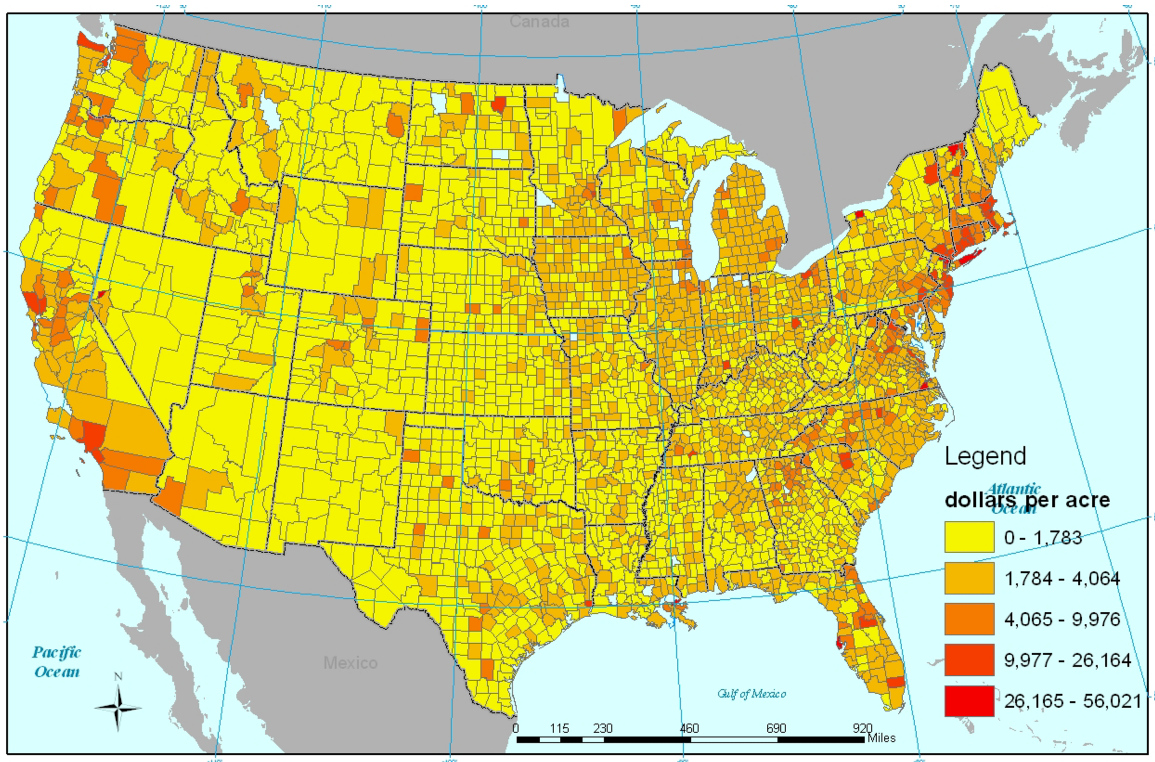


Figure 7: Average Farmland Price per Acre by County (2002 Agricultural Census)



Approaches to Mitigating Hypothetical Bias

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Abstract

Contingent valuation is one of the few tools available to measure economic benefits of nonmarket goods. Therefore the validity of the method is an important research area that underlies all four of the W1133 objectives. In this paper we describe preliminary results from a validity study that elicited both actual and hypothetical donations for a whooping crane reintroduction effort. Two approaches were taken to mitigate hypothetical bias: a cheap talk script that informs study participants about what hypothetical bias is and requests participants to avoid it; and a follow-up to the CV question about how certain respondents are that they would actually donate if asked to do so. We explore how well these two approaches predict the results of the actual donation treatment.

The survey instrument described the history of whooping cranes and the demise of their population to one flock of only 15 birds. An effort to reintroduce a flock of whooping cranes that would spend summers in Wisconsin and winters in Florida was then described. Study participants were asked to make a donation to purchase radio transmitters for new chicks to facilitate successful migration from Wisconsin to Florida. The sample was split into three treatments. In one treatment, respondents were asked to make a real donation. In the other two treatments, respondents were asked about making a hypothetical donation. In one of the hypothetical treatments respondents were told about hypothetical bias and asked to try answer the question as they would for an actual donation. In the other hypothetical treatment, respondents who said they would make a donation were asked how certain they are that they would actually pay for the program if they had been asked to do so.

Similar to past studies we find that more individuals say they will make a donation when the payment is hypothetical relative to the actual payment treatment. In the actual donation treatment, 26% of the respondents said they would make a donation (and actually sent us a check). This compares to 38% in the cheap talk treatment and 55% in the treatment with the follow-up certainty question. The estimates of mean willingness to donate from each of these treatments are all significantly different from each other with an estimated mean of $21 for the actual donation treatment, $36 for the cheap talk treatment and $65 for the certainty follow-up treatment. However, when we use information from the follow-up certainty question to calibrate the willingness to donate response, we get a mean of $30 which is not significantly different from the estimate based on the actual donation data.

Introduction

The validity of contingent values is a contentious issue. CV practitioners recognize that studies vary greatly in the degree of associated validity. Studies comparing contingent values to actual payments consistently find that respondents report higher willingness to pay in a hypothetical payment situation than in an actual payment situation. Such results provide evidence of the existence of "hypothetical bias." Schulze et al. (1981) define hypothetical bias is "the potential error induced by not confronting the individual with an actual situation". While the existence of hypothetical bias has been confirmed in many studies, less attention has been focused on the nature and causes of hypothetical bias. Meta-analyses (List and Gallet 2001; Little and Berrens 2003) have recently been conducted to investigate study design factors affecting hypothetical bias. List and Gallet found private good studies result in less hypothetical bias than studies in which public goods are valued. Likewise they found hypothetical bias to be larger in willingness to accept studies than willingness to pay studies. Certain elicitation methods were also found to affect hypothetical bias. Little and Berrens (2003) expanded the List and Gallet meta-analysis by adding many more studies and including variables for referendum formats, certainty corrections and cheap talk scripts. Little and Berrens found negative significant coefficient estimates on the referendum and certainty correction variables, suggesting that the use of the referendum format and a certainty correction reduce hypothetical bias. The use of a cheap talk script was found to reduce hypothetical bias in one of the four models estimated in this meta-analysis.

The two approaches to mitigating hypothetical bias explored in this paper are use of a follow-up certainty question and cheap talk. In the follow-up certainty question approach, study participants are asked to rate on a 10-point Likert scale (1=very uncertain and 10=very certain) how certain they are that they would actually pay (or not pay if they said *no* to the contingent donation question). Then information on reported levels of certainty is used to re-code responses to the willingness to donate question to provide an estimate of mean willingness to pay similar to the actual donation treatment. More importantly, the certainty scale information can be used to identify a pool of yes respondents to the contingent donation treatment that are indistinguishable from the individuals who actually made donations across a range of measures collected in the survey (attitudes, experience, demographic characteristics, etc.).

Cummings and Taylor (1999) were the first to implement cheap talk in the contingent valuation setting. They developed a script for laboratory experiments to encourage study participants to respond to the contingent valuation question as they would if they were making an actual financial decision. The script, that explicitly described the hypothetical bias problem, was read aloud to the study participants prior to completion of a contingent valuation question. The original script was quite long (see Cummings and Taylor 1999 for the substance of the script). The results of the Cummings and Taylor experiments were promising in that the CV treatment with cheap talk script provided responses that were similar to responses in the actual payment treatment. Since the original Cummings and Taylor study, several others have investigated the use of a cheap talk script. One of the unanswered questions is how long does the cheap talk script needs to be and what information needs to be provided? Implementing a cheap talk script with a mail survey necessitates a shorter script. Lusk (2003) and Aadland and Caplan (2003) investigated the use of a cheap talk script with a mail survey. Lusk used a fairly long script while

Aadland and Caplan used a much shorter script. In both studies, the cheap talk script was found to reduce hypothetical bias for some types of respondents. We built on these studies to develop a "medium" length cheap talk script in a mail survey.

The Good

Whooping cranes are the most endangered crane species in the world; they are threatened primarily by the conversion of their wetland habitat into agricultural lands or urban development areas. Though once widespread, since the 1950's only one flock of whooping cranes has survived. The International Whooping Crane Recovery Team has been orchestrating efforts to ensure the survival of this species. As part of these efforts, a second flock of whooping cranes is being bred and introduced into the wild. Each year, whooping crane chicks are hatched in captivity and taught behaviors crucial to their survival in the wild. As whooping cranes are migratory birds, one important aspect of this program is teaching the young cranes how to make the 1,250 mile migration journey from northern Wisconsin to Florida. After being led to Florida by an ultralight aircraft their first year, the cranes are then able to make the return trip to Wisconsin unassisted the next spring. They will also continue the migration annually as a flock, without the assistance of an aircraft. However, to ensure the success of the program, radio transmitters are placed on the leg of each crane to monitor the birds during migration and throughout the year. If a bird is in danger or sick, scientists will intervene and rescue the bird. The first class of cranes, 18 birds, was hatched in the spring of 2001. The project will continue until the flock has grown to 125 cranes (approximately 10-25 years). At the time of our study, funding was needed to purchase radio transmitters for whooping crane chicks who were to be hatched in the spring of 2004. The transmitters cost around $300 each, and while survey respondents were not told the cost of the transmitters, they were told that the transmitters could only be provided if there was sufficient support in the form of donations.

The Survey

In January 2004, a mail survey was distributed to a random sample of residents of Madison, Wisconsin. The sample was randomly split into three treatments: 1) an actual donation treatment; 2) a contingent donation with follow-up certainty questions treatment; and 3) a contingent donation treatment with a cheap talk script. Each person surveyed received a cover letter, a question and answer sheet, and a survey booklet. The beginning of the survey booklet described the endangered nature of the whooping cranes as well as the ongoing project to establish a second flock of whooping cranes and the role of radio transmitters in this project. A pretest confirmed that the description of the reintroduction project was clear and that many of those surveyed knew of the project before receiving our survey. This is not surprising given the proximity of the sample population to the Necedah National Wildlife Refuge where the cranes spend their summers (approximately 100 miles from Madison, WI to Necedah National Wildlife Refuge). Information about the reintroduction project has appeared in the local news from time to time, establishing the credibility of the good, and so also our survey, to the respondent. The willingness to donate question came after the description, and was followed by questions concerning previous knowledge of the reintroduction project, environmental attitudes, and socio-demographic information. Ten days after the survey packet was mailed, a reminder/thank you postcard was sent to all respondents. A second survey packet was sent to all nonrespondents two weeks after the postcard.

Five hundred five surveys were sent to each of the three treatments. All three treatments used a dichotomous choice question to ask for donations of a specific dollar amount to purchase radio transmitters for the whooping cranes. The five offer amounts used in each treatment were \$10, \$15, \$25, \$50, and \$100. The actual donation treatment gave the respondents the opportunity to donate a specified amount of money to purchase radio transmitters. Those who said yes were asked to include a check for the stated amount with their completed survey. The contingent donation with certainty treatment included a contingent donation question that was immediately followed by a certainty question. This question asked the respondent to state on a 10-point scale how certain they were that they would actually send a donation if they had been asked to do so, or if they said no to the donation question, how certain they were that they would not make a donation. The endpoints of the scale were labeled with 1 being "Very Uncertain" and 10 being "Very Certain".

The contingent donation with cheap talk treatment included the same dichotomous choice question as the contingent donation with certainty treatment, but did not include the follow-up certainty question. Instead the donation question was preceded by a medium length cheap talk script. This script explained to participants that studies have shown that it is difficult for many people to answer questions about a hypothetical situation as if it was real, and "often more individuals say they will make a donation in the hypothetical situation than when the situation is real". The script then asked respondents to try to avoid this problem and make sure they answer the contingent donation question as if they were being asked to make an actual donation. The three treatments differed only by the presence or absence of the cheap talk script, the certainty question, or the request for an actual donation. The rest of the survey material, including the project description and other follow up questions were identical across treatments.

Results

The response rates are shown in Table 1. Overall the response rates for the two hypothetical treatments were significantly higher than that of the actual donation treatment. Responses to other questions in the survey were compared across treatments to test for sample selection bias. We examined differences in prior knowledge, environmental interest and demographic characteristics. Based on these comparisons, we conclude that respondents in the three treatments represent the same population. Table 2 summarizes the characteristics of the survey respondents.

Similar to past studies, we found that more individuals said yes to the donation question when the donation was hypothetical relative to the actual donation treatment. In the actual donation treatment, 26% of the respondents said they would donate and sent us a check. Fifty-five percent of the respondents in the follow-up certainty treatment said they would make a donation and 38% of the respondents in the cheap talk treatment said they would make a donation. The percents of respondents saying yes in the follow-up certainty treatment and the cheap talk treatments were both significantly greater than the percent saying they would donate in the actual donation treatment (Table 3). Not surprisingly, these results extend to both parametric and nonparametric estimates of mean willingness to donate (Table 4).

Mitigating Hypothetical Bias

While our study confirms the existence of hypothetical bias, we are most interested in approaches to mitigating the hypothetical bias. The cheap talk script reduced hypothetical bias relative to the standard CV approach but did not eliminate it (Tables 3 and 4). The follow-up certainty question can be used to convert some of the "yes" response to the CV question to "no" responses. The idea is that individuals who say "yes" but are very uncertain are likely to say "no" in an actual payment question. The question is: how certain do individuals need to be to provide a response to the hypothetical question that is comparable to one that they would provide in an actual payment situation? In a previous study (Champ and Bishop 2001), we found that individuals who said yes to the CV question and circled an 8, 9, or 10 on the certainty scale had, on most questions in the survey, statistically indistinguishable responses from the group of respondents who said yes in the actual payment treatment. We concluded that the individuals who said yes to the CV question and circled 1-7 on the certainty scale would not actually pay if asked to do and were responsible for the hypothetical bias. Re-coding the CV data also provided estimates of mean willingness to donate similar to the actual donation treatment. In our current study, we see the mean certainty level is 7.7 and the median is at 8 on the 10 point scale (Table 5). A majority (59%) of the respondents circled an 8, 9 or 10. We use 8 on the certainty scale as our starting point for re-coding the less certain yes responses to no responses. We also look at 7 and 9 as cutoff points (Table 6). We see that using 8 as a cutoff gives a distribution of response to the CV question that is statistically similar to that of the actual donation treatment. Likewise the estimated mean willingness to donate is similar for the CV treatment with the data recoded to that of the actual payment treatment (Table 4). As these results are preliminary, we have not thoroughly compared the distributions of responses for other survey questions between the actual payment yes respondents and the CV yes respondents who circled 8, 9, or 10 on the certainty scale. However, preliminary results suggest the two groups are very similar. Multivariate Models

Another approach to better understanding treatment effects, is to compare multivariate models. Table 7, 8, and 9 provide pairwise comparisons of the logisitic models. Likelihood ratio tests are used to assess the equality of models. In Table 7 we see that we reject the hypothesis that the actual and cheap talk models are equal. Likewise, we reject the hypothesis of equality of the models based on the CV treatment and the actual payment treatment (Table 8). When the CV data are recoded based on the certainty scale (certainty less than 8, recoded as "no"), we find the logistic models to be similar between the actual payment treatment and the recoded CV treatment (Table 9). These results are consistent with the earlier results comparing distribution of response to the willingness to pay question and estimates of mean willingness to donate (Tables 3 and 4). That is to say, the cheap talk data are not providing results similar to the actual payment data. However, the CV results recoded so that certainty levels less than 8 are recoded as "no" are similar to the actual payment results.

Conclusions

The consistency of the results from our previous research (Champ and Bishop 2001) and the current study, suggest to us that the certainty scale allows us to identify individuals responsible for hypothetical bias. Although the cut-off in both studies was 8, we are not suggesting this result will generalize across studies. The distribution on the certainty scale may vary with different types of public goods. At this time, a modified cheap talk script in a mail survey does not seem to be a solution to eliminating hypothetical bias. However, we recommend experiments continue with the cheap talk scripts to systematically identify the important attributes of the script that eliminate hypothetical bias.

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Table 1: Response Rates

	Actual	CV w/ Follow-up Certainty	Cheap Talk
Mailed	975	730	760
Undeliv. or deceased	43	24	32
Useable	225	242	242
Response Rate	23%	34%	33%

Table 2: Survey respondent characteristics by treatment

	Actual	CV w/ Follow-up Certainty	Cheap Talk
Mean age	51.8	53.9	51.5
Mean number of years in Wisconsin	38.7	41.1	40.7
Percent with children	73%[a]	70%	65%[a]
Percent female	42%[b]	32%[b]	39%
Median Education	college graduate	college graduate	College graduate
Median Income	$60,000 - 69,999	$60,000 – $69,999	$60,000 - $69,999
Had prior knowledge of the reintroduction project	72%	73%	68%
Had knowledge of the International Crane Foundation	92%	91%	89%
Had visited the International Crane Foundation	32%	30%	28%
Frequently donates money to environmental causes	23%	23%	22%
Agree or strongly agree with the statement "The possibility that animals native to Wisconsin may go extinct worries me."	71%	75%	75%

[a]significant difference between Actual and Cheap Talk
[b]significant difference between Actual and CV + Follow-up Certainty

Table 3: Percent of Respondents answering "yes" to the willingness to donate question

	Actual n=216	CV w/ Follow-up Certainty n=224	Cheap Talk n=232
$10	47.4%	75.0%	47.5%
$15	32.0%	66.7%	52.8%
$25	32.6%	56.6%	50.0%
$50	11.5%	40.0%	23.1%
$100	6.7%	35.3%	14.7%
Total	26.3%	54.6%	38.5%

Table 4: Mean willingness to donate by treatment

	Actual n=216	Cheap Talk n=224	CV w/ Follow-up Certainty n=232	Certainty(8) n=232
Mean WTD	$21	$36	$65	$30
95% CI	[14, 30]	[22, 50]	[36, 94]	[19, 42]
Turnbull LB	$17	$23	$44	$24
95% CI	[11, 22]	[16, 29]	[35, 53]	[17, 31]

Table 5: Distribution of Response to Follow-up Certainty Question

Certainty Level	Percent	Cum. Percent
1=very uncertain	2%	2%
2	1%	3%
3	1%	4%
4	2%	6%
5	5%	11%
6	19%	30%
7	11%	41%
8	22%	63%
9	8%	71%
10=very certain	29%	100%

Mean certainty level = 7.7
Median certainty level = 8

Table 6: Distribution of response to CV question with recoding based on responses to the follow-up certainty question

	Actual	CV w/ Follow-up Certainty	Certainty(7)	Certainty(8)	Certainty(9)
$10	47.4%	75.0%	55.6%	47.2%	27.8%
$15	32.0%	66.7%	52.9%	47.1%	29.4%
$25	32.6%	56.6%	37.3%	33.3%	23.5%
$50	11.5%	40.0%	23.6%	14.5%	7.3%
$100	6.7%	35.3%	20.6%	17.6%	11.8%
Total	26.3%	54.6%	37.9%	31.7%	19.8%

Table 7: Logistic Regressions, Actual and Cheap Talk Treatments

Variables	Actual (n=196)	Cheap Talk (n=211)	Actual + CT (n=407)
Constant	-16.849 (65.637)	4.475 (22.035)	-6.420[1] (2.813)
Offer	-.027[1] (.009)	-.032[1] (.008)	-.029[1] (.006)
Aware ICF (1=yes, 0=no)	2.071[2] (1.223)	.875 (.806)	1.280[1] (.654)
I think having whooping cranes in WI is worth the cost (1=disagree, 0=agree)	-.361 (.822)	-2.202[1] (.886)	-1.131[1] (.561)
I can't afford to make a donation (1=disagree, 0=agree)	3.811[1] (.807)	2.501[1] (.575)	3.025[1] (.442)
I like the idea of reintroducing whooping crane (1=disagree, 0=agree)	-8.831 (23.926)	-.428 (.985)	-1.455[2] (.835)
I think the radio transmitters will be purchased regardless of whether or not I make a donation (1=disagree, 0=agree)	.898[2] (.491)	.573 (.434)	.540[2] (.304)
I felt that if I said I would donate, I would more likely see a whooping crane in WI (1=disagree, 0=agree)	-1.076[1] (.503)	-1.198[1] (.440)	-1.080[1] (.319)
Impacts on wildlife should be considered when evaluating plans to develop natural areas (1=disagree, 0=agree)	1.365 (1.052)	.863 (1.204)	1.768 (1.087)
I would rather see the money go to a better project. (1=disagree, 0=agree)	7.844 (30.534)	-7.619 (21.823)	-.313 (.749)
I take trips away from my dwelling to watch birds or other wildlife (1=frequently; 0=otherwise)	.600 (.479)	.684[2] (.414)	.587[1] (.302)
-2 LL (LR = 19.028; $\chi^2_{(\alpha=.05;df=10)}$=18.31)	122.243	169.839	311.110

[1]Significant at α = .05 level
[2]Significant at α = .10 level

Table 8: Logistic Regressions, Actual and Follow-up Certainty without Recoding Responses

Variables	Actual (n=196)	CV w/ Follow-up Certainty (n=221)	Actual + CV w/ Follow-up Certainty (n=417)
Constant	-16.849[1] (65.637)	-4.081[1] 2.757	-4.637[1] 2.243
Offer	-.027[1] (.009)	-.027[1] (.007)	-.022[1] (.005)
Aware ICF (1=yes, 0=no)	2.071[2] (1.223)	-.782 (.722)	-.020 (.544)
I think having whooping cranes in WI is worth the cost (1=disagree, 0=agree)	-.361 (.822)	-1.806[1] (.654)	-1.222[1] (.483)
I can't afford to make a donation (1=disagree, 0=agree)	3.811[1] (.807)	3.233[1] (.504)	3.250[1] (.383)
I like the idea of reintroducing whooping crane (1=disagree, 0=agree)	-8.831 (23.926)	-3.149[1] (1.272)	-3.186 (1.139)
I think the radio transmitters will be purchased regardless of whether or not I make a donation (1=disagree, 0=agree)	.898[2] (.491)	1.4828[1] (.457)	1.017 (3.03)
I felt that if I said I would donate, I would more likely see a whooping crane in WI (1=disagree, 0=agree)	-1.076[1] (.503)	-.612 (.421)	-.869[1] (.303)
Impacts on wildlife should be considered when evaluating plans to develop natural areas (1=disagree, 0=agree)	1.365 (1.052)	1.019 (.907)	1.112 (.760)
I would rather see the money go to a better project. (1=disagree, 0=agree)	7.844 (30.534)	1.366 (1.148)	1.071 (.743)
I take trips away from my dwelling to watch birds or other wildlife (1=frequently; 0=otherwise)	.600 (.479)	1.016[1] (.428)	.647[1] (.294)
-2 LL (LR = 39.66; $\chi^2_{(\alpha=.05;df=10)}=18.31$)	122.243	165.611	327.514

[1]Significant at $\alpha = .05$ level
[2]Significant at $\alpha = .10$ level

Table 9: Logistic Regressions, Actual and Follow-up Certainty Data Recoded

Variables	Actual (n=196)	CV8 (n=219)	Actual + CV8 (n=414)
Constant	-16.849 (65.637)	-11.323 (60.777)	-11.323 (60.777)
Offer	-.027[1] (.009)	-.023[1] (.008)	-.023[1] (.008)
Aware ICF (1=yes, 0=no)	2.071[2] (1.223)	-1.403[2] (.738)	-1.403[2] (.738)
I think having whooping cranes in WI is worth the cost (1=disagree, 0=agree)	-.361 (.822)	-.978 (.696)	-.978 (.696)
I can't afford to make a donation (1=disagree, 0=agree)	3.811[1] (.807)	9.880 (19.040)	9.880 (19.040)
I like the idea of reintroducing whooping crane (1=disagree, 0=agree)	-8.831 (23.926)	-1.531 (1.229)	-1.531 (1.229)
I think the radio transmitters will be purchased regardless of whether or not I make a donation (1=disagree, 0=agree)	.898[2] (.491)	1.043[1] (.386)	1.043[1] (.386)
I felt that if I said I would donate, I would more likely see a whooping crane in WI (1=disagree, 0=agree)	-1.076[1] (.503)	-.387 (.375)	-.387 (.375)
Impacts on wildlife should be considered when evaluating plans to develop natural areas (1=disagree, 0=agree)	1.365 (1.052)	.840 (.975)	.840 (.975)
I would rather see the money go to a better project. (1=disagree, 0=agree)	7.844 (30.534)	-6.952 (47.316)	-6.952 (47.316)
I take trips away from my dwelling to watch birds or other wildlife (1=frequently; 0=otherwise)	.600 (.479)	.412 (.393)	.412 (.393)
-2 LL (LR = 16.275; $\chi^2_{(\alpha=.05;df=10)}$=18.31)	122.243	175.234	313.752

[1]Significant at α = .05 level
[2]Significant at α = .10 level

Comparing Videotape Survey Administration and Phone Interviews in Contingent Valuation of Forest Fire Management

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Abstract

Returning forests to a more natural fire regime is often viewed as an important element in ecosystem management of forests. For such a shift in forest management to be successful, there must be public support. Bringing about a more natural fire regime through prescribed burning is an expensive proposition. So the USDA Forest Service needs more than just public support, it is important to have public willingness to pay as well. An important research issue is what is the best way to measure public willingness to pay for National Forests, since fire protection on these is a non-market good. The contingent valuation method has been used for this purpose in the past. This research tests the convergent validity of willingness to pay responses obtained via videotape survey administration and responses obtained using phone-interviews supplemented by an informational booklet. The phone-booklet approach has an interviewer reading text and referring the respondent to drawings in the mailed booklet contrasting wildfire and prescribed fire. The videotape administration also starts with an initial phone call and then by mailing a videotape to the respondent along with a short answer booklet. The announcer on the videotape verbally presents the text and questions that were read to respondents in the phone interview. Results indicate there was no statistical difference between video and phone-booklet survey models in terms of response rates or reasons for refusing to pay for the prescribed burning program. Median willingness to pay (WTP) for the prescribed burning program using the mail booklet-phone interview was $508 per household. The result from the video survey is $583. The confidence intervals for these two estimates overlap indicating they are not statistically different. However, the videotape survey administration offers the potential for cost savings in large samples where phone interviews would become expensive. Given the convergent validity, the potential for using videotape as part of a contingent valuation survey appears promising for valuing public programs that are too complex to realistically display with still photos and figures. The relatively high willingness to pay using either approach suggests that the

USDA Forest Service should find not only a majority of the public support prescribed burning, but they would be supportive of paying for this program to return their National Forests to a more natural fire regime as part of ecosystem management.

1. Introduction

Contingent Valuation (CVM) has grown in widespread application for valuing improvements in forest condition and protection of natural resources. CVM is frequently used by agencies to value different forest management options whether it be harvesting methods, stand condition or forest fire management. As a result of this increasing use of CVM, the validity of the method has received increasing scrutiny (Bishop and Heberlein, 1979; Barro, et al., 1996; Cummings and Taylor, 1999). While economists have tended to focus on criterion validity (Bishop and Heberlein, 1979; Brookshire, et al., 1982; Cummings and Taylor, 1999; Champ, et al. 1997), the opportunity for such tests are limited with respect to public goods due to the difficulty of constructing cash experiments. With the advent of Cummings and Taylor's "Cheap Talk" design to combat hypothetical bias, and the use of uncertainty intervals to ex-post calibrate stated WTP to its cash equivalent (Champ, et al.) validity research is moving beyond just criterion validity. Recent research focuses on other important details in CVM such as understanding the respondents' motivations that determine their WTP responses (Chilton and Hutchinson, 2003), and the role of attitudes in CVM responses (Pouta, 2004). However, there has been less investigation of convergent validity of survey of different modes (Loomis and King, 1994).

The preferred survey administration mode is in-person (Mitchell and Carson, 1989; Arrow, et al. 1993). However, in-person interviews of general households needed to estimate passive use values are frequently prohibitively expensive, and are rarely used except in very high profile policy analyses or natural resource damage assessment. The most frequently used survey administration form is mail surveys. However, mail surveys require significant reading ability on the part of the respondent. Arrow, et al. suggests that phone interviews may be able to mimic some of the strong features of in-person interviews. However, pure phone surveys are limited due to inability to provide the respondent with visual aids. A combination of phone recruitment-mailed survey booklet-phone interview with the aid of the survey booklet (hereafter called phone-booklet-phone) has proved an effective combination in a number of CVM surveys (Hanemann, et al. 1991; Loomis, et al., 2002). The respondent has the questions and visual aids in front of them while the phone interviewer asks the questions. However, these phone-booklet-phone interviews can also be quite expensive ranging from $50 to $100 per completed interview due to the multiple contacts required and the cost of the in-depth interviews. Internet surveys may be the wave of the future, but presently inconsistent web browsers, slow phone modems, and incomplete coverage of low income households, makes them less than ideal at present. However, according to the U.S. Census Bureau, in 1999 approximately 85% of American households with TVs also had VCRs. The technology of VCRs is easy to use, and the medium offers many of the advantages of Internet, but few of the drawbacks. In addition, using a videotape with an on-camera narrator and visual aids has the potential to mimic an in-person interview, at a fraction of the cost. Once produced, videotape distribution is relatively inexpensive. To our knowledge, no one has yet taken advantage of even the basic features that videotapes offer for conducting a contingent valuation method survey. We believe the videotape medium may be as effective as the phone-booklet-phone interview method at obtaining an adequate response rate, reducing protest refusals to pay and estimating willingness to pay (WTP). Thus, the objective of this study is to determine the convergent validity of the new videotape approach with the more traditional phone-booklet-phone survey method with respect to response rates, protest refusals to pay versus non-protest refusals to pay responses, and WTP estimates.

2. Hypotheses Regarding Response Rate and Protest Responses

There are two contacts in both the phone-booklet-phone approach and the videotape approach. In the phone-booklet-phone approach there is an initial random digit dialing phone call with a short initial interview. The address to mail a survey booklet is verified, and a time is scheduled for an in-depth (20 minute) interview. The videotape survey proceeds in a similar fashion with an initial contact, except a videotape is mailed and the respondent mails back the answer booklet. Thus, the first test of convergent validity is whether households respond equally to the initial phone call, and then whether they follow through on answering the in depth Contingent Valuation Method (CVM) questionnaire with the two survey administration modes.

Ho: $\text{RESPONSE}_{\text{Video}} = \text{RESPONSE}_{\text{Phone-booklet}}$

This will be tested using separate contingency tables and χ^2 tests for both the first and second interviews.

Responses to the WTP questions elicited during the in-depth interview are the main focus of our analysis. First, phone-booklet-phone and video survey responses are compared on reasons for refusing to pay anything for the public program. Some refusals are valid expressions of zero WTP since they reflect lack of value for the good or low income (i.e., inability to pay). Other respondents that give a zero valuation or refuse to pay because they reject the scenario or rationale that citizens should have to pay for this program, are often termed protest responses (Mitchell and Carson; Jorgensen, Syme, Bishop and Nancarrow, 1999; Halstead, Luloff and Stevens). These respondents often do not "buy into" the premise that they are responsible for paying for the solution, or are unconvinced the solution will actually work, or feel government will not spend the money collected on the specific program. It is possible that survey administration mode may result in systematically different responses.

To determine what might potentially be a protest response the following strategy was used in the voter referendum CVM question sequence. First, if a respondent indicated he or she would vote against the program at their initial bid amount, they were asked whether they would pay $1. If they said they would not pay $1, they were asked an open-ended question "Why did you vote this way?". The phone interviewer was instructed to type in exactly what the respondent said. After all interviews were completed, the reasons were analyzed for content to classify answers by similar reasons given by the respondent. As noted by Jorgensen, et al. (1999: 140) this open-ended response approach avoids having respondents fit themselves into pre-set protest categories or having the interviewer place them into pre-set categories. The same basic procedure was used in the videotape survey, where the respondent wrote down their reasons.

Comparing the overall protest reasons given, we will test the null hypothesis of no difference between the two survey administration modes in terms of proportions of protests and non-protest refusals to pay. The null hypothesis is that the distribution of refusals to pay and protest responses to the CVM survey are independent of survey administration mode:

Ho: $PROTEST_{Video} = PROTEST_{Phone\text{-}Booklet}$

This will be tested using a contingency table. The significance test will be performed using a χ^2 statistic.

3. WTP Model and Related Hypothesis Tests

As suggested by the NOAA panel on contingent valuation, a voter referendum willingness to pay question format was used (Arrow, et al., 1993). Hanemann (1984) and Cameron (1988) both provide motivations for how a respondent may answer a dichotomous choice CVM question. Hanemann views the respondent as evaluating the difference in utility associated with the status quo versus paying some amount ($X) to have the program. If the difference in utility is positive for the program, the individual would respond "Yes". If the difference in utility is distributed logistically, a logit model can be used to estimate the parameters and allow for calculation of WTP.

Comparisons of mean WTP estimates across survey administration mode will be used to establish if there is convergent validity in the benefit estimates of the public program. The null hypothesis tests of convergent validity is:

Ho: $WTP_{video} = WTP_{Phone\text{-}booklet}$

The results are determined by whether the confidence intervals overlap or not, calculated using the method suggested by Park, et al.

4. Phone Survey-booklet and Video Design

The public program used to compare video and phone-booklet-phone interviews was forest fire prevention in California. The survey booklet and videotape were developed in conjunction with forestry professionals in California. Both described the acreage that is burned by wildfires in an average year as well as the typical number of houses lost to wildfire each year. Next, a program increasing the use of prescribed fire or controlled burning in California was described. Specifically, respondents were told that the prescribed burning fuel reduction program would reduce potential wildfire fuels through periodic controlled burning. It was acknowledged that prescribed burning does create some smoke, although far less than a wildfire. Then the respondent was provided additional information and drawings contrasting wildfire and prescribed fire. The cost of financing this program of prescribed burning was described as a cost-share program between the State of California and the county the individual lived in.

The WTP elicitation wording was:

"*California is considering using some state revenue as matching funds to help counties finance fire prevention programs. If a majority of residents vote to pay the county share of this program, the Expanded California Prescribed Burning program would be implemented in your county on federal, state, and private forest and rangelands. Funding the Program would require that all users of California's forest and rangelands pay the additional costs of this program. ...If the Program was undertaken it is expected to reduce the number of acres of wildfires from the current average of 362,000 acres each year to about 272,500 acres, for a 25% reduction. The number of houses destroyed by wildfires is expected to be reduced from an average of 30 a year to about 12. Your share of the Expanded California Prescribed Burning program would cost your household $X a year. If the Expanded Prescribed Burning Program were on the next ballot would you vote __In favor ___Against?* "

The $X was replaced with one of 15 different bid amounts developed from previous fire prevention surveys in Florida (Loomis, et al. 2002).

The basic format of the survey booklet and script had previously been through several focus groups in two different states. In the first treatment, the survey was conducted through a phone-booklet-phone process. To obtain a representative sample of households, random digit dialing of the households living in a sample of California counties was performed. The counties were selected so there was a mix of counties that frequently experience wildfires, counties that occasionally experience wildfires, and counties that almost never experience wildfires. Once initial contact was established, we elicited initial attitude and knowledge of wild and prescribed fire, followed by the scheduling of appointments with individuals for detailed follow-up interviews. During the interim time period, a color survey booklet was mailed to the household.

The 15-minute videotape was designed to closely follow the layout of the booklet and question order of the telephone interview. First, a script was created by adhering to the exact wording of the survey booklet and interviewer script used in the first phone interview. The video is simple and includes only a headshot of the narrator, the same two graphics in the booklet, and occasional written text on the screen including the wording of the questions. In order to focus solely on the survey mode effects, the video does not deviate from the booklet or telephone script. The video, like the booklet, begins by defining important fire management terms like "prescribed fire" and "wildfire." Then, the narrator continues to describe the current problem and suggested solution in detail. Ultimately, respondents were asked questions about whether or not they agree with the proposed solution and whether or not they would be willing to pay a certain dollar amount for the solution to be implemented. The script and video was edited and revised slightly following two focus groups.

The initial contact of potential households for the videotape was much like the phone-interview process. To obtain a representative sample, random digit dialing of the households was used in the same counties that were used in the telephone survey. A videotape, answer sheet, and postage-paid self-addressed envelope were mailed to individuals who agreed to participate in the survey. Follow-up contact was made with non-respondents, including sending a replacement videotape if necessary.

5. Results

5.1. Comparison of Survey Response Rates

Because the survey was conducted in two waves, we compare the response rates from the initial random digit dial phone survey and the follow-up in-depth interviews separately in Table 1. We obtained 49.8% in the initial phone contact in the video survey and 41.3% with the initial phone contact in the phone-booklet-phone, a response rate not statistically different at the 5% level using a chi-square test (calculated χ^2 of 1.955 versus critical of 3.84 with one degree of freedom). However, response rates to the follow-up were higher for the phone-mail booklet-phone at nearly 73% as compared to the 65% for the video. The direction of the difference is surprising as one would have expected the more novel video survey would have yielded a higher response rate for the video, although the difference is not statistically significant at the 5% level (calculated χ^2 is .411). Perhaps, having a preset appointment with the phone interviewer calling back and recording responses, with nothing for the respondent to have to initiate or mail back is an advantage to the phone-survey booklet approach over the video. However, the video mail back rate is in the upper end of many other CVM general public mail back survey response rates.

Table 1: Response Rates for Video and Phone-Mail-Phone Surveys

	Video	Phone	Total
First Wave - Screener			
Total Initial Sample Contacted	223	794	1017
Completed Initial	111	328	439
1st Wave Response Rate	**49.78%**	**41.31%**	
Chi-Square			1.955
Second Wave - In-depth Interview/Returned			
Net Sample for Second Wave	111	257	368
Completed	72	187	259
2nd Wave Response Rate	**64.86%**	**72.76%**	
Chi-Square			0.411

5.2 Reasons Why Households Would Not Pay for the Program

Table 2 presents the analysis of refusals to pay, i.e., individuals that indicated they were in favor of the prescribed burning program at no cost, but then would neither pay their initial bid amount nor pay $1 in the follow-up willingness to pay question. These individuals appear to favor the program but essentially have a zero WTP. Table 2 lists the reasons why a person would not pay the $1. The first four reasons listed in Table 2 are not considered protest responses because having no value for the program or receiving no benefits from the program, as well as not being able to afford to pay, are valid reasons for zero WTP. However, the other three categories of responses (italicized in Table 2) are considered protests because they were frequently prefaced with, "I am in favor of program" or "I'm all for it, but I think the program should be paid for by those living in the forests or with existing taxes."

The chi-square of protest refusals to pay versus non-protest refusals to pay for video versus phone is .202. The critical chi-square is 3.84, and so we accept the null hypothesis that there is no statistical difference between the two surveys in terms of non-protest and protest reasons for not paying $1 to expand the prescribed burning program. Thus the two survey modes have convergent validity with respect to reasons people gave for refusing to pay.

Table 2: Reasons Why Respondent Would not be Willing to Pay $1 for the Program

Reason	Video	Phone	Total
No Value/No Benefits	1	1	2
Cannot Afford	1	3	4
Taxes Already too High	1	2	3
Other	1	0	1
Total	**4**	**6**	
Should be paid for with Existing Taxes	*2*	*4*	*6*
Those that Live in Forest Should Pay	*2*	*0*	*2*
Other	*1*	*1*	*2*
Total	**5**	**5**	

**Italicized considered protest responses for purposes of the chi-square analysis.*

5.3 Results of Logit Regressions

Due to the small sample size for the videotape survey (n=67), we conserved degrees of freedom and estimated a simple logit model with the log of the bid amount (X1), a dummy variable for whether the respondent was retired (X2), per capita income (X3), and a dummy variable representing whether or not the respondent believes prescribed burning creates health problems (X4) as the independent variables. Of course a similar specification was used for the phone-booklet-phone logit model as well. As is customary, we excluded an equivalently small number of protest responses from the logit analysis for both the video and phone treatments.

As can be seen in Table 3, the bid slope coefficients are statistically different from zero at conventional levels (1% for the phone-mail-phone and 5% for the videotape) for both types of survey administration. The sign on the bid coefficient is negative, indicating consistency with demand theory, in that the higher the cost to the household, the less likely a household would agree to pay for the program. The likelihood ratio statistic indicates that both overall logit models are statistically significant at the 1% level.

5.4 WTP Results

Median willingness to pay is calculated because the coefficient on the log of the bid amount was outside the range for applying Hanemann's formula (1984) for the mean. According to Hanemann (1984), medians are often used in voter referendum CVM because means are more sensitive to any errors or unusual observations, and medians are a "generally more robust measure of central tendency". For evaluating voting behavior, the median has a natural interpretation as the maximum dollar amount that 50% of the population would vote in favor of. To calculate WTP all non-bid variable coefficients are multiplied by their respective means and added to the constant term. This can be seen in Hanemann's formula (1984) for calculating median WTP when the bid amount is logged:

$$\text{Median WTP} = \exp((Bo+B_2X_2+B_3X_3+ B_4X_4)/B_1)$$

Where Bo is the constant term, and the other non bid coefficients (B_2 , B_3, B_4) are multiplied by their respective means (X_2, X_3, X_4) and added to the constant term.

Median willingness to pay for the video survey was $583 while for the phone-mail-phone was $508, less than a 20% difference and an indicator of convergent validity. Confidence intervals were calculated using a technique that requires an adaptation of the Krinsky-Robb method to dichotomous choice CVM (Park *et al*., 1991). The 90% CI for the phone-booklet-phone is $283 to $2,064. Due to the small sample size for the video survey the confidence interval is rather large, spanning from $218 to more than $50,000 at the upper tail. However, the lower limit of the 90% confidence interval of the video surveys overlap the lower limit of the median willingness to pay estimate of the phone-mail-phone survey, indicating there is no statistical difference between the two median willingness to pay estimates. Thus it appears the new videotape approach and more traditional phone-booklet-phone have convergent validity.

Table 3: Logit Model Used to Calculate Willingness to Pay for the Prescribed Burning Program

Phone-Booklet-Phone Survey			
Variable	**Coefficient**	**z-Statistic**	**Probability**
Constant	4.2482	4.0392	0.0001
Log of Bid	-0.7187	-3.4507	0.0006
Retired	0.2861	0.6311	0.5280
RxHealth Prob	-0.6921	-0.8179	0.4134
Income Per Capita	5.65E-06	0.6914	0.4893
Mean dependent variable	0.7517		
Log likelihood	-73.1246		
Restricted log likelihood	-81.2628		
LR statistic (4 df)	16.2764		
Probablility (LR stat)	0.0027		
McFadden R-squared	0.1001		
Observations	145		

Video Survey			
Variable	**Coefficient**	**z-Statistic**	**Probability**
Constant	1.9904	1.3301	0.1835
Log of Bid	-0.6044	-2.0017	0.0453
Retired	2.0548	2.3212	0.0203
RxHealth Prob	-1.0651	-0.8396	0.4011
Income Per Capita	3.89E-05	1.7093	0.0874
Mean dependent variable	0.6842		
Log likelihood	-28.6001		
Restricted log likelihood	-35.5483		
LR statistic (4 df)	13.8965		
Probablility (LR stat)	0.0076		
McFadden R-squared	0.1955		
Observations	57		

6. Discussion and Conclusion on Convergent Validity

Using a chi-square test we did not find a statistical difference in survey response rates between the two survey administration modes for both the initial random digit dialed interviews and the follow-up CVM responses. Reasons for not being willing to pay for the prescribed burning program were similar as well for the survey administered via videotape and via phone-booklet approaches. There was also no statistical difference in mean WTP between the two approaches, with both annual WTP estimates relatively similar, within 20% of each other at $583 for the video survey and $508 for the phone-mail-phone survey.

The results indicate that the innovative survey administration mode via videotape yielded results comparable to the more conventional mixed mode phone-booklet approach. The overall equivalency of results between the two survey modes is encouraging. The videotape survey costs more for the initial production, but is less expensive per unit than the follow-up phone interviews. The videotape technology also offers the potential to present actual fire footage and more dynamic images, something we did not undertake in this study to maintain consistency with the booklet. However, the phone-booklet approach offers a live interviewer, which may result in a more engaged respondent even if the interaction is only audio. Further research investigating the convergent validity of videotape versus a pure mail and in-person interviews is clearly warranted to evaluate the full potential of using videotape to present information about public goods and eliciting willingness to pay.

The relatively high willingness to pay using either approach suggests that the USDA Forest Service should find not only a majority of the public support prescribed burning, but they would be supportive of paying for this program to return their National Forests to a more natural fire regime as part of ecosystem management.

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WTA for Consumptive and Non-consumptive Use Access to Private Lands when Affirmative Responses are Poisson Events

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The purpose of this presentation was to seek information concerning how best to statistically estimate discrete choice data where few survey respondents indicated willingness to accept a stated bid. The data discussed during this presentation are from a 1994 national survey of private land owners called the National Private Land Ownership Survey (NPLOS). This survey was conducted as a cooperative effort between the NRCS, the USFS's Southern Research Station (USFS), and the University of Georgia's Department of Agricultural and Applied Economics (John Bergstrom).

The survey largely concerned the willingness of private land owners to allow access to their lands by the pubic. Included in the survey were questions asking how much land owners would be willing to accept (WTA) in compensation to open up their land to the public. WTA values were sought for consumptive, such as hunting or fishing, and non-consumptive, such as camping or hiking, uses.

The issue is that few respondents were willing to accept the stated bids. Of 3,140 returned surveys, 332 (11%) and 303 (10%) accepted the stated bid for, respectively, consumptive and non-consumptive uses. Standard statistical procedures for estimating WTA require that the data be more balanced with respect to affirmative and negative responses. However, the survey instrument was designed so that if a respondent did not accept the stated bid they were asked to select from a menu the reason for not accepting the bid. If they selected "the bid was too low," then respondents were asked to state a bid that they would accept and to indicate the amount of acreage that they would lease at this amount.

Review of the results quickly revealed the reason for the low number of affirmations. The survey instrument was designed to elicit compensation amounts that varied between $0 and $20 per acre. Survey results for consumptive uses indicate that that the mean bid for compensation was $7.90, for those who accepted the bid the mean compensation level was $9.93, for those who rejected the bid the mean compensation level was $8.12, and for those who rejected the stated bid, but gave their own bid the mean compensation level was $70.48 per acre. For non-consumptive uses the mean bid for compensation was $7.82, for those who accepted the bid the mean compensation level was $9.86, for those who rejected the bid the mean compensation level was $8.25, and for those who rejected the stated bid, but gave their own bid the mean compensation level was $106.59 per acre. Given these results, it is clear that the stated compensation amounts are $60 to $100 per acre too low.

The first question asked of the audience concerned the statistical legitimacy of using the "additional information" provided by the survey to adjust the number of affirmative respondents. However, it was noted that the adjustment would only increased the number of accepted bids to 367 (12%) respondents for consumptive and 329 (11%) for non-consumptive uses. So even if statistically valid (and the audience agreed that this process was statistically valid), this process did not solve the problem.

The next question of the audience concerned proper statistical methods for dealing with this problem. To start off the discussion, Poisson estimation was offered as a solution. Discussion related to this question varied, but Poisson estimation was quickly eliminated as a solution. About half of the audience thought that low affirmation was a problem and half didn't. One individual suggested taking the log of the bid level. However, this comment led to discussion concerning the validity of the mean bid. Dr. Loomis, citing Dr. Joe Cooper, suggested a double bounded model. Dr.s Loomis and Hellerstein suggested a review of the open ended sample and noted that if the parameter estimates of the model are statistically significant and of the right sign, then there is no issue. On this point Dr. Ready did not agree. Dr. Ready's position was that nothing could be done to save this investigation and suggested, instead, estimation of a supply function keeping in mind that only 10% of the population participated in the survey. In the end, discussion settled on the possibility of conducting a follow-up survey. It was suggest that a follow-up survey include questions related to owner liability, that the survey elicit much higher bid levels, and that the survey elicit willingness to pay for restricted access rather than willingness to accept compensation for free access. Following the presentation, Dr. Kerkvliet suggested a review of the medical literature were positive outcomes are often small relative to "failures."

To date, actions have been taken in terms of follow-up. Following Drs. Loomis and Kerkvliet's suggestions, a review of the medical literature has been pursued and Dr. Cooper has been contacted. Several articles from the medical literature offer potential solutions. We have also followed Dr. Ready's advice and have estimated a supply function. However, this research direction has not been fruitful because of additional (and compounding) data issues. The current thinking is that, because of poor construction of the survey instrument, the data are insufficient for estimating realistic willingness to accept functions. The data are also old. For these reasons the current study is being set aside and funding to conduct a follow-up survey of south-eastern land holders (including Appalachia) is being sought.

Intercept and Recall:
Examining Avidity Carryover in On-Site Sample Data

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Intercept and Recall:
Examining Avidity Carryover in On-Site Sample Data

Abstract:

This study examines the related issues of measurement errors in trip counts to a system of recreation sites collected on-site, and the proper statistical weighting of past-season counts for the site of interception. We find that for our sample of jet skiers visitation avidity for the interview site carries over across seasons. We show that the proper weighting of past season counts is different from the standard on-site correction appropriate for current-season counts. We also find strong indication of the presence of measurement error in our application. For the Poisson-lognormal framework we recommend interpreting trip and welfare predictions as upper bounds of true population measures when exogenously verified trip counts are not available.

Key words: On-site Sampling, Recreation Demand Systems, Poisson-Lognormal Distribution, Simulated Maximum Likelihood

Introduction

Studies on seasonal recreation demand generally elicit direct information from respondents on past and future trips to the destinations of interest (e.g. [6, 16, 28]). Regardless of the data collection mechanism this raises the issue of the respondent's ability to accurately recall past and correctly forecast future visits even if no quality changes or other policy measures are stipulated for the recreation sites. It is reasonable to assume that for most respondents at least some of the reported trip counts are inaccurate, i.e. measured with error from the researcher's perspective. This potential shortcoming of collected trip information and its implications for model estimation and welfare predictions has to date not found much attention in the recreation demand literature.

To some extent the problem of incorrectly measured dependent variables in count data models has been investigated in other fields of applied economics. In most of these applications, however, the focus rests on *under*reported counts (e.g.[8, 18, 24]). Cameron and Trivedi [3], Ch. 10, illustrate a variety of approaches for accommodating underreported counts in a generalized count data framework. These models generally require the researcher to be able to assign or estimate a common probability that an event is recorded, conditional on occurrence, within the context of a given application. This would be a daunting task in recreation demand analysis, as recording probabilities are likely respondent-specific. In addition, these probabilities may well change as actual trips accumulate throughout a given season. More importantly, in the recreation context, reported counts may deviate from actual counts in either direction. According to Cameron and Trivedi [3], p. 310, tractable models to handle this situation were still "underdeveloped" in the late 1990s. Today, such models are being developed but have yet to emerge in the published literature.[1]

An additional complication in collecting recreational trip counts arises when respondents are intercepted on-site. This is a common strategy to gather information on users of recreational amenities in a cost-effective manner, especially when only a small segment of the wider population is expected to visit the site or system of sites. In that case, the researcher has two fundamental choices: sampling at the very end of a given season (assuming that the season end is clearly identifiable and exogenous to users), or sampling during or throughout the season. Both approaches have their benefits and drawbacks. End-of-season sampling naturally avoids forecasting errors in stated counts, at least for the season of intercept. At the same time, however, recall problems can be expected to be more pronounced as respondents have to explore their "mental trip log" over a longer time horizon. In addition, on-site end-of-season sampling carries the risk of sample selection if end-of-season users are systematically different from other users in the wider population of visitors. In contrast, intercepting visitors throughout the season is likely to generate a more representative sample of the underlying population but exposes reported counts to the risks of both recall and forecasting bias, with the former increasing and the latter diminishing as the interview timing approaches the season end.

Furthermore, regardless of the timing of on-site sampling, counts for the interview site likely follow a different probability distribution from the one specified by the researcher for the general population of users, as intercepted respondents are likely more frequent visitors to the examined site than the prototypical user in the underlying population. This enhanced avidity of the respondent for the site of interception must be explicitly captured in the modeling framework to avoid biased trip and welfare estimates (e.g. [7, 14]).

If the researcher has strong concerns regarding the accuracy of forward-looking trip reports but at the same time desires to sample visitors throughout the season to avoid selection problems and to assure a reasonable sample size within the limits imposed by constrained survey budgets, an attractive option might be to ask respondents not only about trips for the current season (and possibly future seasons), but also about visits during past years. The researcher may hope that a standard estimation framework that solely analyzes past counts, and is uncorrected for on-site sampling, can recover the preferences of the underlying population of users for that past season if recall errors can be adequately addressed. If average site quality and season length do not change much over time, these preferences could be interpreted as time-invariant and applied to the current (and near-future) seasons. However, such an approach will fail to produce unbiased estimates and predictions if on-site avidity "carries over" across seasons, i.e. if the fact that a given respondent was encountered at the interview site this season also implies enhanced avidity for the site in past years. While on-site corrections for current season counts are by now well understood, the statistical properties of *past* counts for *current* interview sites has to date not been examined in the empirical literature.

The aim of this study is twofold. We illustrate conceptually one possible avenue of accounting for measurement error into a multi-site system of recreation demand. We then employ this framework using current and past trip data to examine to what extent avidity carries over across seasons. We find that avidity carryover is very pronounced for our sample of jet skiers in the Lake Tahoe area and propose a new estimator that corrects past trip reports for current on-site sampling. Our empirical evidence also suggests that parameter estimates and trip and welfare predictions based on corrected current counts are significantly different from analogous results for corrected past counts. We hypothesize that this divergence is in part attributable to recall and forecasting errors.

Model Formulation

Utility-theoretic Framework

We stipulate that person i derives aggregate utility in season t from taking trips to the $j=1...J$-site recreation system collected in vector $\mathbf{y_{it}}$ and from consuming a numeraire composite commodity b. Specifically,

$$U_{it} = U(\mathbf{y_{it}}, \mathbf{q_t}, \mathbf{h_i}, b), \tag{1}$$

where $\mathbf{q_t}$ denotes site attributes, and $\mathbf{h_i}$ is a vector of person or household characteristics. Assuming seasonal separability of utility[2], we apply the Incomplete Demand System (IDS) framework described in LaFrance and Hanemann [11]. Utility maximization subject to an (assumed binding) budget constraint yields the Marshallian quasi-demand system

$$\mathbf{y_{it}} = \mathbf{y}(\mathbf{p_i}, \mathbf{q_t}, \mathbf{h_i}, m_i) \tag{2}$$

where $\mathbf{p_i}$ is a vector of prices associated with the destinations included in the system, and m_i denotes annual income.[3] As shown in LaFrance and Hanemann [11], these demand equations display, in theory, all desired utility-theoretic properties. LaFrance and Hanemann [10] illustrate how this framework can be empirically implemented for some common functional forms of demands. We follow Shonkwiler [21] and apply a Log II demand specification within a count data framework. We initially specify trips to follow a Poisson distribution with expected site-specific demand given by

$$E\lfloor y_{ijt} \rfloor = \lambda_{ijt} = \exp(\mathbf{a_{ijt}} + \beta_{p,ij} p_{ij}) \cdot \beta_m m_i \quad , \tag{3}$$

where we have implemented the utility-theoretic IDS restrictions on price coefficients of $\beta_{p,ik} = 0, k \neq j$, and $\beta_{m,i} = \beta_m, \forall i$,[4] and simplifying restriction $\beta_{p,ij} = \beta_{p,j} \; \forall i$. Shifting vector $\mathbf{a_{ijt}}$ comprises all site and respondent characteristics multiplied by their respective coefficients.

Unobserved Heterogeneity and Measurement Error

It is likely that trip demand includes respondent-specific components that are unobserved by the researcher. This individual heterogeneity can be incorporated into a Poisson system by combining expected demand for the Poisson distribution with a multiplicative lognormal error term. This approach was originally proposed by Aitchison and Ho [2], first implemented in the recreation demand context by Shonkwiler [20], and recently investigated in the context of on-site sampling by Egan and Herriges [4]. Heterogeneity-adjusted conditional expected demand is thus given by

$$E\left[y_{ijt} \mid \varepsilon_{ij}\right] = \lambda_{ijt} \cdot \exp\left(\varepsilon_{ij}\right) = \tilde{\lambda}_{ijt} \tag{4}$$

where ε_{ij} is normally distributed with mean zero and variance $\sigma^2_{\varepsilon,j}$. To keep our model tractable we assume that error terms are individual and site-specific, but invariant over time. An intuitive interpretation of this error would be the presence of unobserved individual preferences for an equally unobserved (or costly-to-measure) site-specific quality (e.g. choice and difficulty of nearby hiking trails, water depth at nearby beaches etc.) and an abundance or lack of such quality at site *j*.

Recall and forecasting errors in reported counts can be modeled in analogous fashion. Assume that a given individual *i* is interviewed at site *j* on day τ of the current season, where τ indexes any day between the start (τ =1) and the end (τ =*T*) of the season. Let $\nu_{ij,\tau}$ and $\nu_{ij,T-\tau}$, respectively, be the errors associated with recall and forecasting problems. Both errors are assumed normally distributed with zero mean and variances $\sigma^2_{\nu j,\tau}$ and $\sigma^2_{\nu j,T-\tau}$, respectively. Their covariance over day-of-season can be assumed to be negative as $\nu_{ij,\tau}$ ought to increase with τ while the second error term should decrease as τ approaches *T*. Since the data available for this analysis do not allow for an empirical distinction between the two error components, we sum them to yield a combined, zero-mean measurement error ν_{ij}.[5] For tractability, we assume that the variance of this combined error is invariant of the day of interception for a given site, i.e. $\sigma^2_{\nu j,\tau} = \sigma^2_{\nu j}, \forall \tau$. Introducing notation $\tilde{y}$ for seasonal trip counts reported with error we can derive the conditional Poisson expectation for mis-measured counts as

$$E\left[\tilde{y}_{ijt} \mid \varepsilon_{ij}, \nu_{ij}\right] = \tilde{\lambda}_{ijt} \cdot \exp\left(\nu_{ij}\right) = \tilde{\tilde{\lambda}}_{ijt} \tag{5}$$

where, as indicated above, $\tilde{\lambda}_{ijt}$ is the heterogeneity-adjusted expectation of the true conditional probability mass function (pmf) for seasonal trips. The multiplicative measurement error term has the desirable ability to handle all possible reporting scenarios: underreported counts ($\nu_{ij} < 0$), unbiased counts ($\nu_{ij} = 0$), and overreported counts ($\nu_{ij} > 0$).

To link trip reports associated with a given respondent over sites we specify that the heterogeneity terms follow a multivariate normal distribution with full variance-covariance matrix, i.e.

$$\begin{aligned} &\boldsymbol{\varepsilon}_{\mathbf{i}} = \begin{bmatrix} \varepsilon_{i1} & \varepsilon_{i1} & \cdots & \varepsilon_{iJ} \end{bmatrix}' \sim mvn(\mathbf{0}, \boldsymbol{\Sigma}) \quad \text{with} \\ &\boldsymbol{\Sigma} = \begin{bmatrix} \sigma^2_{\varepsilon 1} & \sigma_{\varepsilon 12} & \cdots & \sigma_{\varepsilon 1J} \\ \sigma_{\varepsilon 21} & \sigma^2_{\varepsilon 2} & \cdots & \sigma_{\varepsilon 2J} \\ \vdots & \vdots & \ddots & \vdots \\ \sigma_{\varepsilon J1} & \sigma_{\varepsilon J2} & \cdots & \sigma^2_{\varepsilon J} \end{bmatrix} \quad \text{and} \quad \mathrm{E}\left[\boldsymbol{\varepsilon}_{\mathbf{i}} \boldsymbol{\varepsilon}'_{\mathbf{g}}\right] = 0 \; g \neq i. \end{aligned} \tag{6}$$

Similarly, the vector of site-specific measurement errors is stipulated to follow a multivariate normal distribution with mean zero and full variance-covariance matrix $\boldsymbol{\Gamma}$. As indicated in (6), all individuals share a common variance-covariance matrix for the heterogeneity error vector. We assume the same holds for the measurement error.[6]

If both information on actual and stated trip counts were available, the researcher could in theory identify and separately estimate the elements of $\boldsymbol{\Sigma}$ and $\boldsymbol{\Gamma}$. To date, this has rarely been the case in applications of recreation demand as it requires exogenous monitoring of a person's trip taking activities. Our application is no exception in this respect. We can only estimate second moments for the *combined effects* of heterogeneity and measurement error. Assuming independence between the two error components, we specify a combined multivariate normal error vector as $\boldsymbol{\mu}_\mathbf{i} = \boldsymbol{\varepsilon}_\mathbf{i} + \mathbf{v}_\mathbf{i}$ with $E[\boldsymbol{\mu}_\mathbf{i}] = \mathbf{0}$ and $E[\boldsymbol{\mu}_\mathbf{i}\boldsymbol{\mu}_\mathbf{i}'] = \boldsymbol{\Omega} = E[\boldsymbol{\varepsilon}_\mathbf{i}\boldsymbol{\varepsilon}_\mathbf{i}'] + E[\mathbf{v}_\mathbf{i}\mathbf{v}_i'] = \boldsymbol{\Sigma} + \boldsymbol{\Gamma}$.

The unconditional density of $\tilde{\mathbf{y}}_\mathbf{it}$ is thus Poisson-lognormal (PLN, Aitchison and Ho [2]) with

$$f(\tilde{\mathbf{y}}_\mathbf{it}) = \int\limits_{\boldsymbol{\mu}_\mathbf{i}} \prod_{j=1}^{J} \frac{\exp\left(-\tilde{\tilde{\lambda}}_{ijt}\right) \cdot \tilde{\tilde{\lambda}}_{ijt}^{\tilde{y}_{ijt}}}{\tilde{y}_{ijt}!} f(\boldsymbol{\mu}_\mathbf{i})\, d\,\boldsymbol{\mu}_\mathbf{i} \quad , \tag{7}$$

where $f(\boldsymbol{\mu}_\mathbf{i})$ denotes the multivariate normal density, and the dimensionality of the integral is commensurate to the number of elements in $\boldsymbol{\mu}_\mathbf{i}$. The desirable properties of this mixture distribution in the context of recreation demand systems are discussed in detail in Egan and Herriges [4]. Borrowing from their notation, the first two moments of the unconditional marginal distribution can be derived as

$$\begin{aligned} &E[\tilde{y}_{ijt}] = \lambda_{ijt} \cdot \exp\left(\frac{\sigma_{\varepsilon,j}^2 + \sigma_{\nu,j}^2}{2}\right) = E[y_{ijt}] \cdot \exp\left(\frac{\sigma_{\nu,j}^2}{2}\right) = \tilde{\delta}_{ijt} \qquad \text{and} \\ &\mathrm{V}[\tilde{y}_{ijt}] = \tilde{\delta}_{ijt} + \tilde{\delta}_{ijt}^{\,2} \cdot \left(\exp\left(0.5 \cdot \sigma_{\mu,j}^2\right) - 1\right) \end{aligned} \tag{8}$$

where $\sigma_{\mu,j}^2 = \sigma_{\varepsilon,j}^2 + \sigma_{\nu,j}^2$. As is evident from the first equation in (8) the estimated expectation for the mis-measured trip count for a given person can be expressed as the product of the correct expectation and an exponentiated error factor that always exceeds one as long as the measurement error variance is nonzero. While we cannot separately identify the two variance components and directly extract the true expectation of y_{ijt}, equation (8) suggests the interpretation of λ_{ijt} and $\tilde{\delta}_{ijt}$ as lower and upper bounds, respectively, for $E[y_{ijt}]$. The lower bound holds exactly if both variance terms are zero. The upper bound reflects the correct expectation only if the variance for the measurement error is zero.

A cautionary note is in order at this point: When comparing sets of reported counts for different seasons, but from the same sample of individuals and system of sites it would be tempting to interpret larger variance terms in $\mathbf{\Omega}$ for a given season as indicative of more severe measurement problems. However, such a conclusion would only be valid if reported trip counts refer solely to past recreation behavior and forecasting errors do not apply. If reported seasonal counts include both recalled and forecasted trips, the two sources of measurement error, $v_{ij,\tau}$ and $v_{ij,T-\tau}$, may in theory cancel each other in part or fully. Conversely, seemingly unbiased or "accurate" counts can occur for one of two reasons: either both recall and forecasting errors are zero, or they cancel each other exactly. We will return to this issue in our discussion of estimation results.

Correcting for on-site sampling

As originally discussed in Patil and Rao [15], if the population density of a random variable x is given by $f(x)$, the weighted or "size-biased" density for the same variable measured on-site takes the form of $f^s(x) = (x/E[x]) \cdot f(x)$. The proper statistical approach for addressing on-site sampling for the univariate Poisson distribution is shown in Shaw Shaw [19]. Egan and Herriges [4] extend this framework to the Poisson-lognormal distribution and show how the density in (7) can be corrected for *current* season counts that are collected on-site. Specifically, if the interview is conducted at site k, the joint trip density for the current season to the system of sites takes the form

$$f^k(\tilde{\mathbf{y}}_{\mathbf{it}}) = \frac{\tilde{y}_{ikt}}{E[\tilde{y}_{ikt}]} \int_{\boldsymbol{\mu}_{\mathbf{i}}} \prod_{j=1}^{J} \frac{\exp\left(-\tilde{\tilde{\lambda}}_{ijt}\right) \cdot \tilde{\tilde{\lambda}}_{ijt}^{\;\tilde{y}_{ijt}}}{\tilde{y}_{ijt}!} f(\boldsymbol{\mu}_{\mathbf{i}})\, d\,\boldsymbol{\mu}_{\mathbf{i}}$$
$$= \frac{\tilde{y}_{ikt}}{\tilde{\delta}_{ikt}} \int_{\boldsymbol{\mu}_{\mathbf{i}}} \prod_{j=1}^{J} \frac{\exp\left(-\tilde{\tilde{\lambda}}_{ijt}\right) \cdot \tilde{\tilde{\lambda}}_{ijt}^{\;\tilde{y}_{ijt}}}{\tilde{y}_{ijt}!} f(\boldsymbol{\mu}_{\mathbf{i}})\, d\,\boldsymbol{\mu}_{\mathbf{i}} \qquad (9)$$

where the superscript to *f(.)* indexes the intercept site. The term outside the integral is the multiplicative weight assigned to the density of $\tilde{y}_{ikt}$.

This raises the question if past season counts for the current interview site also need to be weighted to allow for pronounced avidity for the intercepted respondent with respect to the interview destination. We approach this as an empirical issue and propose what Patil and Rao [15] deem a general weighting function that, in our context, accommodates the extreme cases of "zero avidity carryover" and "full avidity carryover". Specifically, using subscript *t-1* to denote the season preceding the sampling season, we specify the size-corrected joint Poisson-lognormal density as

$$f^k(\tilde{\mathbf{y}}_{\mathbf{it-1}}) = \frac{w(\tilde{y}_{ikt-1})}{E[w(\tilde{y}_{ikt-1})]} \int_{\boldsymbol{\mu}_{\mathbf{i}}} \prod_{j=1}^{J} \frac{\exp\left(-\tilde{\tilde{\lambda}}_{ijt-1}\right) \cdot \tilde{\tilde{\lambda}}_{ijt-1}^{\;\tilde{y}_{ijt-1}}}{\tilde{y}_{ijt-1}!} f(\boldsymbol{\mu}_{\mathbf{i}}) \qquad \text{where}$$
$$w(\tilde{y}_{ikt-1}) = (\tilde{y}_{ikt-1} + 1)^{\alpha} - \alpha, \qquad 0 \le \alpha \le 1. \qquad (10)$$

The weighting function *w(.)* has several desirable properties. First, it accommodates counts of zero and thus a scenario where a respondent intercepted at site k in the current season did not visit that site in the preceding year. Second, as α approaches zero the weight term in (10) approaches one. This would imply that no on-site correction is needed for past counts. We label this outcome as "zero carryover". Third, as α approaches one the weight term takes the form of the weight in (9), indicating that a full on-site correction is needed for past season visits to the interview site, i.e. that there is "full carryover" of avidity for the intercept site. A value of α between zero and one would imply that past season trips to the interview site require a different on-site correction than current season counts. Naturally, a shortcoming of this formulation is that *w(.)* equals zero for the joint outcome of $\alpha = 1$ and $\tilde{y}_{ikt-1} = 0$. In that case, the weighting term in (10) is no longer well defined as its denominator goes to zero as well. Since there are a few individuals in our data that reported zero trips to the interview site for the preceding season, we cannot directly implement the specification in (10) with an imposed constraint of $\alpha = 1$. Instead, as shown in the estimation section, we use the empirical confidence interval for α to examine this hypothesis.

For this study, we estimate model (9) using current season counts, and model (10) using counts for the season preceding the sampling year. The integrals in (9) and (10) are simulated using 1000 draws of Halton vectors (e.g. [27]). Evaluation of the leading term in (9) is straightforward as it is not a function of $\boldsymbol{\mu}_\mathbf{i}$. In contrast, the computation of the sampling weight in (10) poses a greater challenge as its denominator depends on $\boldsymbol{\mu}_\mathbf{i}$ and does not have closed form. Specifically,

$$E\left[w(\tilde{y}_{ikt-1})\right] = \sum_{\tilde{y}_{ikt-1}=0}^{\infty}\left(w(\tilde{y}_{ikt-1})\cdot f(\tilde{y}_{ikt-1})\right) = \sum_{\tilde{y}_{ikt-1}=0}^{\infty}\left(w(\tilde{y}_{ikt-1})\cdot \int_{\mu_{ik}} f(\tilde{y}_{ikt-1} \mid \mu_{ik}) f(\mu_{ik}) d\mu_{ik}\right) \qquad (11)$$

where $f(\tilde{y}_{ikt-1})$ is the marginal Poisson-lognormal density of $\tilde{y}_{ikt-1}$. The integral in the last term in (11) must be simulated apart form the simulation routine used to evaluate the integrals in (9) and (10). In addition, the summation over $y_{ik,t-1}$ in (11) needs to be numerically approximated as well.[7] Our general estimation framework is simulated maximum likelihood (e.g. [26]). The algorithm produces estimates of the slope coefficients in (3), the elements of variance-covariance matrix $\mathbf{\Omega}$, and, for the past season model, the avidity parameter α.[8]

Data

The data for this analysis stem from an on-site survey of jet skiers implemented during the summer seasons of 2001 and 2002 at six lakes and reservoirs in the Tahoe region of the central Sierra Nevada. A detailed description of the survey procedures is provided in Moeltner and Shonkwiler [14]. For this study we use information on both current season and past season trips to five of the six lakes[9]. To be specific, visitors interviewed in 2001 provided trip information for the years 2000 and 2001. A different set of respondents, captured in the 2002 round of the survey, reported trips for 2001 and 2002.[10] After eliminating individuals who took more than 40 trips to the system of sites and / or spent more than one day at the interview location, we retain 159 completed questionnaires yielding a panel of 159x5 = 795 observations for both "current year trips" (=trips in 2001 for the 2001 sample, and trips in 2002 for the 2002 sample) and "past year trips" (=trips in 2000 for the 2001 sample, and trips in 2001 for the 2002 sample).[11]

Table 1 summarizes some basic lake and trip characteristics for this sample. As can be seen from the table, visitors reported a total of 2329 trips to the recreation system, approximately evenly distributed over current and past seasons. The largest numbers of seasonal trips are observed for Lahontan and Boca reservoirs. Both destinations offer numerous easy access and launching points, generally free of charge. Distances from visitor origin to destinations are comparable across lakes, with means in the 50 to 70 mile range.

A more detailed picture of trip distributions for our sample is given in Table 2. The table depicts the mean over individuals of the number of trips taken to each of the five sites, distinguished by season and by on-site versus off-site counts. For example, the first cell in the table indicates that the average number of trips to Boca for those interviewed *at Boca* for the season of intercept is 9.74. In contrast, respondents interviewed at other sites only took an average of 0.51 trips to Boca (second cell, first row). The "all" columns show the unweighted average of all trip counts for each site, regardless of on-or off-site status. The most important insight that can be gained from this table is the pronounced difference in trip averages between on- and off-site counts *for both seasons*. This suggests that a correction for size-biased sampling may be indicated for both current and past trip counts. As will be shown below, our estimation results confirm this postulation.

Estimation Results

We estimate three different models. It is important to emphasize that all three models are based on the same underlying sample of visitors, i.e. the same data set except for the dependent variable. Specifically, model 1 uses past season counts and does not correct for on-site sampling, i.e. the avidity parameter α in (10) is constrained to zero in this model. Model 2 is also based on past season counts, but implements the avidity correction for past counts suggested in (10). A comparison of results generated by models 1 and 2 will illustrate the implications of ignoring avidity carryover. Model 3 employs current season counts, in conjunction with the standard on-size correction illustrated in Egan and Herriges [4] and shown in equation (9). We hypothesize that both models 2 and 3 correctly control for size-biased sampling. Also, heterogeneity effects ought to be relatively similar for both specifications, given that they are based on the exact same sample of visitors, and that seasonal variations in site quality are not very pronounced for the research region (see footnote 10). The two models should differ, however, in their susceptibility to recall and forecasting errors. Specifically, model 2 should be free of forecasting error but more vulnerable to recall problems. Measurement errors in model 3, in turn, will be a combination of recall and forecasting deviations. As outlined in the model formulation section an examination of the magnitude of variance terms estimated by the two models will provide some insight into the relative importance of pure recall errors (for past counts) and combined recall and forecasting errors (for current season counts) associated with the two specifications, although an ordinal comparison of measurement errors is not possible due to the potential "cancellation effect" for the current season model discussed above. Our main focus in the discussion of model results will rest on differences in trip predictions and welfare measures generated by the three specifications.

All models share the same basic set of explanatory variables, i.e. site and year-specific intercept terms to compactly capture site characteristics and potential inter-seasonal quality changes at each destination, a separate own-price term for each site[12], and the natural logarithm of income. The intercept terms correspond to the shifting vector $\mathbf{a_{ijt}}$ in (3), although we model these site indicators to be shared by all respondents for ease of estimation, i.e. $\mathbf{a}_{\mathbf{ijt}} = \mathbf{a}_{\mathbf{jt}} \; \forall i$. The models thus include all necessary components to estimate a Log II-type incomplete demand system ([10]).[13]

Estimation results are given in Table 3. Focusing first on a comparison of the past-counts models 1 and 2 the main result captured in the table is the location of the avidity parameter α near the center of its [0,1] support. In addition, this parameter is estimated with high precision as indicated by its comparatively small standard error. Invoking asymptotic normality, the 95%

confidence interval for α is {0.57, 0.72}. At the same time, the value of the log-likelihood function at convergence is much improved by the introduction of the avidity parameter as shown in the last row of the table. A likelihood ratio test clearly rejects a null hypothesis of $\alpha = 0$. As mentioned above, the likelihood function is not defined at $\alpha = 1$ for some individuals, which preempts the application of standard test procedures to verify this hypothesis. However, the tight confidence interval for α shown above suggests that it is highly unlikely that α is located in the vicinity of one. We thus conclude that, at least for our application, the distribution for past counts needs to be adjusted for on-site sampling (i.e. $\alpha \neq 0$), and that this adjustment is significantly different from the size-biased weight appropriate for current season counts (i.e. $\alpha \neq 1$).

The omission of this adjustment in model 1 translates into different estimates for slope coefficients as well as inflated variance terms compared to the corrected model. The difference in slope coefficients is especially pronounced for some of the price terms (Boca, Lahontan, Stampede). This, in turn, translates directly in substantial differences in trip and welfare predictions for these two models, as will be shown below. The price coefficient for Tahoe, which emerges as positive in model 1 and insignificant in model 2, needs to be interpreted with caution. Given the large size of this lake and its multiple shoreline attractions, many intercepted jet skiers did not travel directly to the interview site, but launched their jet ski at a different location. This introduces measurement errors into the travel cost computations for such individuals. This problem did not become apparent until later in the survey period. As a result, the questionnaire did not capture the possibility of non-identical travel endpoints and interview sites.

The estimation results generated by current-season model 3 are quite different from those produced by the past-count versions for both site indicators and price terms. Furthermore, the variance and covariance terms for this model are significantly smaller than the analogous elements estimated by models 1 and 2. As mentioned above, this could be indicative of reduced measurement error associated with current season trips, a cancellation effect of recall versus forecasting errors, or both. Another possible interpretation of this stark difference in the estimated elements of $\mathbf{\Omega}$ is that visitors may resort to the long-run seasonal mean when prompted to forecast future trips. If this long-run mean is similar for a large share of survey participants, as could be reasonably expected, variance estimates would be deflated compared to variance terms associated with past counts. Information on long-run trip averages would be needed to further examine this hypothesis. Overall, the pronounced differences in estimated elements of $\mathbf{\Omega}$ between on-site corrected models 2 and 3 casts strong doubt on the notion that all variability in the random error component of $\tilde{\tilde{\lambda}}_{ijt}$ in equation (5) flows from individual heterogeneity. Our results thus provide strong indication that trip reports for at least one of the two models, and likely for both, are affected by measurement error.

Trip Predictions

Table 4 depicts model predictions for the average number of trips, over individuals, to each site. Lake Tahoe is omitted from this and the following table due to the difficulties in accurately measuring travel costs and estimating a reliable price coefficient for this destination, as mentioned above. These predictions can be compared to the sample statistics provided in table 2. However, it should be noted that the “all” column in table 2 depicts a smeared average over all on- or off-site trips associated with a given lake. These sample averages are not indicative of latent user demand for the wider population. To elicit latent demand per site, estimated parameters from on-site corrected models need to be employed in the expression for expected visits commensurate with the stipulated underlying pmf for the population of interest. This expression is given by $\tilde{\delta}_{ijt}$ in equation (8). Naturally, expected population counts are biased for model 1 given its mis-specified likelihood function. As evident from equation (8), trip predictions for the latent population of visitors are also biased for models 2 and 3 if measurement errors are present. However, given our conceptual framework, for these models we can at least interpret estimated population counts as "upper bounds" of true counts, as mentioned earlier.

The entries in table 4 were computed as follows: We take 10,000 draws from the empirical distribution of slope coefficients and variance terms and compute the mean trip count over individuals for each site and draw using the expression for the first moment of the unconditional marginal distribution of $\tilde{y}_{ijt}$ given in (8). We then examine the properties of the resulting simulated distribution of mean counts for each site. Specifically, table 4 reports the lower (LB) and upper bounds (UB) of the simulated 95% confidence interval for these trip means. In addition, we follow Moeltner [12], Moeltner and Shonkwiler [14], and Shonkwiler and Hanley [23] by reporting a statistic that relates the point estimate of the mean to the spread of its confidence interval. This indicator of relative efficiency is denoted as "spread-over-mean" (s.o.m) in the table.

As can be seen from the table, trip predictions generated by model 1 are substantially larger than those produced by models 2 and 3. In part, this is a direct effect of the inflated variance estimates produced by this model (see table 3). Moreover, these predictions exceed even on-site sample counts for all sites, which casts serious doubt to this model's ability to accurately recover latent population demand. It should also be noted that the confidence intervals for these predictions do not overlap with those generated by model 2 for three of the four sites, and the s.o.m. index substantially exceeds analogous measures associated with the other two specifications. Model 2, in turn, produces trip predictions that lie below on-site sample counts for all sites. For two of the four destinations (Boca and Lahontan) trip predictions are located between on-site and off-site sample counts, an expected finding for latent population demand. This desirable property holds for all predictions associated with model 3. For two of the sites (Donner and Stampede) models 2 and 3 yield similar point estimates and overlapping confidence intervals. For the other sites, point estimates are significantly different for the two on-site corrected specifications as judged by the lack of overlap of confidence intervals. In general, though, trip counts for both models 2 and 3 appear of plausible magnitude and are characterized by relatively tight confidence intervals and corresponding low s.o.m. values. It thus appears that either set of counts, if properly corrected for on-site sampling, provides a suitable basis to estimate latent population demand to the recreation system.

Welfare Estimates

For the same four sites, seasonal compensating variation (CV) is captured in table 5. As discussed in Moeltner and Shonkwiler [14] the policy relevance of such welfare measures is given by potential bans on jet ski use at lakes and reservoirs in the central Sierra Nevada due to environmental considerations, as well as the possibility of exhaustive water extraction from these reservoirs during drought periods. As shown in Shonkwiler [21], for the Log II IDS seasonal CV for representative individual *i* and site *j* can be derived as

$$\begin{aligned} cv_{ij} &= m_i - \left(m_i^{1-\beta_m} - (1-\beta_m)\cdot\left(\frac{1}{\beta_{p,j}}\cdot\exp\left(\alpha_j + \beta_{p,j}p_{ij} + 0.5\cdot\sigma^2_{\varepsilon,j}\right)\right)\right) = \\ & m_i - \left(m_i^{1-\beta_m} - (1-\beta_m)\cdot\left(\frac{1}{\beta_{p,j}}\cdot\exp\left(\alpha_j + \beta_{p,j}p_{ij} + 0.5\cdot\sigma^2_{\mu,j}\right)\right)/\exp\left(0.5\cdot\sigma^2_{v,j}\right)\right) \end{aligned} \quad . \tag{12}$$

We simulate the distribution of the mean of (12) over individuals for each site in analogous fashion to the process described above for mean trip predictions. As for trip predictions welfare measures for model 1 will be biased given the omitted on-site correction in its likelihood function. As evident from (12), CV estimates for models 2 and 3 are biased if measurement error is present, but can be interpreted as upper bounds of the true underlying welfare measures (since $\exp\left(0.5 \cdot \sigma_{v,j}^2\right) > 1$ for any $\sigma_{v,j}^2 > 0$).

From table 5 we observe $E\left(\sum_{i=1}^{n} cv_{i,\mathrm{model\,1}}\right) > E\left(\sum_{i=1}^{n} cv_{i,\mathrm{model\,2}}\right) > E\left(\sum_{i=1}^{n} cv_{i,\mathrm{model\,3}}\right)$ for all sites. However, confidence intervals for models 1 and 2 overlap for Boca, Lahontan, and Stampede, and confidence intervals for models 2 and 3 overlap for all sites except Boca. However, except for Stampede, confidence intervals are significantly tighter for the on-site corrected models, as indicated by lower s.o.m. statistics compared to model 1. Overall, there is less agreement and more noise in welfare estimates for models 2 and 3 than there is for trip predictions. In part, this is due to the large difference in estimates for the income coefficient for these two models (see table 3), and the prominent role this coefficient plays in the expression for seasonal CV. Naturally, this provides a dilemma for the researcher who now needs to decide which set of counts to choose to derive reliable estimates of welfare effects for the latent population of users. Perhaps a conservative approach would be to argue that the expected CV is located between the lower of the lower bounds and the higher of the upper bounds of the two confidence intervals associated with the two models. Ultimately, though, only the ability to disentangle heterogeneity effects from measurement errors will provide guidance as to the relative validity and reliability of estimates and predictions generated by the two specifications.

Conclusion

In this study we examine in more detail the statistical properties of on-site collected trip reports to a system of recreation sites for current and past seasons. We find that for our sample of jet skiers visitation avidity for the site of intercept carries over across seasons. This requires a proper weighting of past season counts in the joint probability mass function of reported trips to avoid model mis-specification and biased estimation results. This weighting is different from the full size-biased weights appropriate for current-season counts.

We also address the related issue of errors in reported trip counts. While our data set is not suitable to empirically test for the presence of such errors, we find, however, a strong indication for misreported counts in our application. We anchor this conclusion in the facts that our models 2 and 3 produce distinctly different parameter estimates and welfare predictions even though (i) they are both properly adjusted for on-site sampling, (i) they are both based on an identical set of individuals (thus controlling for heterogeneity effects), and (iii) that inter-seasonal quality changes, subtle as they may be, are explicitly captured in both specifications.

We believe that measurement errors in trip counts can seriously affect estimation results, and may have been misinterpreted as pure heterogeneity effects in past recreation studies based on similar econometric specifications. Our conceptual framework will hopefully provide a starting point for future efforts in this direction. A closer examination of the magnitude and direction of such errors will crucially hinge on researchers' ability to collect both reported and exogenously monitored counts. If unambiguously correct trip information is not available for a given season, we recommend interpreting trip and welfare predictions flowing from econometric specifications similar to the framework employed in this study as upper bounds of true population measures.

Notes:

[1] The discrete normal distribution, originally introduced by Kemp [9] and recently promoted by Shonkwiler [22] constitutes a promising approach to model the joint occurrence of positive and negative integers in a given application.

[2] A richer inter-temporal model of consumer choice would link utilities across seasons, either through allowing for state dependence to directly enter seasonal utility (e.g. [1, 13]) or through inducing forward-looking rationality in a fully dynamic model (e.g. [17]). Implementation of the former approach requires substantially more choice occasions than were available for this analysis. The latter modeling strategy is computationally involved, especially given the econometric adjustments to site demands proposed in this study. In addition, as argued in Swait et al. [25], p. 95, consumers' recreation behavior is somewhat unlikely to flow from a fully dynamic optimization framework as mental processing costs would likely outweigh the gains in utility associated with (correctly) anticipating the effect of current decisions on future benefits.

[3] For simplicity, we assume travel costs and annual income to remain constant for the short time period (2 years) examined in our application.

[4] While these restrictions explicitly rule out cross-price effects in the uncompensated site-specific demand equations, they still allow for substitution between sites through compensated demands. Specifically, as shown in Englin et al. [5], and Shonkwiler [21] the Hicksian cross-price effects are non-zero as long as β_m is positive.

[5] Specifically, the survey underlying our application only asked respondents for the *total* number of seasonal trips to the site of interception and the other sites in the system, regardless of the interview date. A more refined instrument would elicit both counts up to and including the interview day and counts forecasted for the remainder of the season.

[6] The main intuition for allowing for site-specific variance in *heterogeneity effects* is that certain sites may have an unobserved quality attribute that is highly desirable to some and at the same time perceived as a strong disamenity by others, while other sites may trigger less extreme responses in expected trip behavior. Similarly, the rationale for non-zero off-diagonal elements in $\mathbf{\Sigma}$ is that a given pair of sites may be similar or opposing with respect to an unobserved quality attribute. If *both* sites are relatively well endowed or relatively lacking in the attribute as perceived by the prototypical visitor, their covariance term is positive. If there is a distinct imbalance in the attribute across the two sites, their covariance is negative. Analogously, the main rationale for site-specific variances in measurement error is that visitors likely differ in their ability to accurately recall and predict trips. To the extent that visits to some sites may be more memorable or easier to plan / forecast than for other destinations for the average user, error variances will change over destinations. A positive covariance in $\mathbf{\Gamma}$ would indicate a systematic tendency to over- or under-predict visits for the typical user for a given pair of sites. While the intuition for this possibility is not as compelling as for the case of covariances associated with heterogeneity we a priori leave $\mathbf{\Gamma}$ unconstrained.

[7] We use 800 support points to simulate this sum. Estimation results stabilized at 600-800 points.

[8] The models are estimated using Matlab v.6.5. The program code is available from the authors upon request.

[9] One of the destinations (Lake Topaz) was excluded from this study as very few visitors interviewed there took trips to any of the other sites in the system.

[10] Ideally, our modeling framework should be applied to a sample of visitors collected during a single season to minimize the effects of unobserved site quality changes over time. In our case,

limited sampling budgets for each of the two sampling years did not allow for the collection of a sufficient number of observations for any single season. We therefore pool the data over the two seasons. However, as shown in the next section, our empirical application controls, at least to some extent, for site quality changes over time. Also, the three seasons spanned by our sample (2000 to 2002) were characterized by very similar weather conditions (dry and warm), as is typical for this geographic region. Water levels at the five lakes were also comparable across the three seasons. Overall, we are thus confident that our model is largely unaffected by unobserved variability in site quality.

[11] Restrictions on survey length preempted collecting trip details for visits other than the one intercepted on-site. Our analysis thus rests on the implicit assumption that relevant trip details, such as length-of-stay, remain largely unchanged over all (past and future) trips for a given respondent.

[12] As in Moeltner and Shonkwiler [14], we specify access price to incorporate a $0.3 per-mile driving cost for jet ski renters, and $0.4 for jet ski owners to allow for a "load penalty", as well as an opportunity cost of time-component computed as travel time in hours times 1/3 of the hourly wage rate.

[13] The survey also collected limited information on user characteristics, such as age, gender, and education level. However, none of these attributes emerged as significant in preliminary specifications.

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Table 1: Sample Characteristics

Lake	Elevation (feet)	Surface area (square miles)	Shoreline (miles)	Distance (miles, one way) mean	min	max	On-site interviews	Trips past	current	total
Boca	5700	1.5	15	49.1	7.2	221.9	31	308	367	675
Donner	5969	1.5	7.5	53.8	4.4	227.8	51	114	182	296
Lahontan	4150	23.2	69	74.4	1.1	205.6	33	346	375	721
Stampede	5949	5.4	25	56.8	8.7	228.0	26	105	180	285
Tahoe	6230	190.8	75	63.4	7.7	220.0	18	156	196	352
Total							159	1029	1300	2329

Table 2: Trip Statistics for Current and Past Season

Site	Current season trips (mean)			Past season trips (mean)		
	on-site	off-site	all	on-site	off-site	all
Boca	9.74	0.51	2.31	5.58	1.05	1.94
Donner	2.86	0.33	1.14	1.37	0.41	0.72
Lahontan	9.48	0.49	2.36	8.21	0.60	2.18
Stampede	4.58	0.46	1.13	1.65	0.47	0.66
Tahoe	8.06	0.36	1.23	5.28	0.43	0.98
All sites	6.45	0.43	1.64	4.10	0.59	1.29

Table 3: Estimation Results

Variable	Model 1 Coeff.	s.e.		Model 2 Coeff.	s.e.		Model 3 Coeff.	s.e.	
Boca00	-5.861	(1.137)	***	-5.634	(0.977)	***	-	-	-
Donner00	-8.186	(1.177)	***	-8.028	(0.961)	***	-	-	-
Lahontan00	-2.992	(1.102)	***	-5.936	(0.732)	***	-	-	-
Stampede00	-6.702	(0.965)	***	-7.667	(1.234)	***	-	-	-
Tahoe00	-9.365	(1.101)	***	-8.375	(0.981)	***	-	-	-
Boca01	-6.503	(1.041)	***	-8.252	(1.041)	***	-2.052	(0.555)	***
Donner01	-7.743	(1.131)	***	-8.363	(0.929)	***	-1.320	(0.657)	**
Lahontan01	-3.569	(1.268)	***	-6.711	(0.729)	***	-0.631	(0.535)	
Stampede01	-8.026	(1.015)	***	-8.180	(1.086)	***	-2.094	(0.578)	***
Tahoe01	-9.466	(1.032)	***	-8.599	(0.906)	***	-2.334	(0.563)	***
Boca02	-	-	-	-	-	-	-3.077	(0.535)	***
Donner02	-	-	-	-	-	-	-1.952	(0.480)	***
Lahontan02	-	-	-	-	-	-	-0.275	(0.510)	
Stampede02	-	-	-	-	-	-	-3.584	(0.519)	***
Tahoe02	-	-	-	-	-	-	-3.465	(0.486)	***
price Boca	-0.060	(0.014)	***	-0.042	(0.007)	***	-0.016	(0.004)	***
price Donner	-0.025	(0.007)	***	-0.021	(0.008)	**	-0.037	(0.011)	***
price Lahontan	-0.091	(0.020)	***	-0.033	(0.002)	***	-0.036	(0.004)	***
price Stampede	-0.042	(0.010)	***	-0.022	(0.007)	***	-0.008	(0.003)	**
price Tahoe	0.004	(0.001)	***	0.002	(0.001)		-0.006	(0.001)	***
log(income)	0.580	(0.086)	***	0.494	(0.064)	***	0.154	(0.045)	***
log(1/a -1)	-	-	-	-0.578	(0.165)	***	-	-	-
a (avidity parameter)	-	-	-	0.641	(0.038)	***	-	-	-
Variances / Covariances									
Boca	7.862	(1.650)	***	7.664	(1.016)	***	2.369	(0.212)	***
Boca / Donner	3.247	(0.661)	***	2.606	(0.485)	***	0.446	(0.140)	***
Donner	5.574	(1.034)	***	4.709	(0.910)	***	0.890	(0.154)	***
Boca / Lahontan	4.056	(0.982)	***	3.125	(0.367)	***	0.187	(0.151)	
Donner / Lahontan	-1.323	(0.610)	**	-0.170	(0.319)		-0.917	(0.140)	***
Lahontan	6.849	(2.251)	***	6.577	(0.417)	***	1.332	(0.155)	***
Boca / Stampede	4.617	(0.863)	***	3.314	(0.678)	***	0.719	(0.149)	***
Donner / Stampede	3.634	(0.688)	***	2.299	(0.439)	***	0.285	(0.092)	***
Lahnotan / Stampede	1.592	(1.114)		2.411	(0.673)	***	0.140	(0.143)	
Stampede	5.969	(1.586)	***	4.873	(1.278)	***	1.319	(0.305)	***
Boca / Tahoe	3.305	(0.535)	***	3.586	(0.574)	***	0.344	(0.101)	***
Donner / Tahoe	3.266	(0.505)	***	2.292	(0.409)	***	0.324	(0.119)	***
Lahnotan / Tahoe	-0.396	(0.313)		-0.206	(0.333)		-0.837	(0.176)	***
Stampede / Tahoe	0.446	(0.315)		0.329	(0.421)		-0.480	(0.155)	***
Tahoe	5.807	(0.681)	***	3.276	(0.573)	***	2.027	(0.182)	***
Log-Lhf (abs. value)	829.865			797.485			963.018		

White-corrected standard error in parentheses
*=sign at 10%, ** = sign. at 5%, ***=sign. at 1%

Table 4: Trip Predictions

Site		Model 1	Model 2	Model 3
Boca	mean	14.914	5.174	0.787
	LB	5.661	3.299	0.641
	UB	36.173	8.287	0.959
	s.o.m.	2.05	0.96	0.40
Donner	mean	1.767	0.338	0.414
	LB	1.029	0.258	0.317
	UB	3.291	0.447	0.529
	s.o.m.	1.28	0.56	0.51
Lahontan	mean	28.61	1.739	0.925
	LB	4.61	1.339	0.691
	UB	123.47	2.282	1.217
	s.o.m.	4.15	0.54	0.57
Stampede	mean	2.254	0.463	0.50
	LB	1.074	0.298	0.31
	UB	5.205	0.756	0.67
	s.o.m.	1.83	0.99	0.71

LB (UB) = lower (upper) bound of 95% simulated confidence interval for the sample mean

s.o.m. = spread over mean (spread of the simulated confidence interval over mean)

Table 5: Welfare Estimates

Site		Model 1	Model 2	Model 3
Boca	mean	238.369	123.294	58.96
	LB	118.715	76.649	29.17
	UB	498.987	201.609	131.96
	s.o.m.	1.60	1.01	1.74
Donner	mean	76.79	17.853	11.323
	LB	37.42	9.94	7.796
	UB	162.27	34.851	16.632
	s.o.m.	1.63	1.40	0.78
Lahontan	mean	336.431	53.261	26.416
	LB	67.899	36.11	17.914
	UB	1335.767	81.101	39.073
	s.o.m.	3.77	0.84	0.80
Stampede	mean	52.789	29.146	128.237
	LB	32.451	12.361	28.93
	UB	96.359	78.953	468.958
	s.o.m.	1.21	2.28	3.43

LB (UB) = lower (upper) bound of 95% simulated confidence interval for the mean over individuals

s.o.m. = spread over mean (spread of the simulated confidence interval over mean)

A Bioeconomic Model of the Great Salt Lake Watershed

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Abstract: We present a computable general equilibrium model of the interface between the watershed containing the Great Salt Lake (GSL) and the regional economy that impacts the GSL ecosystem. With respect to the ecosystem, the model treats the various representative species as net-energy maximizers and bases population dynamics on the period-by-period sizes of surplus net energy. Energy markets - where predators and prey exchange biomass - determine equilibrium energy prices. With respect to the regional economy, we model five production sectors (at the aggregate industry level) - brine cyst harvesters, the mineral-extraction industry, agriculture, recreation, and a composite-good industry - as well as the household sector. By performing dynamic simulations of the joint ecosystem-regional economy model, we isolate the effects of period-by-period stochastic changes in salinity levels and an initial shock to species-population levels on the ecological and economic variables of the model. As a result, we demonstrate how the model can be used to estimate the economic benefits of managing an ecosystem within its watershed.

JEL Classification: C68, D58, Q57

Keywords: Net energy, biomass demand and supply, regional economy, Great Salt Lake

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1. Introduction

Management of the Great Salt Lake (GSL) watershed has evolved sporadically during the past 150 years – from a state provision in 1850 appropriating two islands in the lake for herding purposes, to a state-sponsored study in 1958 focusing solely on the need for extensive diking to control the lake's intermittent flood levels, to a plan published by the Utah Department of Natural Resources (DNR) in 2000 promoting *inter alia* the maintenance of the lake and its marshes as a critical waterfowl flyway system (DNR, 2000 and Adler, 1999). As Adler (1999) points out, this planning process is perhaps best described as a slow evolution toward a broadly focused, multiple-use plan that nevertheless lacks sufficient research and monitoring, has often been institutionally disjointed, and is inappropriately tethered to the lake's official meander line rather than its watershed. Echoing this sentiment, the DNR has noted that "managers [of the GSL] do not fully understand how reductions in inflows and other water and land uses [within the watershed] will affect population dynamics and species interactions (page 48, DNR, 2000)." How these effects in turn feedback through the regional economy is even less understood.

This paper demonstrates a new integrated ecological/economic, or bioeconomic, model of the GSL watershed that (a) accounts for the basic ecological relationships and human activities that interact within the lake's watershed and (b) enables the measurement of ecosystem externalities that might occur as a result of "shocks" within the watershed and ecosystem, thereby identifying the degree to which certain species may be threatened. In other words, the paper demonstrates one approach that the DNR might use to help it understand the interrelationships between human activity and biological interactions within the GSL watershed and how these interrelationships impact the vulnerability of any given species. The model, patterned closely after Finnoff and Tschirhart (2003 and 2004) (henceforth FT), is based on individual-species behavior directing aggregate outcomes in a multiple-species food web. In effect, a general-equilibrium ecosystem model (GEEM) is combined with a computable general-equilibrium (CGE) model of the regional economy, providing a tight integration of the GSL's ecology and economy.

Our model extends FT in three important respects. First, it incorporates stochastic ecological parameters, such as the salinity and nitrogen balances of the lake at any given point in time. Second, unlike FT's application to a marine ecosystem, the application here is to an inland water body where water in- and outflows are crucial to the health of the ecosystem and economy. The model is therefore an initial attempt at capturing the multi-dimensional effects of human intervention in an ecosystem, rather than solely through the harvesting of a focal species as in the case of a marine environment. Third, commercial harvesting of the focal species – brine shrimp – is not of the species itself, but rather of its eggs. Thus, harvesting impacts the species' population dynamics in a unique way, which has been heretofore unexplored in the literature.

We find evidence that the GSL ecosystem is stable at current levels of human intervention and at the current level of government regulation of the brine-shrimp industry. However, our results illustrate the extent to which unintended ecological and economic consequences may occur as humans intentionally interact with the ecosystem. We demonstrate these consequences through a simple simulation exercise that is initiated by a series of one-time species-population shocks to the ecosystem in concert with period-by-period stochastic shocks to the lake's salinity and nitrogen balances. The primary goal of this exercise is to demonstrate how the model can be used for management purposes, in order to better understand the specific ways in which water- and land-use changes within the watershed affect population dynamics and species interactions within the GSL ecosystem.

The next section describes the GSL ecosystem and presents the simple ecology underlying the GEEM sub-model. Here, we not only discuss the basic food web within which the various species interact, but also the constrained optimization problems solved by each species on an individual basis. Section 3 describes the CGE regional-economy sub-model and the mechanisms through which humans impact the GSL. In this section, we portray the household- and industry-level optimization problems that motivate these impacts. Section 4 presents results from a simple dynamic simulation of the joint GEEM-CGE bioeconomic model in which the various species encounter alternate 10% positive and negative one-time population shocks. Lake salinity and nitrogen balances are assumed to encounter periodic random shocks drawn from a normal distribution. Section 5 concludes with a summary of our findings and a discussion of future research avenues. The specific parameter values and functional forms used to calibrate our bioeconomic model to the steady-state equilibrium are provided in a technical appendix.

2. The Great Salt Lake Ecosystem

Figure 1 displays a map of the GSL. The ecosystem is estimated to be 3,011 square miles in area, approximately half of which is encompassed by the lake’s meander line, while the land area that actually contributes water to the lake (i.e., its watershed) is an estimated 22,000 square miles (Adler, 1999; Aldrich and Paul, 2002). In size, therefore, the GSL is the largest saline and terminal lake in North America and the fourth largest in the world (Adler, 1999; Arnow and Stephens, 1990). The lake is located within five Utah counties and three-quarters of the state's wetlands are located along its shores (Adler, 1999). More than 50% of the state's 1.8 million people live within 20 miles of its meander line and adjacent wetlands (DNR, 2000).

[INSERT FIGURE 1 HERE]

Approximately 66% of total inflow to the lake is in the form of surface water; the three largest sources being the Bear, Weber, and Jordan Rivers. These rivers flow into the southern arm of the lake (primarily Gilbert Bay), but incoming freshwater is prevented from mixing with the lake's northern arm (Gunnison Bay) due to a massive east-west railroad causeway constructed in 1902. As a result, only the southern arm maintains a salinity balance conducive to brine-shrimp (the focal species) reproduction. Along with mineral extraction (primarily salt and magnesium), wildlife viewing, and waterfowl hunting, the brine-shrimp industry accounts for a predominant share of the lake's economic value.

There is an extensive literature on the GSL's unique biology and limnology. Aside from gleaning what statistics are available from this literature for model-calibration purposes, three universally acknowledged characteristics of the GSL have guided the formulation of our bioeconomic model. First, while the diversity of species in the lake itself is considered quite low, its biological productivity is extremely high. In other words, the GSL's food web is simple and capable of supporting dense species populations. Second, the reproductive capability of the brine shrimp is highly sensitive to the lake's salinity and nitrogen balances. These balances are in turn sensitive to anthropogenic activity within the lake's boundaries itself (e.g., through mineral extraction) as well as within the watershed (e.g., through agricultural production and urbanization). Thus, the brine shrimp population contends not only with these indirect impacts, but also with the direct impacts of commercial harvesting and predation by waterfowl and shorebirds. Third, the GSL ecosystem is considered a critical waterfowl flyway system, reflected by its designation as one of 19 habitat sites in the Western Shorebird Reserve Network (Adler, 1999). An estimated five to 10 million waterfowl and shorebirds (representing 257 different species) annually utilize the ecosystem's resources for migration and nesting purposes. As a result, wildlife viewing is emerging as one of the GSL's most lucrative industries.

Figure 2 presents a schematic of the ecosystem's basic food web, based primarily on a synthesis of Gliwicz, et al. (1995), Wurtzbaugh (1995), Belovsky (1996), Belovsky and Mellison (1997 and 1998), Stephens (1997a, 1997b, and 1999), Belovsky, et al. (1999), DNR (2000), and Stephens and Birdsey (2002). As with all ecosystems, the sun is the primary energy source. Green algae (*Dunaliella*) obtain energy (and thus biomass) from the sun and are regulated primarily by the inflow of fresh water and nutrient loadings, which determine the lake's nitrogen and salinity balances. The growth in green algae is believed to be parabolic with respect to salinity level and increasing with respect to the nitrogen balance.

[INSERT FIGURE 2 HERE]

Both brine flies (*Ephydra cinerea*) and brine shrimp (*Artemia fransiscana*) prey on algae and in turn are preyed upon by waterfowl and shorebirds (designated simply as waterbirds). Corixid bugs (*Trichocorixa verticalis*) also prey on the brine shrimp. Most importantly from an economic standpoint, the brine shrimp produce hard-cased eggs, or cysts, that over-winter to produce the next generation of shrimp. Cysts are harvested in the fall (under relatively strict governmental regulation) and sold primarily as high-grade prawn feed to large-scale operations in Southeast Asia and Latin America (Isaacson, et al. 2002). Estimated market value of the GSL cysts averaged approximately $30 million from 1992-1997 and has fluctuated between $75 million and $150 million since then (Isaacson, et al., 2002 and *The Salt Lake Tribune*, 2001).

The GSL is similarly rich in mineral deposits, particularly salt and magnesium chloride. Approximately three million tons of mineral products are extracted from the lake annually by six companies, averaging roughly $220 to $300 million in aggregate market value (DNR, 2000; Isaacson, et al., 2002; Adler, 1999). Mineral production at its current level results in 95,000 - 180,000 acre feet of water diverted per year, although if used to their fullest extent, perfected water rights would allow approximately 360,000 acre feet diverted per year (DNR, 2000).

As in FT, our analysis of the GSL ecosystem occurs at the micro level – individual organism behavior drives ecosystem behavior. The analysis exploits three themes fundamental to economics – rational behavior, efficiency, and equilibrium. Simultaneous solutions for equilibrium "energy prices" and biomass quantities evolve in "energy markets" as a result of the predator-prey interactions between representative "demanders" for and "suppliers" of biomass. Representative organisms are assumed to maximize their energy flow subject to limiting resources, respiration requirements, predator-prey relationships, etc. Maximization yields the organism biomass demands for and supplies to other organisms in the food web. In a general equilibrium, demands and supplies are equal at the species' level. In an economic system, long-run general equilibrium is obtained through entry and exit of firms as they respond to changes in profits. Analogously, long-run general equilibrium is obtained in the ecosystem when species populations are adjusted upward (downward) in response to positive (negative) surplus net energies at the species level. To facilitate our discussion of the GSL food web, we assign numbers to each species included in Figure 2 (including the sun) according to Table 1.

[INSERT TABLE 1 HERE]

As mentioned above, each representative organism of a given species i ($i = 1,...,6,\ i \neq 3$) is a net-energy maximizer, where net energy is defined as the difference between energy inflows and outflows. Consider, for example, an adult brine shrimp's net-energy maximization problem,

$$\underset{\{x_{21}\}}{Max}\ R_2 = [e_1 - e_{21}]x_{21} - e_2\left[[1+t_{25}e_{52}]y_{25}(x_{21}) + [1+t_{26}e_{62}]y_{26}(x_{21})\right] - f_2(x_{21}) - \beta_2, \quad (1)$$

where R_2 is a brine shrimp's net energy measured in power units (e.g., watts or kilocalories) per unit of time, constant e_i is the energy embodied in a unit of species i's biomass (kilocalories/kilogram), and variable e_{ji} is the energy (kilocalories/kilogram) that a member of species j must expend to locate, capture, and handle a unit of species i's biomass (i.e., it is the given energy price species j "pays" for preying on a unit of species i's biomass, $j > i$). For example, e_{21} is the energy a shrimp expends in preying on a unit of algae, e_{52} is the energy a waterbird expends in preying on a biomass unit of shrimp, etc. Within the ecosystem energy prices are endogenous, determined by demand and supply interactions explained below.

Variable x_{21} is the biomass (in kilograms/time) transferred to, or demanded by, a shrimp from algae and variable y_{ij} is the biomass transferred from, or supplied by, a member of species i to the population of species j. For example, y_{25} is the biomass supplied by a shrimp to the waterbird population and y_{26} is the biomass supplied by a shrimp to corixid bugs. Note that y_{25} and y_{26} are strictly increasing, concave functions of x_{21}, implying that as a brine shrimp demands more algae biomass it in turn supplies more of its biomass to its predators.

Variable f_2 represents the respiratory energy expended by a shrimp in reproduction, defecation, defense of territory, etc. Since f_2 depends on energy intake, it too is a strictly increasing, concave function of x_{21}. On the other hand, β_2 is a shrimp's constant rate of basal metabolism, which is independent of energy intake. Finally, constant t_{ij} is a "tax rate" on each member of species i to account for the energy it expends to avoid being captured by members of species j, e.g., t_{25} is a shrimp's tax rate for avoiding waterbirds and t_{26} is its tax rate for avoiding corixid bugs. In the case of brine shrimp, this energy disbursement would be due to schooling effort, etc. Note that the total tax paid by a member of species i is assumed to increase in the effort expended by members of species j to capture it. For example, as waterbirds expend more effort to capture a given supply of shrimp the per-unit energy price of shrimp (e_{52}) increases, thus increasing the tax paid by any given shrimp (in terms of a greater amount of energy that the shrimp expends avoiding capture).

To summarize equation (1), the first term ($\left[e_1 - e_{21}\right]x_{21}$) represents a shrimp's energy intake, while the sum of the last three terms ($e_2\left[\left[1+t_{25}e_{52}\right]y_{25}\left(x_{21}\right)+\left[1+t_{26}e_{62}\right]y_{26}\left(x_{21}\right)\right]$, $f_2\left(x_{21}\right)$, and β_2) represent energy outflow. The *R* functions for each representative species are similarly described in Table 2. Note that for algae we assume the salinity and nitrogen balances (represented by the cumulative variable S_a and measured as a deviation from the steady-state level) directly affects variable respiration f_1. This seems to reflect general findings in Wurtsbaugh and Berry (1990), Rushforth and Felix (1982), Stephens and Gillespie (1976), and Van Auken and McNulty (1973).

[INSERT TABLE 2 HERE]

In solving its net-energy maximization problem (as in equation (1)), each organism sets the marginal energy received from preying on a lower species equal to the sum of (a) the marginal energy lost from being preyed upon by a higher species and (b) marginal respiration. The resulting first-order conditions can be solved for the vector of six equilibrium demands $\boldsymbol{x_{ji}}$, where each x_{ji} is a function of *inter alia* the entire vector of energy prices $\boldsymbol{e_{ji}}$. These demand expressions may then be substituted into their corresponding y_{ij} supply functions to obtain a vector of traditional supplies as functions of $\boldsymbol{e_{ji}}$.

A short-run equilibrium (within a reproductive period) emerges satisfying two properties. First, aggregate demand and supply are equated in each of six biomass markets (i.e., between each predator-prey pair), resulting in species biomass levels that are consistent with their corresponding market-clearing energy prices. For example, in the brine shrimp-algae biomass market the market-equilibrium condition is expressed as $N_2x_{21} = N_1y_{12}$, where N_1 and N_2 represent algae and brine shrimp population levels, respectively. In this case, N_2x_{21} represents brine shrimp aggregate demand for algae biomass and N_1y_{12} represents algae aggregate supply of biomass to brine shrimp. The resulting algae biomass level consumed by brine shrimp is consistent with the equilibrium energy price e_{21}. Second, each species population is constant. A representative organism and its species may have nonzero net energy at its maximum, however a nonzero net energy leads to population changes in the long run (across reproductive periods). Positive(negative) net energy implies greater(lesser) fitness, thus inducing a population increase(decrease). Populations adjust toward a long-run equilibrium in which all individuals have zero net energy and the short-run equilibrium conditions hold (analogous to a competitive economy where the number of firms in an industry changes in accordance with positive or negative profits).

The bioeconomic model ultimately captures this population adjustment through an equation relating next period's population to this period's population of species i. To begin, consider how population changes for a top predator such as waterbirds. In the steady state it must be the case that births equal deaths. If s_5 is the lifespan of a representative waterbird, then the total number of waterbird births and deaths must be N_5/s_5, with per-capita steady-state birth and death rates of $1/s_5$. Letting the representative waterbird's maximized net energy be given by $R_5(x_{52}, x_{54}; \boldsymbol{N^t}) = R_5^*$, where (a) x_{52} and x_{54} are optimum biomass demands as functions of equilibrium energy prices e_{52} and e_{54} and (b) $\boldsymbol{N^t}$ is a vector of all species' populations, it must be the case that $R_5^* = 0$ in the steady state.

Reproduction requires energy, which is subsumed in the functional form of f_5. Let v_5^{ss} be a waterbird's steady-state variable respiration and $\rho_5 v_5^{ss}$ be the proportion of this variable respiration devoted to reproduction. Thus, in a steady state the energy given by $\rho_5 v_5^{ss}$ over all members of the waterbird species yields the number of births that exactly offset deaths, i.e., *Births* = *Deaths* □ $N_5^t\left[\rho_5 v_5^{ss}\right] = N_5^t / s_5$, where $\rho_5 = 1/\left[v_5^{ss} s_5\right]$ converts reproductive energy into individuals. If the waterbird species is not in the steady state, then $R_5^* \neq 0$ and an individual's variable respiration is v_5. Assuming that the proportion of R_5^* available for reproduction is the same as that from v_5, the total energy now available for reproduction is $\rho_5\left[R_5^* + v_5\right]$. Further assuming that reproduction is linear in available energy, it follows from $N_5^t\left[\rho_5 v_5^{ss}\right] = N_5^t / s_5$ that $\rho_5\left[R_5^* + v_5\right]$ yields a per-capita birth rate of $\left[R_5^* + v_5\right]/\left[s_5 v_5^{ss}\right]$. Finally, assuming that the death rate is independent of energy available for reproduction, the waterbird population adjustment equation may be written as,

$$N_5^{t+1} = N_5^t + \frac{N_5^t}{s_5}\left[\frac{R_5^* + v_5}{v_5^{ss}} - 1\right]. \tag{2}$$

Note that (2) reduces to $N_5^{t+1} = N_5^t$ in the steady state and that $R_5^* > (<) 0$ is sufficient for the waterbird population to increase(decrease), i.e., $N_5^{t+1} > (<) N_5^t$, when $v_5 > (<) v_5^{ss}$. Further, because biomass demands depend on the period-*t* populations of each species, the population adjustment for species *i* indirectly depends on the populations of all other species.

If the species is not a top predator and is prey for another species, then in the steady state births equal the sum of deaths and individuals lost to predation. Using brine flies as an example, recall that each individual fly loses $y_{45}(x_{41})$ in biomass per period to waterbirds. The summation of all individual losses to predation yields total brine-fly biomass lost to predation, and total biomass divided by an individual brine fly's weight, w_4, in turn yields the number of individuals lost to predation, i.e., $N_4^t y_{45}\left(x_{41}\right)/w_4$. Therefore, the steady-state number of births (from respiration energy) equals the sum of deaths from predation and natural mortality net of losses to predation,

i.e., $N_4^t \rho_4 v_4^{ss} = N_4^t \left[\left[y_{45}\left(x_{41}^{ss}\right)/w_4\right]\left[1-1/s_4\right]+1/s_4\right]$, resulting in

$\rho_4 = \dfrac{\left[\left[y_{45}\left(x_{41}^{ss}\right)/w_4\right]\left[1-1/s_4\right]+1/s_4\right]}{v_4^{ss}}$. Again, assuming that equal proportions of R_4^* and f_4 are available for reproduction, the non-steady-state population-update equation for brine flies becomes,

$$N_4^{t+1} = N_4^t\left[1+\left[\frac{\left[\left[y_{45}\left(x_{41}^{ss}\right)/w_4\right]\left[1-1/s_4\right]+1/s_4\right]}{v_4^{ss}}\right]\left[R_4^*+v_4\right]-\left[\left[y_{45}\left(x_{41}^{ss}\right)/w_4\right]\left[1-1/s_4\right]+1/s_4\right]\right],$$

(3)

where in the steady state (3) reduces to $N_4^{t+1} = N_4^t$. The population-updating equations for each representative species are provided in Table 3.

[INSERT TABLE 3 HERE]

The brine-shrimp and cyst population-updating equations require further discussion. The cyst population in period $t+1$, i.e., N_3^{t+1}, equals period-t brine-shrimp births (the first term) net of the period-t cyst harvest, H_3^t (discussed further in Section 3). This updating equation abstracts from two facets of brine-shrimp and cyst population dynamics. First, two to three generations of brine shrimp are typically reproduced by ovoviviparity in a single season (from spring to mid-summer) prior to the reproduction of a single generation of cysts by oviparity at the end of the season (late summer to late fall). We have avoided modeling the process of ovoviviparity reproduction, as this would unnecessarily complicate the model. Second, a fraction of un-harvested cysts do not survive the winter to hatch into next season's first generation of brine shrimp due *inter alia* to being washed up on shore and desiccating. However, scant empirical information about the over-wintering process is presently available, thus precluding us from explicitly accounting for over-wintering survivability in our cyst population-updating equation. With respect to the brine-shrimp population-updating equation, we assume that period *t+1*'s population, i.e., N_2^{t+1}, is the sum of N_3^{t+1} and the brine-shrimp steady-state population, N_2^{ss}. This is an 'accounting convention' that maintains a consistency between our estimate of the steady-state population and subsequent populations that arise in future periods through model simulation.

3. The GSL Regional Economy

Our CGE model of the GSL regional economy closely follows FT. The FT approach is "myopically dynamic" in that it consists of a sequence of static optimizations resulting in a dynamic equilibrium where the sequences are linked through the evolution of factor stocks and household saving. Households are intertemporal utility-maximizers making savings decisions (for the purpose of future consumption) based on myopic expectations about future prices. Current consumption is over regionally produced goods and imports of a composite good (discussed below), given prices. The savings process consists of households instantaneously purchasing investment goods with their savings to augment their capital endowments for future periods. Balanced growth is assumed to occur when the capital stock and labor force grow at the same rate. Finally, incomes are endogenously derived from (a) the sale/rental to firms of the household's (homogeneous and perfectly mobile) labor, land, and capital endowments (the latter being partially determined by savings) and (b) government revenue obtained through the sale of water rights to the mineral-extraction and agricultural industries and certificates of registration (COR's) to the brine shrimp industry (discussed below). The resulting household product demands and factor supplies satisfy the neoclassical tenants of non-negativity, continuity, and dependence solely on relative prices.

Production in the regional economy occurs at a high level of aggregation in five (single-product) production sectors: the brine-shrimp fishery, recreation/wildlife-viewing, a composite good, and the mineral-extraction and agricultural sectors. Individual firms, for simplicity aggregated at the industry level, are myopic, static profit maximizers operating under constant returns-to-scale and given prices. They purchase labor and capital from households to produce differentiated output that is allocated between domestic and export markets given endogenous domestic and export prices and Armington (1969) imperfect-substitution possibilities between the two markets. In addition to labor and capital, agricultural and mineral-extraction firms purchase water allocations determined by the DNR, agricultural firms also purchase land from households, and cyst-harvesting firms purchase certificates of registration (i.e., quotas) from the DNR. Although each sector engages in production for both domestic and export markets, only the composite-good sector is assumed to compete with an imperfectly substitutable import, which is resold to the households. Similar to the households, firms' factor demands and output supplies satisfy the neoclassical tenants of equality between output prices and unit costs and between given factor prices and marginal value products.

The economic system is in general equilibrium when all individuals of all sectors optimize, there exists a set of prices and output levels consistent with zero profits for all firms, and all markets clear. Given the set of market-clearing prices, consumer expenditure exhausts current disposable income to maintain Walras Law, and trade balances in the current account. The final requirement of the static single-period economic model is that it replicates an assumed equilibrium benchmark dataset through model parameterization known as calibration. When the parameterized model is run with the benchmark dataset a general equilibrium for the economy is obtained. The benchmark dataset is presented in the technical appendix.

3.1 The Brine-Shrimp Fishery

The brine-shrimp fishery is modeled as a single, vertically-integrated industry, assumed to encapsulate cyst harvesting, processing, and marketing. As the fishery is heavily regulated by the DNR, we derive a "regulated open-access equilibrium" following FT. The regulatory instrument is total allowable catch (*TAC*). Given its *TAC*, the fishery makes a three-tiered decision each period concerning (a) the amounts of labor, L_f, and capital, K_f, to demand from the household sector in order to harvest cysts at level Q_f, (b) the proportion of Q_f that is exported, and (c) the amount of investment (I_f) to "supply" to the domestic household sector. We assume a Cobb-Douglas production function for Q_f according to,

$$Q_f = d_f L_f^{a_f} K_f^{b_f} N_3^{c_f} \tag{4}$$

where parameters a_f, b_f, and c_f are each less than one and $a_f + b_f + c_f = 1$, d_f is a Hicks-neutral technology parameter, and N_3 is the cyst population as defined above. Given economy-wide wage (w) and rental (r), rates, the cost-minimizing ratio of L_f and K_f is therefore obtained from,

$$\frac{w}{r} = \frac{a_f K_f}{b_f L_f}. \tag{5}$$

The fishery also abides by the following conditions,

$$Q_f = TAC(N_3) = q_f^d\left(p_f^d, p_f^e\right) + q_f^e\left(p_f^d, p_f^e\right) \tag{6a}$$

$$I_f = a_f^I Q_f \tag{6b}$$

$$P_f Q_f = wL_f + rK_f + COR \tag{6c}$$

where a_f^I is a (given) proportionality factor equal to the ratio of the steady-state levels of I_f and domestic quantity of cysts supplied (q_f^d), q_f^e is quantity of cysts exported, p_f^d and p_f^e are the respective per-unit prices of q_f^d and q_f^e, P_f is the composite price of p_f^d and p_f^e, and COR is the fixed certificate-of-registration cost. Equation (6a) states that the cyst harvest (a) equals the total allowable catch for each period, which is ultimately a function of the cyst population in that period, and (b) is divided between the domestic and export markets. This division of Q_f between q_f^d and q_f^e is determined by a (constrained) revenue maximization problem based on the Armington (1969) assumption of imperfect substitutability, which, similar to (5), defines the optimal ratio of q_f^d and q_f^e as a ratio of p_f^d and p_f^e. Equation (6b) states that the effective proportion of the industry "supplied" to households in the form of investment (which in turn adds to the value of the household-sector's capital endowment) is a constant proportion of Q_f, and (6c) is a zero-profit condition.

3.2 The Mineral-Extraction Sector

Similar to the brine-shrimp fishery, we assume a Cobb-Douglas production function for the total quantity of minerals extracted, Q_m , according to,

$$Q_m = d_m L_m^{a_m} K_m^{b_m} W_m^{c_m} , \tag{7}$$

where parameters a_m, b_m, c_m , and d_m and variables L_m and K_m are defined analogously to the brine-shrimp fishery's, the optimal ratio of L_m and K_m is determined analogously to (5), and W_m is a fixed water allocation determined by the DNR. The mineral-extraction sector likewise abides by equations analogous to (6a) – (6c), obviously without a regulatory limit such as the TAC in (6a) and with $P_W W_m$ replacing COR in (6c), where the per-unit price of water P_W is set equal to zero.

3.3 The Agricultural Sector

Similar to the mineral-extraction sector, we assume a Cobb-Douglas production function for the total quantity of agricultural goods produced, Q_a , according to,

$$Q_a = d_a L_a^{a_a} K_a^{b_a} W_a^{c_a} T_a^{g_a} , \tag{8}$$

where parameters a_a, b_a, c_a , and d_a and variables L_a, K_a, and W_a are defined analogously to the mineral-extraction industry's. The variable T_a is the amount of land devoted to agricultural production, with parameter $g_a > 0$ such that $a_a + b_a + c_a + g_a = 1$. Because T_a is effectively a choice variable of the industry, the optimal ratios of L_a, K_a, and T_a require the simultaneous solution of two conditions – one analogous to (5) and the other,

$$\frac{P_T}{r} = \frac{g_a K_a}{b_a T_a} \tag{9}$$

where P_T is the per-unit price of land.

The agricultural sector likewise abides by equations analogous to (6a) – (6c), again without a regulatory limit such as *TAC* in (6a) and with $P_W W_a$ replacing *COR* in (6c), where again the per-unit price of water P_W is set equal to zero. Also, the total cost of land, i.e., $P_T T_a$, is included on the right-hand side of analogous (6c).

3.4 The Recreation/Wildlife-Viewing Sector

Similar to the previous sectors, we assume a Cobb-Douglas production function for the total quantity of recreation and wildlife viewing, Q_R, according to,

$$Q_R = d_R L_R^{a_R} K_R^{b_R} N_5^{c_R}\ , \tag{10}$$

where parameters a_R, b_R, c_R, and d_R and variables L_R and K_R, are defined analogously to the brine-shrimp fishery's. An analogous equation (5) determines the cost-minimizing ratio of L_R and K_R, and analogous equations (6a) – (6c), obviously without a regulatory limit such as *TAC* in (6a) and without a fixed cost such as *COR* in (6c), are also satisfied.

3.5 The Composite-Good Sector

The composite-good sector is modeled slightly differently from the previous sectors, due in part to the role of imports in this sector. Following FT, we assume that importation of the composite good is the residual difference between what domestic households demand overall and what is produced by the domestic composite-good sector. Thus, the domestic composite-good sector effectively imports the foreign-produced composite-good for re-sale to households at zero cost and mark-up. Similar to the other sectors, the composite-good sector abides by conditions analogous to (6a) for determining the proportions of domestic production allocated to the domestic and export markets, (6b) for determining the proportion of domestic production supplied to households in the form of investment, and (6c) for zero profits.

We assume a constant-elasticity-of-substitution (CES) cost function to ultimately determine the total quantity of the domestically produced composite good, Q_C, according to,

$$TC_c = \frac{Q_C}{\phi_C}\left[\delta_C w^{(1-\sigma_C)} + \left[1-\delta_C\right] r^{(1-\sigma_C)}\right]^{\frac{1}{(1-\sigma_C)}} \tag{11}$$

where TC_C is total cost of production, ϕ_C is an efficiency parameter, $0 < \delta_C < 1$ is a distribution parameter, and σ_C is the partial elasticity of substitution. Application of Shepard's Lemma to (11) results in the sector factor demand functions for labor (L_C) and capital (K_C) , respectively,

$$L_C = \left(\frac{Q_C}{\phi_C}\right)^{(1-\sigma_C)}\left[TC_C\left[\frac{\delta_C}{w}\right]\right]^{\sigma_C} \tag{12a}$$

$$K_C = \left(\frac{Q_C}{\phi_C}\right)^{(1-\sigma_C)} \left[TC_C \left[\frac{(1-\delta_C)}{r} \right] \right]^{\sigma_C} .$$

(12b)

Rather than derive Q_C from the (dual) production function associated with (11), we obtain its value directly from the household sector's utility-maximization problem, to which we now turn.

3.6 The Household Sector

The household sector consumes goods from the five producing sectors and saves for future consumption. Following FT, the sector derives gross income (Y) from the sale/rental of its current labor and capital endowment (described further in Section 3.7). Given Y, household behavior is modeled according to a tri-level nesting structure. In the top nest, an allocation is made between composite consumption today (C_T) and composite future consumption (C_F) given composite prices P_{C_T} and P_{C_F}, respectively. In terms of household inter-temporal behavior, C_F is funded through the stock of household savings (S), costing, or valued at, P_S per unit. Savings decisions are based on expected increments to a stream of consumption in future periods (e.g., C_1, C_2, ….), with C_F being a composite measure. Consumer expectations of future consumption are assumed to be myopic, in that current prices, P_{C_T}, are expected to remain constant in all future periods, i.e., from the household's standpoint $P_{C_T} = P_{C_F}$ in each period. $P_S S$ is used to purchase investment goods I (e.g., I_f in (6b) from the brine-shrimp fishery), which add to the stock of household capital to be used for future consumption.

The transformation of household savings into capital services is governed by the identity $P_S S = r\gamma S$, where γ is the initial real rate of return associated with the benchmark value of r (i.e., the proportion of savings translated into capital services in future periods). Household income derived from capital services (i.e., $r\gamma S$) in turn allows future consumption according to the identity $P_{C_T} C_F = r\gamma S$. Manipulation of this expression equates the value of savings to the present value of expected future consumption, i.e.,

$$P_S S = \frac{P_S P_{C_T}}{r\gamma} C_F. \tag{13}$$

Therefore, the household's top-nest utility-maximization problem in any given period is,

$$\underset{\{C_T, C_F, S\}}{Max} \; U_{TN} = \left[\alpha_{TN}^{\left(\frac{1}{\sigma_{TN}}\right)} C_T^{\left(\frac{(\sigma_{TN}-1)}{\sigma_{TN}}\right)} + \left[1-\alpha_{TN}\right]^{\left(\frac{1}{\sigma_{TN}}\right)} C_F^{\left(\frac{(\sigma_{TN}-1)}{\sigma_{TN}}\right)} \right]^{\left(\frac{\sigma_{TN}}{(\sigma_{TN}-1)}\right)} \tag{14}$$

subject to,

$$Y = P_{C_T} C_T + \frac{P_S P_{C_T}}{r\gamma} C_F \tag{15a}$$

$$P_{C_T} = \left[\left[1-\beta_{TN}\right] \overline{P}^{(1-\upsilon_{TN})} + \beta_{TN} P_R^{(1-\upsilon_{TN})} \right]^{\left(\frac{1}{(1-\upsilon_{TN})}\right)} \tag{15b}$$

where $0 < \alpha_{TN} < 1$ and $0 < \beta_{TN} < 1$ are distribution parameters; σ_{TN} and ν_{TN} are partial elasticities of substitution; $\overline{P}$ is a per-unit composite price of the mineral-extraction, agricultural, and composite goods; and P_R is the per-unit price of the recreation/wildlife-viewing good. Equation (14) indicates that utility in the top nest is determined by a CES function defined over current and future composite consumption. Equation (15a) is the household budget constraint and (15b) indicates that P_{C_T} is a CES weighted average of (a) a composite price of the mineral-extraction, agricultural, and composite goods and (b) the price of the recreation/wildlife-viewing good.

From this problem, the first-order optimality condition is obtained for the stock of household savings,

$$S = \frac{\left[1-\alpha_{TN}\right]Y}{\left(P_S^{\sigma_{TN}}\left[\frac{P_{C_T}}{r\gamma}\right]^{(\sigma_{TN}-1)}\left[\alpha_{TN}P_{C_T}^{(1-\sigma_{TN})}+\left[1-\alpha_{TN}\right]\left[\frac{P_S P_{C_T}}{r\gamma}\right]^{(1-\sigma_{TN})}\right]\right)} \tag{16}$$

In the second nest, income for current consumption (C_T) is divided between expenditures on recreation (X_R) at price P_R and the composite consumption commodity ($\bar{X}$) that encompasses the mineral-extraction, agricultural, and composite goods at price $\bar{P}$. Similar to its top next problem, the household sector's second-nest utility-maximization problem is,

$$\underset{\{X_R,\bar{X}\}}{Max} \quad U_{SN} = \left[\alpha_{SN}^{\left(\frac{1}{\sigma_{SN}}\right)} X_R^{\left(\frac{(\sigma_{SN}-1)}{\sigma_{SN}}\right)} + \left[1-\alpha_{SN}\right]^{\left(\frac{1}{\sigma_{SN}}\right)} \bar{X}^{\left(\frac{(\sigma_{SN}-1)}{\sigma_{SN}}\right)}\right]^{\left(\frac{\sigma_{SN}}{(\sigma_{SN}-1)}\right)} \tag{17}$$

subject to,

$$Y - P_s S = \bar{P}\bar{X} + P_R X_R \tag{18}$$

where $0 < \alpha_{SN} < 1$ is a distribution parameter and σ_{SN} is a partial elasticity of substitution. The respective first-order optimality conditions for the recreation/wildlife-viewing and composite consumption commodities are,

$$X_R = \frac{\left(\alpha_{SN}\left[Y - P_S S\right]\right)}{\left(P_R^{\sigma_{SN}}\left[\alpha_{SN} P_R^{(1-\sigma_{SN})} + \left[1-\alpha_{SN}\right]\bar{P}^{(1-\sigma_{SN})}\right]\right)}$$

(19a)

$$\bar{X} = \frac{\left(\left[1-\alpha_{SN}\right]\left[Y - P_S S\right]\right)}{\left(\bar{P}^{\sigma_{SN}}\left[\alpha_{SN} P_R^{(1-\sigma_{SN})} + \left[1-\alpha_{SN}\right]\bar{P}^{(1-\sigma_{SN})}\right]\right)}.$$

(19b)

Finally, in the third nest income is divided between expenditures on the mineral-extraction (X_m), agricultural (X_a), and composite (X_c) goods at prices P_m, P_a, and P_c, respectively. Following Ballard, et al. (1985), the household sector's third-nest subutility-maximization problem is,

$$\underset{\{X_m, X_a, X_c\}}{Max} \quad \bar{X} = X_m^{\lambda_m} X_a^{\lambda_a} X_c^{\lambda_c}$$

(20)

subject to,

$$Y - P_S S - P_R X_R = P_m X_m + P_a X_a + P_c X_c$$

(21)

where λ_i, $i = m,a,c$ are the Cobb-Douglas expenditure shares. The respective first-order optimality conditions for this problem are,

$$X_i = \frac{\lambda_i\left[Y - P_S S - P_R X_R\right]}{P_i}, \quad i = m,a,c.$$

(22)

Combining equations (20) - (22) results in the following definition of $\overline{P}$,

$$\overline{P} = \prod_i \left(\frac{p_i}{\lambda_i} \right)^{\lambda_i}, \quad i = m, a, c \,.$$

(23)

As Ballard, et al. (1985) point out, an especially convenient property of this kind of Cobb-Douglas price index is that the composite price can be calculated without knowing X_i, $i = m,a,c$, thus simplifying our calculations considerably.

3.7 The Market-Clearing and Endowment-Updating Equations

We begin this section by defining the composite price indices for each of the production sectors, reflecting the fact that the indices are weighted averages of domestic and foreign prices. In the composite-good sector, the domestic price faced by households (P_c) is,

$$P_c = \frac{\left(p_c^d q_c^d + p_c^{IM} q_c^{IM} \right)}{\left(q_c^d + q_c^{IM} \right)}$$

(24)

where p_c^d and p_c^{IM} are the domestically determined and exogenous import prices, respectively, and q_c^d and q_c^{IM} are corresponding quantities. As shown in FT, the prices p_c^d and p_c^{IM} are taken by the household sector in a CES cost-minimization problem which determines its optimal mix of the domestically produced and imported composite goods according to,

$$\frac{q_c^d}{q_c^{IM}} = \left(\left[\frac{p_c^{IM}}{p_c^d} \right] \left[\frac{1-\delta^c}{\delta^c} \right] \right)^{\sigma^c}$$

(25)

where δ^c is a distributional share parameter in a CES transformation function and σ^c is an associated elasticity of transformation between domestically produced and imported composite goods.

The domestic prices faced by each production sector (and, except for the composite good, by the household sector) are,

$$P_i = \frac{\left(p_i^d q_i^d + p_i^e q_i^e\right)}{Q_i}, \ i = f, m, a, R$$

(26a)

$$P_c^{'} = \frac{\left(p_c^d q_c^d + p_c^e q_c^e\right)}{Q_c}.$$

(26b)

where, again, $Q_i = q_i^d + q_i^e$, $i = f, m, a, R, c$ and the remaining variables were defined previously in this section. The domestic market-clearing conditions are,

$$q_i^d = I_i + X_i, \ i = f, m, a, R, c.,$$

(27)

which are used to determine X_i, $i = f, m, a, R, c$.

In terms of the household sector's income balance, the following condition holds by definition,

$$Y = w\sum_i L_i + r\sum_i K_i + P_T T_a + P_W \sum_j W_j + COR, \ \ i = f, m, a, R, c, \ \ j = m, a.$$

(28)

and with respect to the economy's balance of payments we have the identity,

$$P_S S - \sum_i p_i^d I_i = p_c^{IM} q_c^{IM} - \sum_i p_i^e q_i^e, \ \ i = f, m, a, R, c,$$

(29)

where the left-hand side represents the savings-investment balance and the right-hand side represents the current-account balance.

Finally, household endowments of capital, labor, land, and water are updated per period according to the following series of equations,

$$\sum_i K_i^{t+1} = \sum_i K_i^t + \gamma S^t, \quad i = f, m, a, R, c \tag{30a}$$

$$\sum_i L_i^{t+1} = (1+n) \sum_i L_i^t, \quad i = f, m, a, R, c \tag{30b}$$

$$\sum_j W_j^{t+1} = \sum_j W_j^t, \quad j = m, a \tag{30c}$$

$$T_a^{t+1} = T_a^t. \tag{30d}$$

Equation (30a) states that the capital endowment in period *t+1* equals the capital endowment in period *t* plus the (real) growth in period *t*'s "stock" of savings, where again γ represents the proportion of savings translated into capital services. Equation (30b) states that the labor endowment in period *t+1* equals the labor endowment in period *t* plus the growth in labor at the rate *n*. Rate $n = \frac{\gamma S^{ss}}{\sum_i K_i^{ss}}$, *i = f, m, a, R, c*, i.e., the rate at which labor would have to grow in the steady state to ensure that the capital-labor ratio remains constant, where the superscript *ss* indicates a steady-state level.

4. Simulation Results

Our simulation results are based on initial one-time shocks to the species' steady-state population levels. Specifically, we shock the populations of algae, brine flies, and corixid bugs downward by 10% each, and simultaneously shock the populations of brine shrimp and waterbirds upward by 10% each. These arbitrary shocks are merely to demonstrate how the bioeconomic model updates these population levels, as well as the remaining ecological and economic variables, over time (for the next 100 periods). In addition to these one-time shocks, recall that the salinity level is also being "hit" with period-by-period random shocks (see the Technical Appendix for further details).

Figures 3 and 4 present the simulation results for the algae and brine cyst populations. Beginning with the algae population note that following the population shocks, algae density (the blue(pink) line without(with) random salinity shocks) returns rather smoothly to a steady state after approximately 10 periods. This steady state is significantly beneath the predicted steady state without human interventions (green line). For this exercise, ecological and economic steady states were determined in isolation from one another, although the data used to calibrate the model is drawn from a point in time where the two sub-models are obviously interacting. Thus, the distance between the green and the blue/pink lines can also be interpreted as the model's degree of error in calibrating the joint model to an overall steady state. In our future work, where we calibrate the model using more actual data, we expect this error to shrink. In the meantime, the steady state established by the blue/pink line is a better approximation to the actual joint steady state of the GSL and the regional economy.

[INSERT FIGURE 3 HERE]

A similar smooth transition to the steady state for the brine cyst population is depicted in Figure 4. Note, however, that the transition occurs more rapidly, after approximately five years. This result is driven by the fact that as the algae population falls and the brine shrimp population increases, the brine shrimp must compete for a diminished food source that now carries with it an increased energy price. The representative brine shrimp "responds" to this higher energy price by reducing the variable respiration available for reproduction and devoting more energy to searching for algae biomass. As a result, not only does the representative brine shrimp reduce its production of brine cysts, but the brine-shrimp population itself shrinks relatively quickly back to its steady-state level. These two reactions lead to a decrease in the brine cyst population, but as the brine shrimp population quickly recovers, so too does the cyst population.

[INSERT FIGURE 4 HERE]

With respect to the path of the regional economy, Figures 5 and 6 present the transition paths for the brine-shrimp fishery capital stock and household demand for recreation/wildlife-viewing. In Figure 5, the brine-shrimp fishery responds to the initial positive(negative) shock to the brine-shrimp(algae) population (which translates into an initial decrease in the cyst population) by decreasing its capital stock. This implies an initial shift of investment out of the brine-shrimp industry. However, following the recovery of the cyst population to its steady-state level, the capital stock returns to its steady-state level rather quickly. Also evidenced in Figure 5 is the slight oscillation of the capital stock around its steady-state value over time, which similarly mirrors the slight oscillations evident in the cyst and brine-shrimp populations over time as well.

[INSERT FIGURE 5 HERE]

With respect to household demand for recreation/wildlife-viewing, we note that the household sector's demand rises steadily over time from its steady-state value of $16 million per period. Two forces account for this steady increase in demand. First, the initial increase in the waterbird population provides an initial *ceteris paribus* positive shock to the household sector's utility. Given that recreation/wildlife-viewing is a normal good, this provides a *ceteris paribus* boost to household demand. Further, since it is assumed that labor supply increases at a constant rate of return (n), household-sector income increases overtime as well. This increase has a multiplier effect on income, since savings increases with income, enabling a higher level of future consumption of all commodities.

[INSERT FIGURE 6 HERE]

5. Conclusions

This paper demonstrates a new technique for modeling the "bioeconomics" of a watershed, in particular the Great Salt Lake (GSL) watershed located in north-central Utah. The bioeconomic model accounts for the basic ecological relationships and human activities that interact within the lake's watershed and enables the measurement of ecosystem externalities that might occur as a result of "shocks" within the watershed and ecosystem, thereby identifying the degree to which certain species may be threatened. Since the regional economy is premised on a household-sector utility-maximization problem, the model is ultimately capable of estimating compensating-variation welfare measures for threatened species that account for the full breadth of interdependencies that exist within the watershed.

This capability should prove useful to regulatory authorities such as the Utah Department of Natural Resources in helping its scientists and policy makers better understand the interrelationships that exist between human activity and biological interactions within the GSL watershed and how these interrelationships impact the vulnerability of any given species. Of course, in order to be truly effective in guiding public policies concerning the GSL ecosystem, the bioeconomic model will ultimately need to be linked with models of the watershed's hydrology and regional economy, particularly that of the Wasatch Front. In addition, much of the ecological data that is currently used to calibrate the model's steady state needs to be updated. These "needs" form the basis of future research avenues; avenues which will enable regional planners to better forecast the effects of economic growth on the GSL ecosystem and to weigh the benefits and costs associated with various aspects of this growth.

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Technical Appendix

We begin with the specific functional forms used for the species' biomass-supply functions appearing in Tables 2 and 3 and the variable-respiration functions appearing in Table 2. The first column in Table A1 presents the functional forms for supply functions y_{12}, y_{14}, y_{25}, y_{26}, and y_{45}, respectively, while the second column presents the variable-respiration functions f_1, f_2, f_4, f_5, and f_6. Specific values for the parameters δ_{ij}^{GSL}, α_{ij}^{GSL}, γ_i^{GSL}, r_i^{GSL}, and r_{ji}^{GSL} are provided below in Table A2.

Table A1. Species' Biomass-Supply and Variable-Respiration Functions.

$\delta_{12}^{GSL} x_{10}^{\alpha_{12}^{GSL}}$	$r_1^{GSL}\left[\left(S_a - S_a^{ss}\right)^2 + 1\right] x_{10}^{\gamma_1^{GSL}}$
$\delta_{14}^{GSL} x_{10}^{\alpha_{14}^{GSL}}$	$r_2^{GSL} x_{21}^{\gamma_2^{GSL}}$
$\delta_{25}^{GSL} x_{21}^{\alpha_{25}^{GSL}}$	$r_4^{GSL} x_{41}^{\gamma_4^{GSL}}$
$\delta_{26}^{GSL} x_{21}^{\alpha_{26}^{GSL}}$	$r_5^{GSL}\left[x_{52} + x_{54}\right] + 0.5 r_5^{GSL}\left[r_{54}^{GSL} x_{52} x_{54} + x_{52}^{\gamma_5^{GSL}} + r_{54}^{GSL} x_{54}^{\gamma_5^{GSL}}\right]$
$\delta_{45}^{GSL} x_{41}^{\alpha_{45}^{GSL}}$	$r_6^{GSL} x_{62}^{\gamma_6^{GSL}}$

The variable-respiration functions for algae and waterbirds requires further explanation. For algae, $S_a^{ss} = 1$ is the steady-state level of salinity and $S_a = s_m + s_a$ is the salinity level in any given time period, where $s_m = \frac{W_m}{W_m + W_a} + \varepsilon_m$ and $s_a = \frac{W_a}{W_m + W_a} + \varepsilon_a$ and ε_m and ε_a are independently distributed normal with means zero and standard deviations equal to 0.1. In other words, the overall salinity level as it impacts algae respiration is a sum of the salinity effects from the mineral-extraction and agricultural sectors, where the salinity effects are in turn weighted averages of the water used in the respective sectors plus independent stochastic shocks that follow mean-zero normal distributions. For waterbirds, variable respiration is a polynomial function that accounts for available prey-substitution possibilities between brine shrimp and brine flies.

Table A2 contains the parameter values and steady-state values of the model's ecological variables. The superscript * indicates that the parameter or variable value is determined as an outcome of the calibration process. As mentioned in the text, those values not determined as an outcome of the calibration process were obtained from the ecological literature cited throughout Section 2.

Table A2. Ecological Parameter and Steady-State Variable Values.

<u>Embodied Energies</u>	<u>Taxes</u>	<u>r parameters</u>*
$e_0 = 1500$	$t_{12} = 0.0000688$	$r_1^{GSL} = 3989$
$e_1 = 1300$	$t_{14} = 0.0000131$	$r_2^{GSL} = 932$
$e_2 = 1000$	$t_{45} = 0.0115926$	$r_4^{GSL} = 1018$
$e_4 = 500$	$t_{26} = 0.0004738$	$r_5^{GSL} = 186$
	$t_{25} = 0.0090030$	$r_{54}^{GSL} = 0.018$
		$r_6^{GSL} = 2399$
<u>Species Populations</u>	<u>Alpha Parameters</u>	<u>Beta Parameters</u>*
$N_1 = 409{,}139{,}538$	$\alpha_{12}^{GSL} = \alpha_{14}^{GSL} = \alpha_{25}^{GSL}$	$\beta_1 = 1.381$
$N_2 = 386{,}392$	$= \alpha_{26}^{GSL} = \alpha_{45}^{GSL} = 0.5$	$\beta_2 = 86.111$
$N_4 = 200{,}000$		$\beta_4 = 53.478$
$N_5 = 200$		$\beta_5 = 47175.134$
$N_6 = 100{,}000$		$\beta_6 = 3.460$
<u>Biomass Demands</u>	<u>Delta Parameters</u>*	<u>Species Life Spans</u>
$x_{10} = 0.007$	$\delta_{12}^{GSL} = 0.0074$	$s_1 = s_2 = s_4 = s_6 = 5$
$x_{21} = 0.656$	$\delta_{14}^{GSL} = 0.0023$	$s_5 = 15$
$x_{41} = 0.401$	$\delta_{25}^{GSL} = 0.1000$	
$x_{52} = 156$	$\delta_{26}^{GSL} = 0.0053$	
$x_{54} = 104$	$\delta_{45}^{GSL} = 0.1647$	
$x_{62} = 0.016$		
$A = N_1 x_{10}$		
<u>Biomass Energy Prices</u>	<u>Gamma Parameters</u>	<u>Species Weights</u>
$e_{10} = 0.09\, N_1^{0.4}$	$\gamma_1^{GSL} = \gamma_2^{GSL} = \gamma_4^{GSL}$	$w_1 = 0.007$
$e_{21} = 0.09 e_1$	$= \gamma_5^{GSL} = \gamma_6^{GSL} = 1.3$	$w_2 = 0.776$
$e_{41} = 0.15 e_1$		$w_4 = 0.887$
$e_{52} = 0.09 e_2$		
$e_{54} = 0.09 e_4$		
$e_{62} = 0.09 e_2$		

With respect to the regional economy, we first account for the functional forms expressed in (6a) for each production sector. Following FT, these functional forms are presented as the first-order conditions that determine sector-level exports through constrained maximization of sector-level CES revenue functions,

$$\frac{q_i^d}{q_i^e} = \left(\frac{\left[1-\delta_i\right] p_i^e}{\delta_i p_i^d} \right)^{\sigma_i} \qquad i = f, m, a, R, c\,. \tag{A1}$$

There is no corresponding first-order condition determining the importation of the composite good since it is assumed that imports are the residual of the household sector's overall demand in excess of domestic production.

We next create a per-sector aggregated social accounting matrix based on data obtained from IMPLAN, thus ensuring cross-sector account balances. Table A3 contains the parameter values and steady-state values of the model's economic variables, presented by sector. Note that all non-composite output and input prices are normalized to one in the steady state (except for $\gamma = 0.04$ and $P_W = 0$), implying that the physical quantities are also the dollar values in the steady state. The superscript * indicates that the parameter or variable value is determined as an outcome of the calibration process.

Table A3. Economic Parameter and Steady-State Variable Values.

Brine-Shrimp	Mineral Ext.	Agriculture	Composite	Recreation	Household
$q_f^d = 0.5$	$q_m^d = 5.1$	$q_a^d = 87.5$	$q_c^d = 370.9$	$q_R^d = 16$	$C_T = 456$
$q_f^e = 9.5$	$q_m^e = 94.9$	$q_a^e = 62.5$	$q_c^e = 10$	$q_R^e = 4$	$C_F = 24$
$I_f = 0.5$	$I_m = 5$	$I_a = 7.5$	$q_c^{IM} = 180.9$	$I_R = 1$	$S = 24$
$a_f^I = 0.05^*$	$a_m^I = 0.05^*$	$a_a^I = 0.05^*$	$I_c = 10$	$a_R^I = 0.05^*$	$Y = 480$
$L_f = 4.96$	$L_m = 45$	$L_a = 40$	$a_c^I = 0.05^*$	$L_R = 10$	$\beta_{TN} = \alpha_{SN} = 0.035^*$
$K_f = 4.96$	$K_m = 50$	$K_a = 40$	$L_c = 100$	$K_R = 10$	$\nu_{TN} = \sigma_{SN} = 0.867$
$a_f = b_f = 0.375^*$	$W_m = 5$	$W_a = 10$		$a_R = 0.375^*$	$\alpha_{TN} = 0.731^*$
					$\sigma_{TN} = 1.6$

$c_f = 0.25$	$a_m = 0.337^*$	$T_a = 60$	$K_c = 100$	$b_R = 0.375^*$	$\lambda_m = 0.0002^*$
$d_f = 0.121^*$	$b_m = 0.375^*$	$a_a = 0.2^*$	$\phi_c = 2^*$	$c_R = 0.25$	$\lambda_a = 0.181^*$
$\delta_f = 0.258^*$	$c_m = 0.25$	$b_a = 0.2^*$	$\delta_c = 0.5^*$	$d_R = 0.945^*$	$\lambda_c = 0.818^*$
$\sigma_f = 2.79$	$d_m = 4.268^*$	$c_a = 0.25$	$\sigma_c = 0.867^*$	$\delta_R = 0.622^*$	
$COR = 0.08$	$\delta_m = 0.26^*$	$d_a = 5.647^*$	$\delta_c = 0.785^*$	$\sigma_R = 2.79$	
$TAC = 0.0000001 N_3^{ss}$	$\sigma_m = 2.79$	$g_a = 0.3^*$	$\sigma_c = 2.79$		
		$\delta_a = 0.522^*$	$\delta^c = 0.488^*$		
		$\sigma_a = 3.9$	$\sigma^c = 2.12$		

Figure 1. Map of the Great Salt Lake.

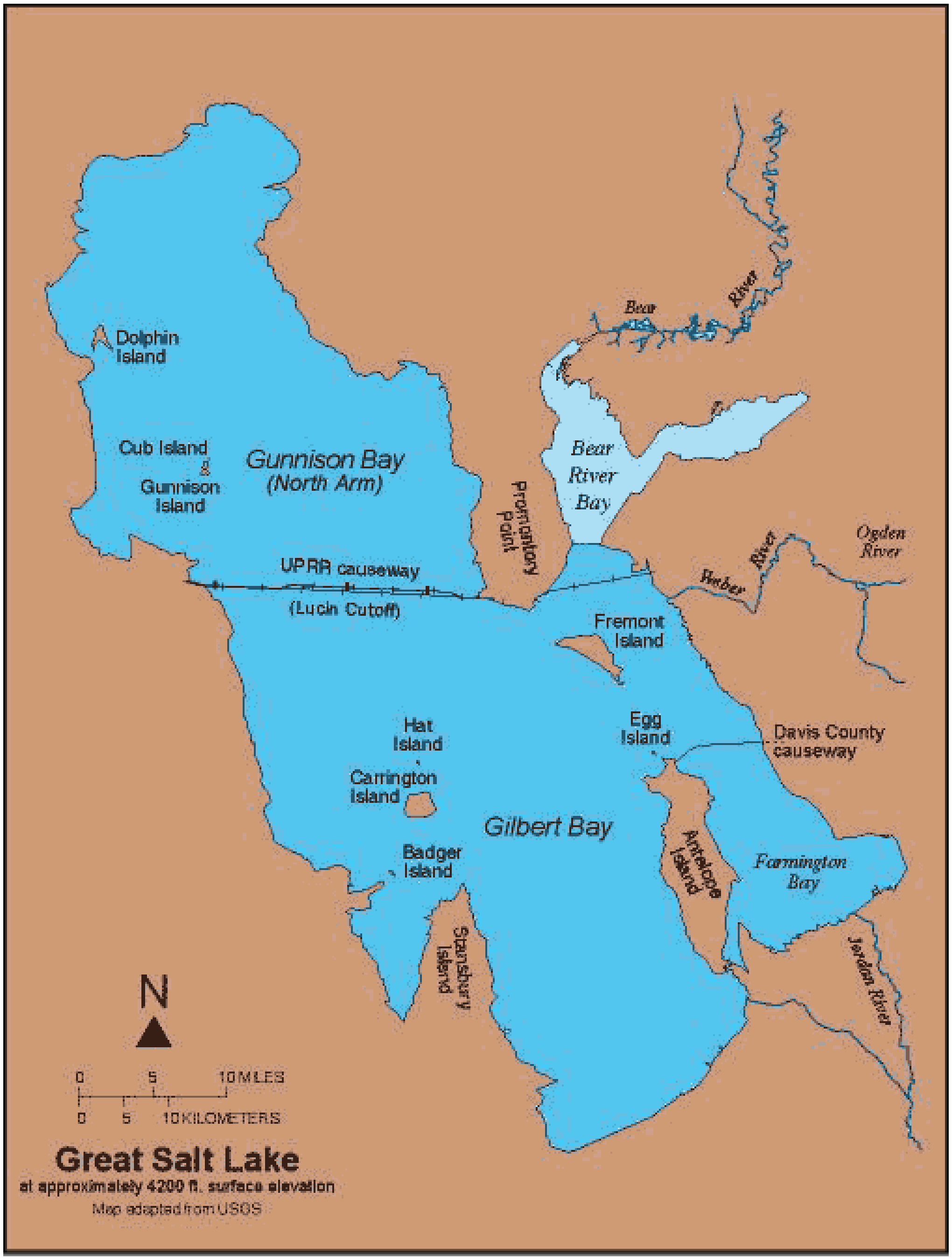

Figure 2. The Great Salt Lake Ecosystem.

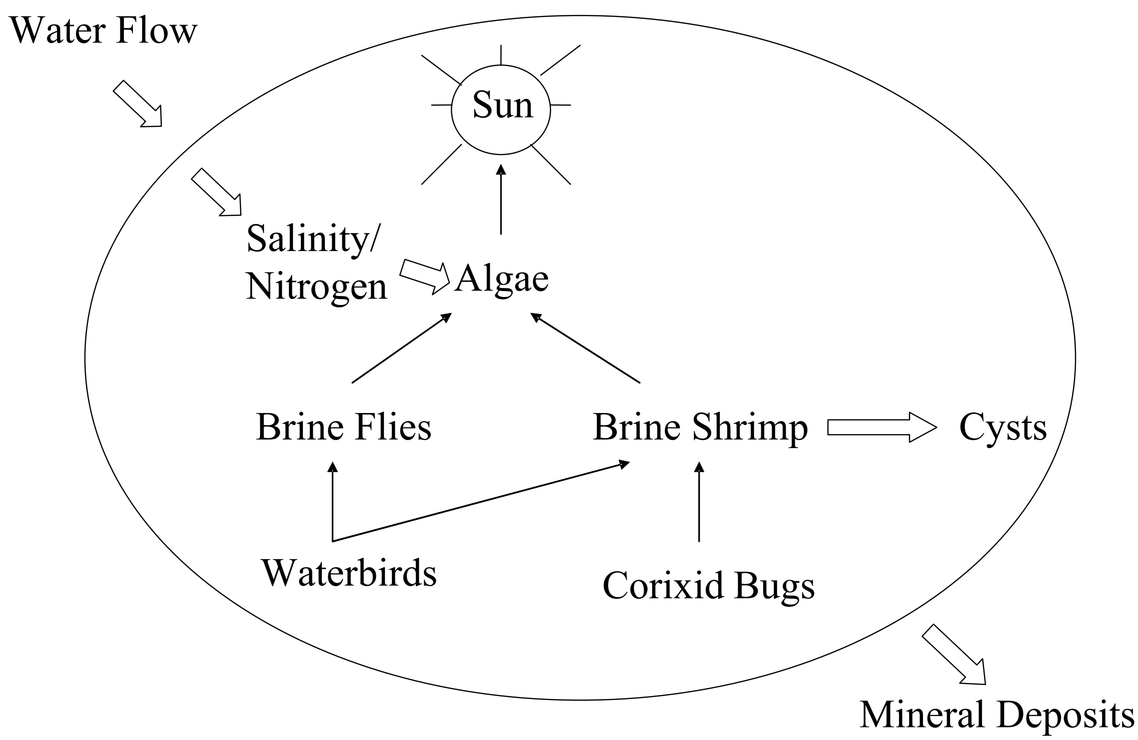

Figure 3. Algae Population Following Initial Negative Shock.

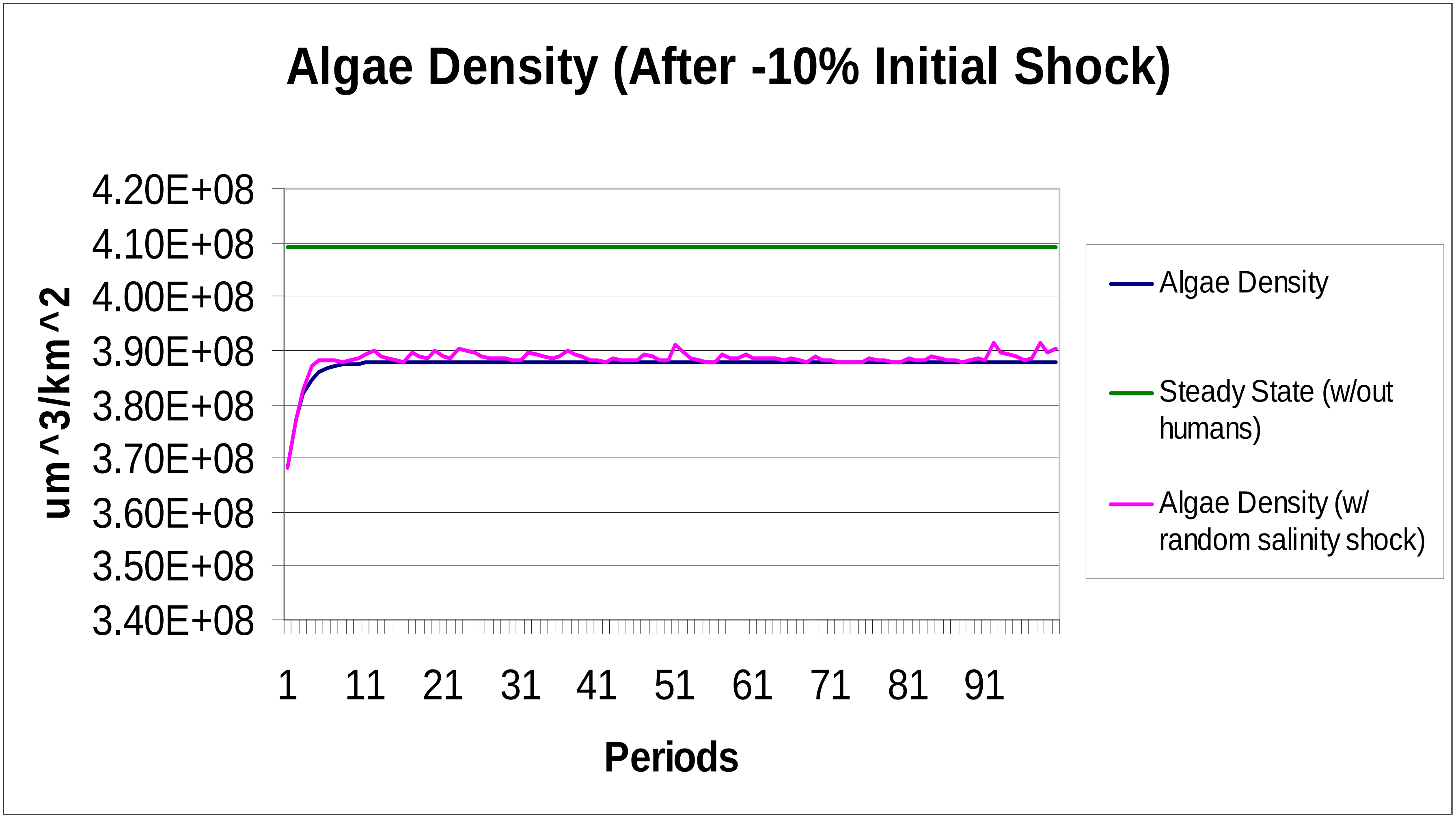

Figure 4. Brine Cyst Population Following Initial Population Shocks.

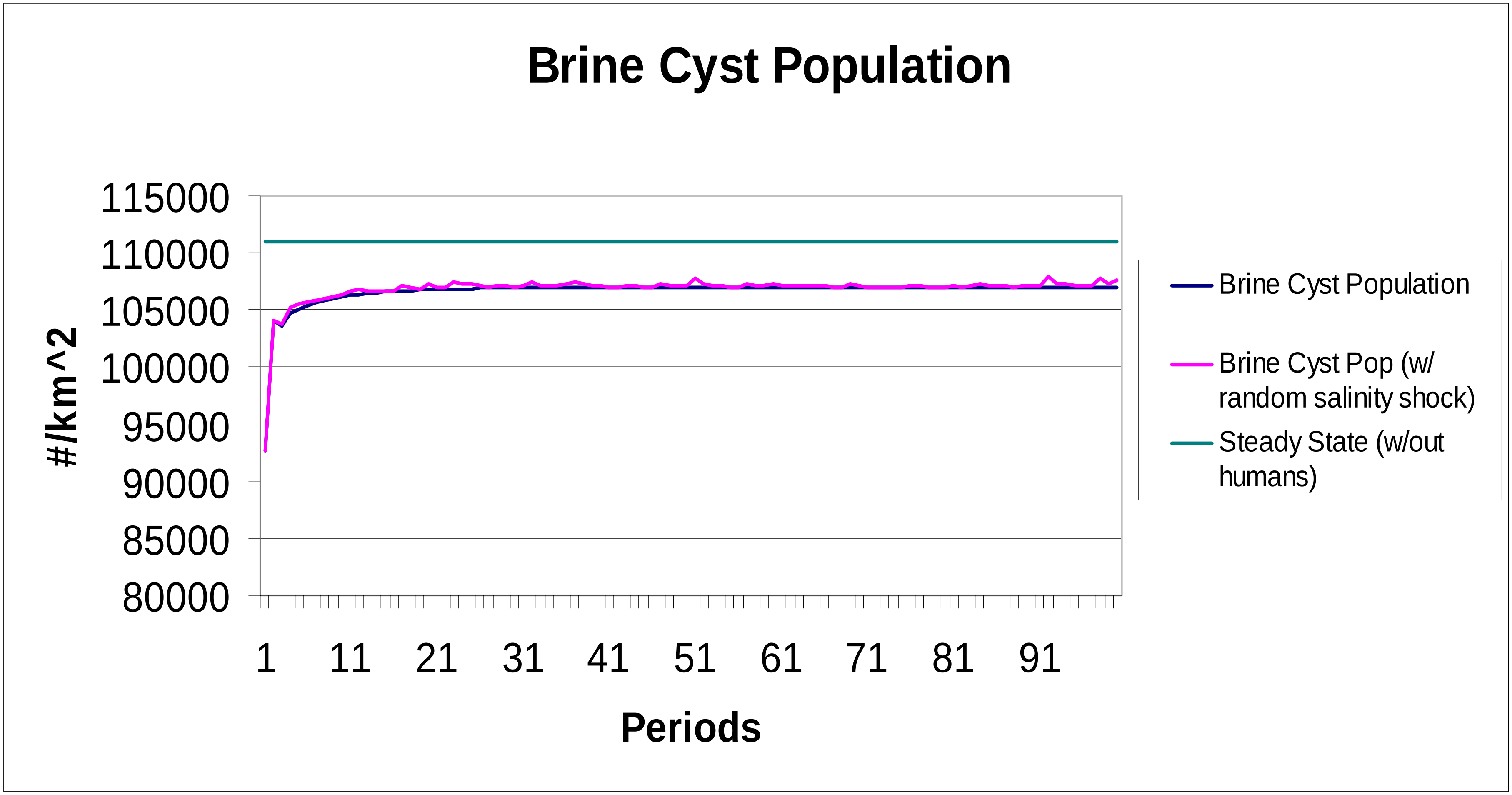

Figure 5. The Brine-Shrimp Fishery Capital Stock Following the Initial Population Shocks.

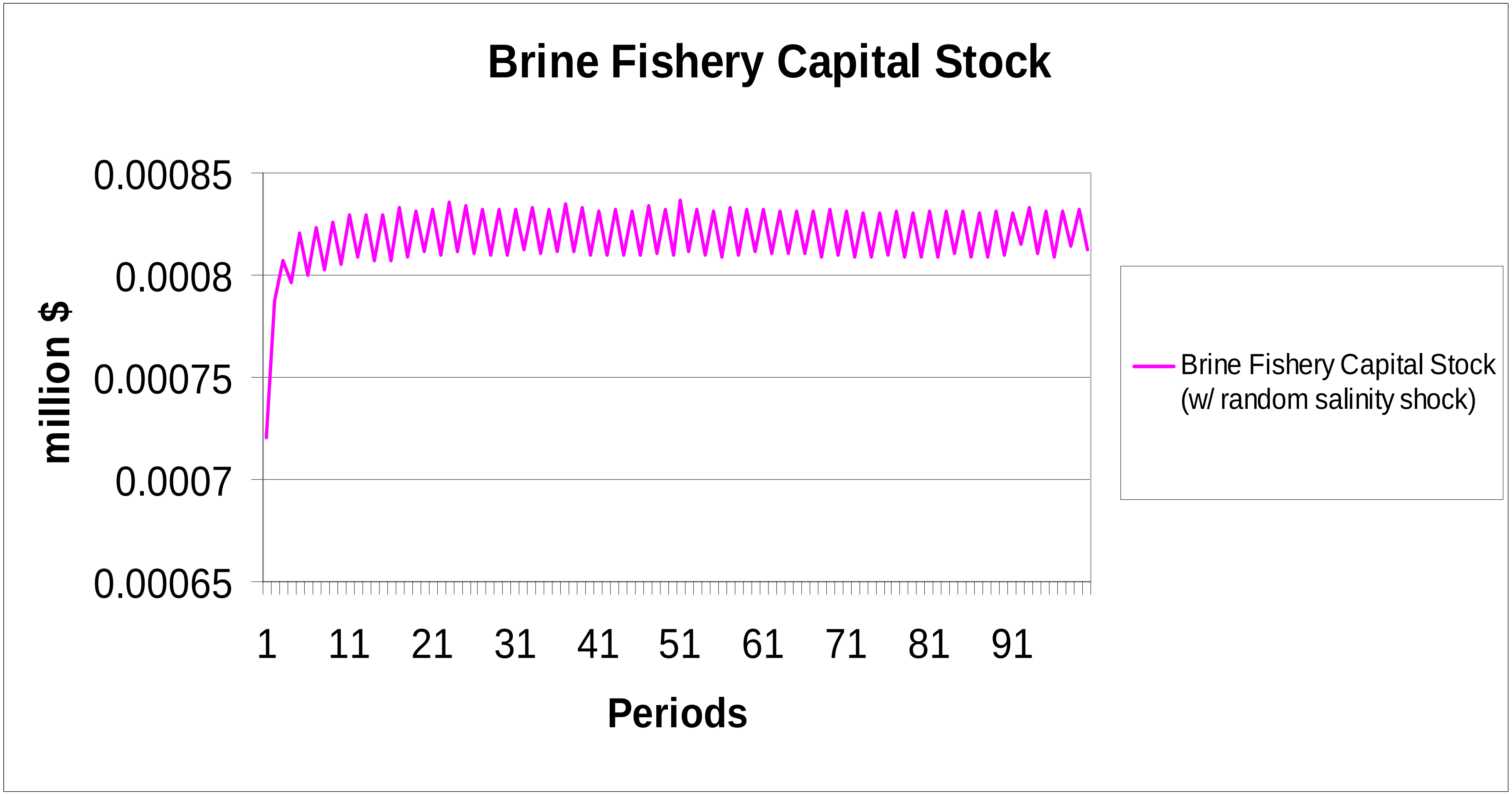

Figure 6. Household Recreation/Wildlife-Viewing Demand Following the Initial Population Shocks.

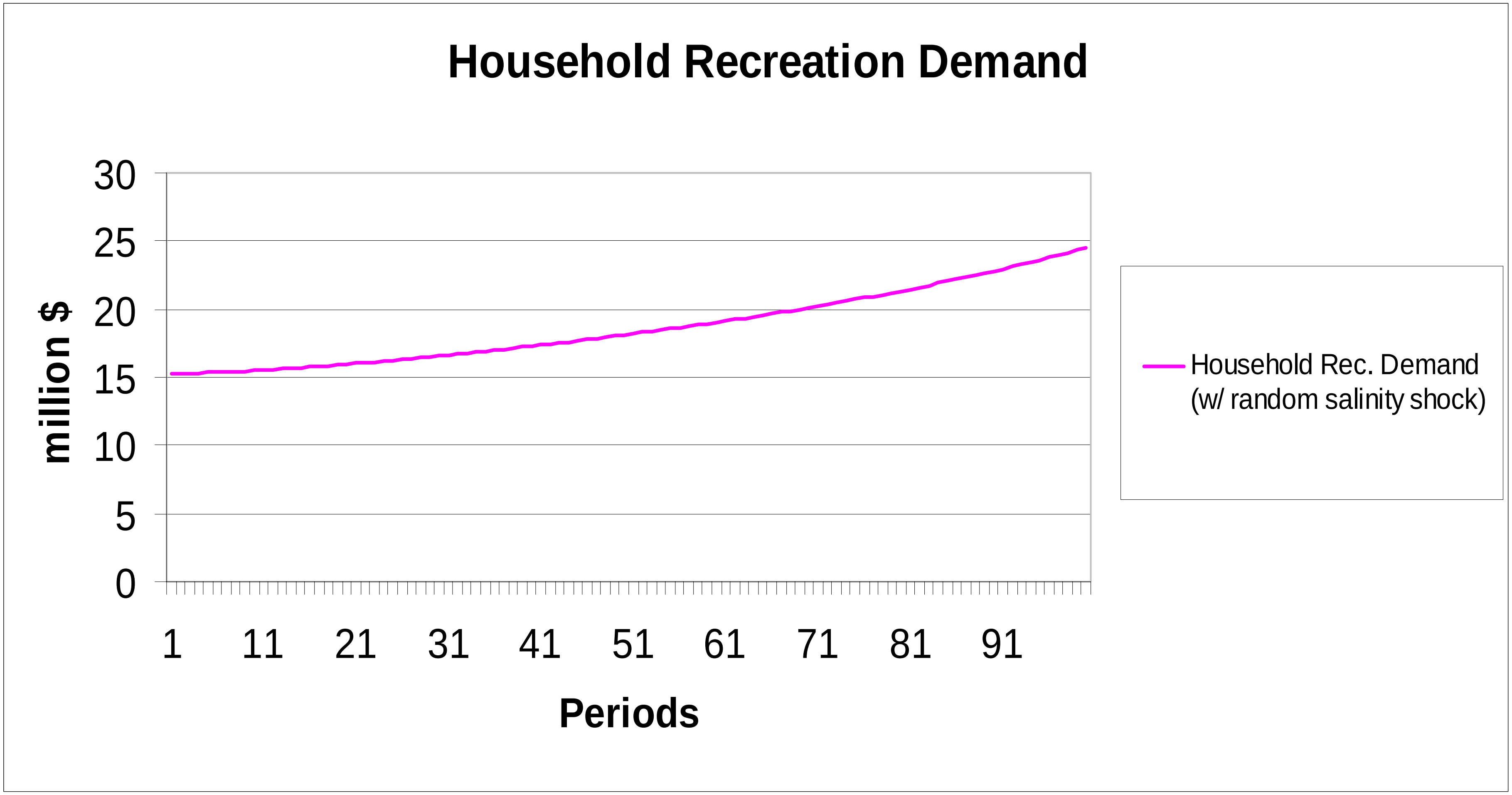

Table 1. Species Identification.

Species Number	Species Name
0	Sun
1	Algae
2	Brine Shrimp
3	Cysts
4	Brine Flies
5	Waterbirds
6	Corixids

Table 2. Species' Net-Energy Functions.

Species Number	Net Energies (R_i)
1	$R_1 = [e_0 - e_{10}]x_{10} - e_1\left[[1+t_{12}e_{21}]y_{12}(x_{10}) + [1+t_{14}e_{41}]y_{14}(x_{10})\right] - f_1(x_{10}, S_a) - \beta_1$
2	$R_2 = [e_1 - e_{21}]x_{21} - e_2\left[[1+t_{25}e_{52}]y_{25}(x_{21}) + [1+t_{26}e_{62}]y_{26}(x_{21})\right] - f_2(x_{21}) - \beta_2$
3	N/A*
4	$R_4 = [e_1 - e_{41}]x_{41} - e_4[1+t_{45}e_{54}]y_{45}(x_{41}) - f_4(x_{41}) - \beta_4$
5	$R_5 = [e_2 - e_{52}]x_{52} + [e_4 - e_{54}]x_{54} - f_5(x_{52}, x_{54}) - \beta_5$
6	$R_5 = [e_2 - e_{62}]x_{62} - f_6(x_{62}) - \beta_6$

* Because brine-shrimp cysts are in egg form they are assumed completely constrained in net-energy production.

Table 3. Species' Population-Updating Equations.

Species Number	Population-Updating Equations
1	$N_4^{t+1} = N_4^t \left[1 + \left[\frac{\left[\left[y_{45}\left(x_{41}^{ss}\right)/w_4 \right] \left[1 - 1/s_4 \right] + 1/s_4 \right]}{v_4^{ss}} \right] \left[R_4^* + v_4 \right] - \left[\left[y_{45}\left(x_{41}^{ss}\right)/w_4 \right] \left[1 - 1/s_4 \right] + 1/s_4 \right] \right]$
2	$N_2^{t+1} = N_2^{ss} + N_3^{t+1}$
3	$N_3^{t+1} = N_2^t \left[\frac{\left[\left[\left[y_{25}\left(x_{52}^{ss}\right) + y_{25}\left(x_{52}^{ss}\right) \right]/w_2 \right] \left[1 - 1/s_2 \right] + 1/s_2 \right]}{v_2^{ss}} \right] \left[R_2^* + v_2 \right] - H_3^t$
4	$N_4^{t+1} = N_4^t \left[1 + \left[\frac{\left[\left[y_{45}\left(x_{41}^{ss}\right)/w_4 \right] \left[1 - 1/s_4 \right] + 1/s_4 \right]}{v_4^{ss}} \right] \left[R_4^* + v_4 \right] - \left[\left[y_{45}\left(x_{41}^{ss}\right)/w_4 \right] \left[1 - 1/s_4 \right] + 1/s_4 \right] \right]$
5	$N_5^{t+1} = N_5^t + \frac{N_5^t}{s_5} \left[\frac{R_5^* + v_5}{v_5^{ss}} - 1 \right]$
6	$N_6^{t+1} = N_6^t + \frac{N_6^t}{s_6} \left[\frac{R_6^* + v_6}{v_6^{ss}} - 1 \right]$

A Pilot Test of a New Stated Preference Valuation Method:

Continuous Attribute-Based Stated Choice

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Abstract

A new stated preference technique is developed and tested. In an interactive computerized survey, respondents move continuous sliders to choose levels of environmental attributes. The total cost of the combination of attributes chosen is calculated according to a preprogrammed cost function, and continuously updated and displayed. Each registered choice reveals the respondent's marginal willingness to pay for each of the attributes.

The method is tested in a museum installation on global climate change. Two construct validity tests were conducted. Responses are sensitive to the shape of the cost function in ways that are consistent with expectations based on economic theory. However, responses showed range effects that indicate potential cognitive biases. Implied marginal willingness to pay values were similar to those estimated using a more traditional paired comparisions stated choice format.

Introduction

The first study using surveys to elicit values for environmental goods was by Robert Davis (1963). Since then, several different formats have been used in contingent valuation. Early studies used value elicitation formats that generate continuous measures of maximum willingness to pay (WTP). These include iterative bidding, open ended questions, and payment cards. While these approaches are efficient in the sense that they can provide a precise WTP measure for each survey respondent, there are concerns about their validity. The iterative bidding approaches has been shown to exhibit starting point effects. With payment cards, the potential exists for range effects, though these are not always found. Because open-ended valuation questions they do not mimic everyday purchase decisions, they are thought to be unfamiliar to respondents,. All three approaches have the potential for strategic responses, depending on the respodent's understanding of how the research results will be used.

Starting with Bishop and Heberlein (1979), dichotomous choice (DC) or referendum formats were increasingly used during the 1980's and early 1990's. DC contingent valuation has several purported advantages over continuous elicitation formats. First, it is thought to be more familiar to respondents because of its similarity to everyday purchase decisions. Second, starting point and range effects do not arise, though there is a concern over potential yea-saying. Third, the DC format can be incentive compatible, so that the respondent's dominant strategy is to truthfully reveal preferences. One drawback of the DC format is that it does not generate a precise measure of WTP for each respondent. Instead, each DC response generates a discrete datum that reveals only whether WTP is greater than or less than the posed cost or price.

A limitation of both continuous and discrete contingent valuation is that they can value only one change in environmental quality at a time. In a contingent valuation survey, the good being valued is defined as a discrete change in environmental quality. If environmental quality involves multiple attributes, then a discrete change in each attribute is described. If the analyst wants to evaluate a different change in environmental quality, one that involves a larger or smaller discrete change or a different combination of changes in multiple attributes, then a new survey must be conducted.

Starting in the early 1990's there has been a shift in valuation practice toward the use of attribute-based stated choice approaches. In a typical stated choice format, the respondent chooses from a set of two or more options; each option differs in its levels of the environmental quality attributes and in the cost to the respondent. A respondent will often make eight or more of these choices. Based on the stated choices, marginal utility of each of the attributes is estimated using a random utility model. With these estimated marginal utilities, it is possible to calculate WTP for any proposed change in environmental quality. A limitation of the stated choice format is that it too generates discrete data, in the sense that each stated choice reveals only ordinal preferences among the options presented in that choice. Many stated choices from each respondent and a large sample size of respondents are needed to identify marginal utility for each of the attributes.

The purpose of this study is to develop a new elicitation method, called the continuous attribute-based stated choice method (CABSCM), that values attributes of environmental quality but collects continuous data. In an interactive computer-based survey, respondents choose levels of each attribute. The total cost of the package of attributes is continuously updated according to a cost function selected by the researcher. Each respondent's choice reveals his or her marginal WTP for each attribute. In a large sample (n=14,100) pilot test, internal validy tests are conducted for the CABSCM. In a second, small sample test, responses to the CABSCM are compared to responses from a more traditional discrete attribute-based stated choice method survey (DABSCM).

Theoretical Foundation

In a typical DABSCM survey, the respondent makes a series of choices among sets of options. In each choice, a given option, j, is defined by the levels of the attributes of environmental quality that would result if that option is chosen, $\mathbf{a}_j = a^1{}_j, \ldots, a^M{}_j$, and in the cost to the respodent, c_j. The respondent's utility from option j is assumed to follow a form given by

$$(1) \qquad U_j = V(\mathbf{a}_j, c_j) + \varepsilon_j = \boldsymbol{\beta}'\mathbf{a}_j - \gamma c_j + \varepsilon_j$$

where $V(\mathbf{a}_j, c_j)$ is the deterministic component of utility, and ε_j is an option-specific error term distributed according to a type II extreme value distribution.

The respondent is assumed to choose the option that gives the highest utility among those available in a given choice set. The probability that option j is chosen from a set of options 1,…,j,…,J is then

$$(2) \qquad \Pr\{j\} = \Pr\{U_j \geq U_i \text{ for all } i \in 1,\ldots J\} = \frac{\exp(\boldsymbol{\beta}'\mathbf{a}_j - \gamma c_j)}{\sum_{i \in J} \exp(\boldsymbol{\beta}'\mathbf{a}_i - \gamma c_i)}$$

The parameters of the utility function, β and γ, are estimated using maximum likelihood techniques. The marginal willingness to pay for a given attribute, a^m, is then the ratio of the marginal utility for that attribute to the marginal utility of income, β^m/γ. The total willingness to pay for a discrete change that affects multiple attributes of environmental quality, $\Delta\mathbf{a}$, is given by $\boldsymbol{\beta}'\Delta\mathbf{a}/\gamma$.

The information needs to estimate a utility function from DABSCM data are high. As in DC contingent valuation, each choice response reveals only partial information about preferences. Specifically, each choice reveals limited information about the ordering of the options. To estimate a marginal utility requires a sample of many respondents, each facing several choices. Typically each respondent is asked to make eight or more choices. When designing a DABSCM survey, care must be taken to construct a set of choices that identifies the parameters β and γ including any attribute interactions that may be of interest. When the number of attributes is large, and interactions are of interest, it may be necessary to construct an experimental design that includes more than eight choices. In such cases, the choices may be divided into subsets, so that different respondents face a different set of choices.

The resulting parameters are aggregates across all respondents, and calculated willingness-to-pay values can be interpreted as median estimates for the respondent population. The marginal utilities can be individualized to some extent by interacting attribute levels or cost with individual characteristics. Alternatively, a random parameters model can approximate variability in preferences within the population. Individual-specific estimates of the parameters can then be derived by combining the population distribution of the parameters with the individual's reported choices, using Bayes Theorem. But these approaches rely on population parameters to generate individual estimates of willingness to pay.

In contrast, the CABSCM generates marginal WTP values for each attribute for each respondent. The preliminary material in a CABSCM survey is similar to what would be included in a DABSCM survey. The attributes are described, and motivation is given for how they might vary independently and how that might affect the respondent's budget. In a CABSCM survey, the respondent is then presented a computer screen with continuous sliders for each attribute in the design.

Figure 1 shows one of the slider screens used in this study. This particular task presents respondents with the possibility that society might invest in planting trees to sequester carbon dioxide, or in improved building efficiency to reduce carbon dioxide emissions. On the screen, respodents can choose any level of tree planting from 0 to 13 million acres, and any level of building efficiency improvement from 0% to 55%. As sliders A or B are moved, slider C (monthly cost per household) moves with them according to a preprogrammed cost function. The total reduction in net U.S. carbon dioxide emissions is given as well. When the respodent is satisfied with the set of attributes and their cost, she enters her choices. A popup screen repeats the total cost, and asks the respondent if she is sure she is willing to pay that much money. A response is recorded when the respondent answers "yes" to the "are you sure" question.

The theoretical foundation for this design differs from that for the DABSCM. Here, it is assumed that each respondent, i, has a utility function $U^i(\mathbf{a}, c)$. This utility function could take the form

$$U^i(\mathbf{a}, c) = \boldsymbol{\beta}^{i\prime}\mathbf{a} - \gamma^i c \tag{3}$$

where $\boldsymbol{\beta}^i$ and γ^i are individual-specific parameters, but the assumption of constant marginal utilities is not required. Given a cost function, $c=f(\mathbf{a})$, the respondent solves the problem

$$\max_{\mathbf{a}} \; U^i(\mathbf{a}, f(\mathbf{a})) \tag{4}$$

A necessary first order condition for this maximization is

$$-\frac{\partial U^i / \partial a_j}{\partial U^i / \partial c} = \partial f / \partial a_j \tag{5}$$

The left hand side of equation (5) is the respondent's marginal WTP for attribute j, while the right hand side is the marginal cost at the combination of attributes chosen.

This choice is shown graphically for one attribute in Figure 2. The cost function is designed such that marginal costs increase as the level of the attribute increases. This curvature in the cost function increases the chance of an internal solution, even in cases where indifference curves are relatively straight. Three indifference curves are shown, drawn to reflect that trees generate positive utility while costs generate disutility. The respondent's optimal choice occurs where an indifference curve is tangent to the cost curve.

Each choice in a CABSCM survey, then, precisely identifies the respondent's marginal WTP for each attribute in the choice, assuming an interior choice. Limit choices, where the attribute slider is set at the top or the bottom of the range provide truncated observations on marginal WTP. With CABSCM data, it is possible to explore how marginal WTP varies across respondents. A marginal value function can be estimated using regression techniques suitable for truncated data, for example Tobit regression, that predicts marginal willingness to pay as a function of the characteristics of the respondent.

Methods

Museum Installation

The interactive computer survey was designed to be included as an installation in an exhibit on global climate change at the Marian Koshland Museum of Science, which opened at the National Academies of Science in April 2004. The installation was designed as an interactive kiosk, with a large flat panel screen, a trackball, and a button for entering choices.[1] Part of the purpose of the installation was to teach museum visitors about the necessity to make tradeoffs when dealing with global climate change.

Working in consultation with the museum designers, three separate topics were developed. Visitors could choose to view any or all of the topics. In each topic, a tradeoff between two attributes is motivated with a short film. The respondent then is presented with a

[1] A web version of the survey can be viewed at http://www.koshland-science-museum.org. Click on "Global Warming Facts & Our Future" and then on "Consider the Alternatives" to start the program.

choice screen such as that shown in Figure 1. The attributes include a mix of actions to mitigate[2] global climate change and actions to adapt to its consequences. These are briefly described in Table 1.

For each attribute, a slider is presented labeled at the bottom and top with the lower and upper bound values shown in Table 1. For drinking water quality, the slider is calibrated using electrical conductivity units, but three labels are presented: "unfit for human consumption" at the bottom of the slider, "tastes slightly salty" at a level corresponding to 700 conductivity units, and "tastes fresh" at the top of the slider. For Topic 1 only, a fourth bar is included that shows the total impact on net CO_2 emissions from the choices made.

Because the survey would be part of a museum installation, the cost figures had to reflect the best available estimates of actual costs. For each attribute, upper and lower bounds on the levels were chosen so that the cost per U.S. household to achieve the upper bound was about $60, based on published estimates (National Academy of Sciences, 1992; National Assessment Synthesis Team, 2000; U.S. Department of State, 2002). The respondent then could commit to spend anywhere from $0 to $60 on each of the two attributes. While the cost function endpoints were based on published estimates, there was little guidance over the shape of the cost function in between the two endpoints. It is important that the cost function be nonlinear, in order to identify marginal WTP for each respondent. Quadratic cost curves were specified for each attribute that passed through the two endpoints, with increasing marginal cost throughout the range.

[2] In the context of global climate change, "mitigation" refers to actions taken to lessen the amount of climate change (for example through decreases in CO_2 emissions), and "adaptation" refers to actions taken to lessen the consequences of global climate change (for example through wetland creation to replace wetlands lost to sea level rise).

Internal Validity Tests

To evaluate the validity of the CABSCM method, two validity tests were designed as part of the museum installation. Three versions of the installation software were developed. Table 1 reflects the design of Version 1. The three version rotated in the museum on a 12 day cycle, four days for each version.

The first validity test explored whether responses were sensitive to the curvature of the cost function. Version 2 of the installation software used a linear cost function instead of the quadratic function shown in Table 1. The slope of the linear cost function was set so that the cost of reaching the upper bound level of the attribute was still $60. Figure 2 shows how a respondent would be expected to react to the two different cost functions, for the planting trees attribute. If preferences are homothetic, a typical respondent would be expected to choose a higher level of an attribute but spend less money on it when faced with the quadratic cost function than when faced with the linear cost function.

The second validity test explored possible range effects. Version 3 of the installation software used the same quadratic cost functions as Version 1, but the upper and lower bounds were set so that the maximum amount that could be "spent" on each attribute was $30, instead of $60. If range effects exist, then we would expect more responses between $0 and $30 in Version 3 than in Version 1, and a downward shift of those responses, in both the attribute levels and the amount of money committed.

Comparison between CABSCM and DABSCM

In addition to the data collected from museum visitors, a second study was conducted that compared the CABSCM survey to a more typical DABSCM survey. A paper survey was designed that presented respondents with four DABSCM choices; for each choice, respondents chose between two combinations of trees planted and building efficiency. Each option in the DABSCM survey was constructed so it was a feasible combination in the CABSCM survey with the quadratic cost function.

Interviews were conducted inside the Koshland museum with museum visitors, and on the Pennsylvania State University campus, with randomly selected faculty and staff. After viewing the introductory video included in the museum installation, each respondent completed both the CABSCM and the DABSCM survey. The order of the two surveys was randomized. The first analysis was a within-respondent comparison of the two survey methods. For each respondent, the marginal WTP for each attribute was determined from the CABSCM response. These were then used to determine which DABSCM response should give higher utility. A preference reversal occurs if the DABSCM choice differed from the choice that was predicted based on the CABSCM response.

A second comparison was made between marginal WTP for the attributes estimated from the DABSCM responses and marginal WTP estimated from the CABSCM survey. The former are estimated using a standard multinomial logit regression. Aggregate measures of the latter are estimated using a Tobit regression on marginal WTP. To simulate what would happen if each method was administered by itself, only responses to the first survey administered are included in this comparison.

Results

Sensitivity to Curvature in the Cost Function and Range Effects

A total 14,100 CABSCM choices were recorded in the museum installation. For each attribute/cost function combination, the population mean attribute level was estimated using Tobit regression, with upper and lower limits as shown in Table 1. Population mean cost commitment for each attribute is also estimated using Tobit regression, with upper and lower limits of $0 and $60 ($30 for Version 3). These are presented in Table 2. For each topic/cost function combination, the mean level of the attribute or cost is presented as well as the population standard deviation (sigma). Standard errors for each estimated parameter are presented in parentheses.

Theory predicts that the average respondent should choose a higher level of each attribute but commit to a lower cost when facing a quadratic cost function (columns 1 and 2 in Table 2) than when facing the linear cost function (columns 3 and 4). For each of the six attributes, this holds true (note that for property damage and salinity, lower numbers represent higher levels of the attribute). The average respondent chose attribute levels that were 7-24% farther up the slider bar, and 7-21% cheaper when faced with a quadratic cost function than when faced with a linear cost function, consistent with theoretical expecations. Log-likelihood tests confirm that the differences are in each case significant at at least the 5% level.

Comparison between the results for the quadratic cost function with the full range available (columns 1 and 2) to the quadratic cost function with a narrower range of opportunities (columns 5 and 6) show that range effects do occur. The average respondent chose attribute levels that were 25-31% lower and "spent" 36-44% less money when faced with the narrower range than when faced with the full range of opportunities. Log-likelihood tests confirmed that these differences are all statistically significant at the 1% level. Respondents who faced the narrow range of opportunities did choose the upper limit more frequently than those who faced the full range (18.6% vs. 15.2%), but not as frequently as would be required for the distributions to be similar.

Comparison Between DABSCM and CABSCM

A total of 109 interviews were conducted where respondents completed both the DABSCM survey and the CABSCM survey. Of these, 48 were conducted at Pennsylvania State University, and 61 were conducted at the Koshland Museum of Science. No difference in any response patterns was detected between surveys completed at Pennsylvania State University versus surveys completed at the Koshland Museum of Science. In 47 interviews, the DABSCM survey was completed first. In the other 62 interviews, the CABSCM survey was completed first. In one of the interviews, the DABSCM was only partially completed. The partial results are included in this analysis.

In the CABSCM survey, respondents experienced exactly the same survey as visitors to the Koshland museum. The CABSCM responses for this sample can therefore be directly compared to the responses for the museum visitors facing the same cost function (the quadratic cost function with the full set of opportunities). We have no expectations about whether the difference in sample selection will lead to differences in preferences, but it is possible that participation in an in-person interview might focus the respondents more, and motivate them to consider their choices more carefully. Tobit estimates of the average attribute levels and cost commitments from the CABSCM responses for this sample were nearly identical to the average for all museum visitors for the same cost function (the differences were less than 4%, and not statistically significant). However, the museum visitor responses exhibited more variability than the responses of participants in the in-person interviews. The Tobit estimate of the standard deviation in attribute levels for museum visitors was 29% higher for both trees and building efficiency than for participants in the in-person interviews, and this difference was statistically significant at the 1% level in both cases.

The most striking result came from comments made by participants who experienced both survey formats. Of those who volunteered an opinion on the two methods, there was a clear preference for the CABSCM format. Respondents found it easier to understand and found the task easier to complete.

The 109 respondents made a total of 516 DABSCM choices. Of these, 27.6% showed a preference reversal. Of these reversals, the CABSCM response implied lower marginal WTP values for the attributes than did the DABSCM response in 57% of cases. In the remaining 43% of cases, the CABSCM response implied higher marginal WTP values for the attributes than did the DABSCM response. The rate of preference reversals was higher among respondents who answered the CABSCM survey first (32.8%) than those who answered the DABSCM survey first (21.8%). This difference in proportions was statistically signficant at the 1% level.

From each CABSCM response, marginal WTP for trees and for building efficiency was calculated. These values are truncated by the data collection process. At the lower end of the tree slider, the marginal cost of trees is 2.61. At the upper bound, it equals 20. For building efficiency, the bounds on marginal cost are 0.57 and 12. A respondent who places a slider bar at the lower (or upper) bound is assumed to have a marginal WTP less than (more than) the marginal cost at that limit.

To estimate the population average marginal WTP, the individual observations are regressed on an intercept only in a Tobit regression. Inspection of the marginal WTP values showed that the distribution for each attribute is clearly skewed, with a longer tail to the right.

The marginal WTP values were therefore log-transformed before the Tobit regression was estimated, and the upper and lower bounds were adjusted accordingly. First, tests were conducted to determine whether survey order affected the CABSCM responses. Neither a dummy variable for survey order nor a log-likelihood test showed any evidence of a difference in responses due to survey order. Still, to avoid any potential for sequencing effects, only CABSCM responses where that method was administered first are considered in subsequent analyses.

The Tobit regression parameters (the average and standard deviation of the log-transformed marginal WTP values) are presented for trees and building efficiency in Table 3. The estimated median marginal WTP for trees was $5.73 per million acres. The estimated median marginal WTP for building efficiency was $1.71 per 1% improvement. Table 3 also gives 95% confidence intervals for these estimates. Because the distribution of marginal WTP is skewed, population means are larger than the medians ($7.68 for trees and $3.12 for building efficiency).

The DABSCM responses also showed no statistical evidence of a survey order effect. Still, only DABSCM responses where that method was implemented first are considered here. A multinomial logit regression for these responses is shown in Table 4. All three attributes in the choice, trees, building efficiency and money, are statistically significant at the 1% level and of the correct sign. Marginal WTP for trees and building efficiency are calculated and presented in Table 4. Krinsky and Robb's Monte Carlo technique was used to simulate 95% confidence intervals for these. Here, the multinomial logit regression provides no estimation of the variability in preferences among respodents, and the estimated marginal WTP should be viewed as both the population median and the population mean.

Comparing the median MWTP from the CABSCM to that from the DABSCM, the CABSCM estimate is 40% higher for trees and 5% higher for building efficiency, but the differences are not statistically significant at even the 10% level.

Discussion

This study benefited greatly from the collaboration with the Koshland Science Museum. First, the Museum had access to professional designers and videographers that resulted in a product that was more polished, professional and user friendly than the typical survey designed by academic researchers. Second, location of the installation in the museum allowed for a very large sample size of respondents at low cost. Third, the installation was located within a larger exhibit where visitors were exposed to high quality, interactive educational material on global climate change. This reduced the need for lengthy explanations in the the survey itself.

The museum context imposed some constraints on the research, however. Most importantly, the survey experience had to be short. This limited the amount of information that could be presented about the attributes being valued. Second, for the general population of museum visitors, the social contract between the researcher and the the respondent was less salient. The survey did mention that responses would be used by researchers, but respondents likely saw their responses as less consequential than they would have if they had been approached individually by the researcher, either in person or through a mail or telephone contact. The museum context might also include more distractions (friends, other exhibits) than the in-person interviews.

A comparison between the two samples showed that the average responses were quite similar between the general sample of museum visitors and the sample that participated in the in-person interviews, but that the variability was lower among respondents to the in-person interviews. We conclude that while the museum context is not ideal for data collection, it did provide responses that, on average, were similar to those that we would have obtained had we used a much traditional survey mode such as in-person interviews. The increased variability is a tradeoff against the ease of data collection and the potential for very large sample sizes.

The internal validity tests of the CABSCM showed mixed results. Responses were sensitive to curvature in the cost function in exactly the ways predicted by economic theory. This is reassuring, in that it shows that respondents are reacting to the cost function, a key assumption behind the method. However, responses were sensitive to the range of opportunities presented. This is not particularly surprising. Similar range effects have been shown in many other contexts. However, it does raise questions about whether respondents are reacting to absolute levels of attributes and cost or to relative levels.

The goods valued in this study are likely to be particularly susceptible to framing effects. Respondents have little prior personal experience with global climate change, tree plantings, building efficiency or carbon dioxide reductions. Further, of necessity, the descriptions of these goods were brief. A more familiar good will likely be less susceptible to range effects than the goods valued in this study.

The comparison between the CABSCM survey method and the more traditional DABSCM method showed that the two methods generate similar estimates of marginal WTP. This result is somewhat surprising. Several studies have shown that discrete contingent valuation methods consistently generate higher estimates of WTP than continuous methods. There does not appear to be a similar systematic difference between how respondents answer CABSCM questions and how they answer DABSCM questions.

Comparing each respondent's choices in the two methods, we saw that respondents exhibited contradictions in their responses 27.6% of the time. These reversals appear to be the result of random effects, and were not systematic. The frequency of reversals where the CABSCM response implied higher marginal WTP than the DABSCM response was similar to the frequency of the opposite type of reversal. The rate of reversals seen between CABSCM and DABSCM does not imply that CABSCM responses are invalid. Both the CABSCM and DABSCM generate data that has random components, even within a single respondent. The reversal rate between CABSCM and DABSCM is similar to that seen within DABSCM surveys. Johnson Mathews and Bingham (2000) included the same pairs more than once in the question sequence in a DABSCM survey valuing life expectancy. They found that 39% of respondents showed at least one reversal in preferences.

We conclude that the CABSCM is a promising method for preference elicitation. Respondents prefer it to the DABSCM, finding the task easier to complete. Each response generates more information about preferences than a single DABSCM response, and fewer respondents can complete the survey more quickly. The method does need to be administered on a computer, though it can be done through a web site.

Extensions to the CABSCM are possible. By varying the cost function, it is possible to identify a marginal WTP function that varies with the attribute level (i.e. to measure the curvature in indifference curves). Interactions among attributes in the utility function also can be identified. Future research on this method should investigate the potential for increasing the number of attributes included in the design. While the method is best suited to attributes that are infinitely scalable, a combination of scalable and discrete attributes is also possible. The range effects seen in this study require more investigation, but those effects do not necessarily imply that the method is not useful, particuarly for goods that are more familiar to respondents.

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Figure 1. CABSCM choice screen.

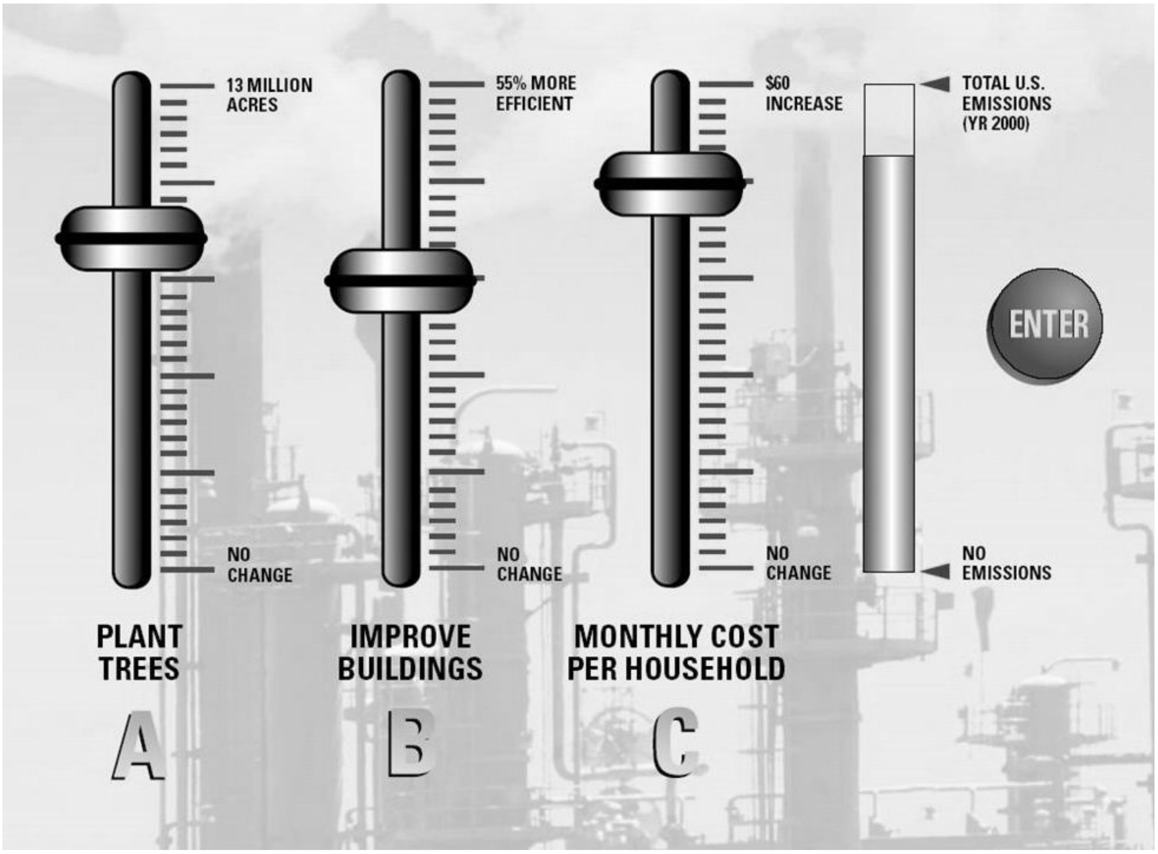

Figure 2. Optimal choice in a CABSCM survey

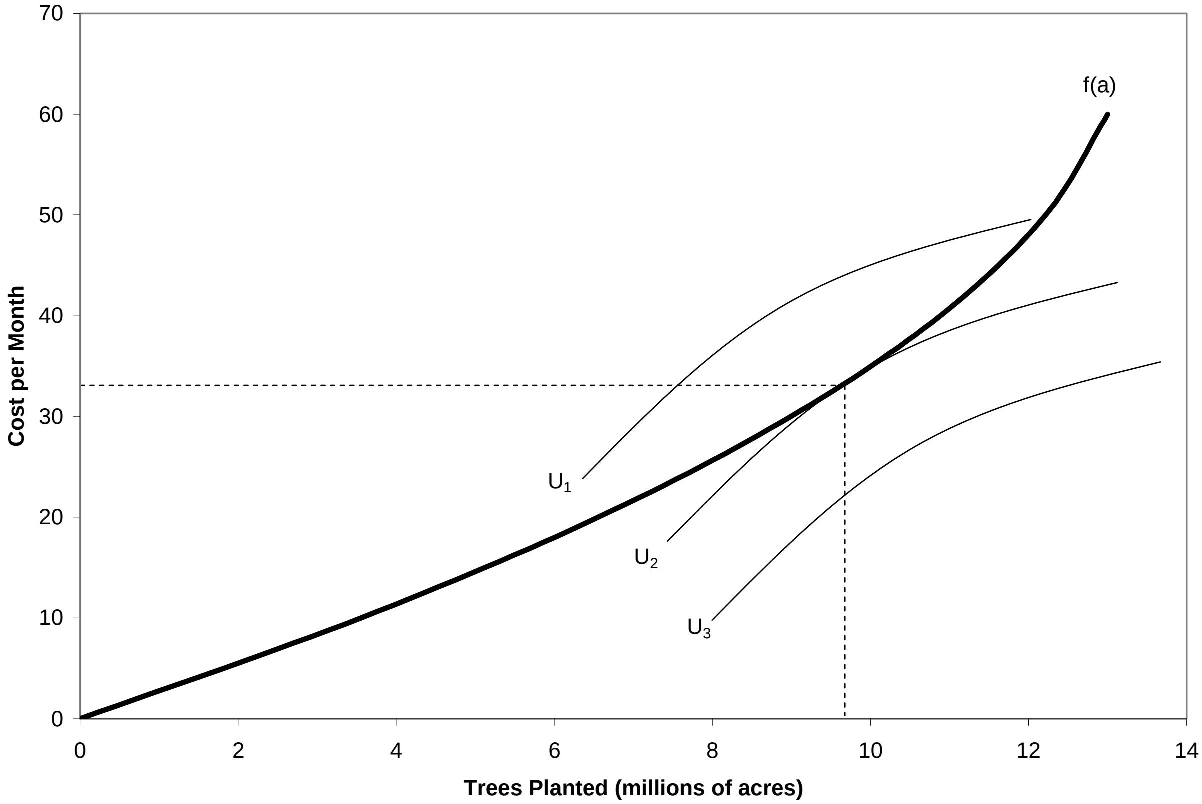

Figure 3. Cost function validity test

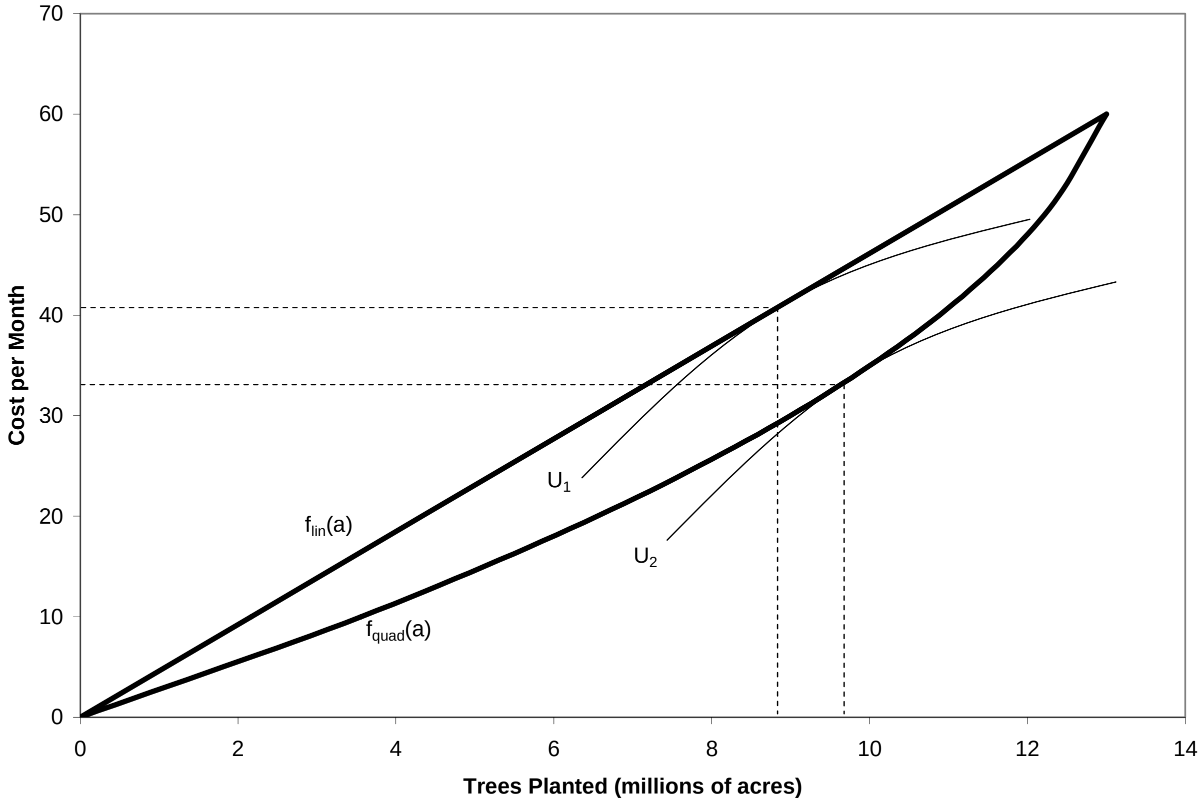

Table 1. Topics and attributes.

Tradeoff	Units	Lower Bound	Upper Bound	Inverse Cost Function
Topic 1 – CO_2 Emissions				
Plant trees to sequester CO_2	Millions of acres per year	0	13	$A = 0.383C - 0.00278C^2$
Improve building efficiency	Percent increase	0	+55	$A = 1.75C - 0.0139C^2$
Topic 2 – Increased Frequency and Severity of Storms				
Replace wetlands lost to increased storms	Millions of acres lost	-5.8	+1.0	$A = -5.8 + 0.21C - 0.00167C^2$
Avoid property damage from increased storms	Percent increase in damage	+30	-10	$A = 30 - 1.33C + 0.0111C^2$
Topic 3- Sea Level Rise				
Avoid property damage from sea-level rise	Percent increase in damage	+30	-10	$A = 30 - 1.33C + 0.0111C^2$
Protect drinking water from saltwater intrusion from sea-level rise	Electrical Conductivity (1000 units)	2.5	0	$A = 2.5 - 0.0783C + 0.000611C^2$

Table 2. CABSCM responses from museum visitors

	Quadratic Costs - $60 Cost Range		Linear Costs – $60 Cost Range		Quadratic Costs – $30 Cost Range	
	Attribute	Cost	Attribute	Cost	Attribute	Cost
Trees Planted						
Mean	7.87	30.07	7.04	32.49	5.45	17.10
	(0.16)	(0.75)	(0.16)	(0.72)	(0.12)	(0.42)
Sigma	5.96	27.93	6.06	27.95	4.57	15.47
	(0.14)	(0.66)	(0.14)	(0.64)	(0.11)	(0.38)
N	1468		1577		1492	
Building Efficiency						
Mean	39.96	36.19	35. 90	39.16	29.23	20.78
	(0.65)	(0.77)	(0.65)	(0.71)	(0.51)	(0.40)
Sigma	23.92	28.44	24.92	27.19	18.72	14.60
	(0.58)	(0.70)	(0.58)	(0.64)	(0.47)	(0.37)
N	1468		1577		1492	
Wetlands Lost						
Mean	-1.470	30.81	-1.766	36.67	-2.532	19.25
	(0.065)	(0.61)	(0.0705)	(0.64)	(0.0591)	(0.38)
Sigma	2.564	24.21	2.865	26.05	2.325	14.93
	(0.0553)	(0.52)	(0.0620)	(0.56)	(0.0546)	(0.35)
N	1644		1757		1689	
Property Damage from Storms						
Mean	16.55	13.29	18.76	16.86	20.40	8.55
	(0.49)	(0.63)	(0.42)	(0.63)	(0.35)	(0.35)
Sigma	19.05	24.32	16.86	25.29	13.40	13.68
	(0.45)	(0.57)	(0.37)	(0.56)	(0.36)	(0.32)
N	1644		1757		1689	
Property Damage from Sea Level Rise						
Mean	12.49	17.94	15. 90	21.16	17.74	11.16
	(0.48)	(0.63)	(0.49)	(0.73)	(0.34)	(0.34)
Sigma	17.74	23.22	18.20	27.31	12.46	13.02
	(0.42)	(0.55)	(0.43)	(0.65)	(0.34)	(0.30)
N	1434		1506		1533	
Drinking Water Salinity						
Mean	0.719	34.37	0.8358	39.94	1.274	19.15
	(0.0274)	(0.68)	(0.0267)	(0.64)	(0.0206)	(0.35)
Sigma	1.004	24.96	1.010	24.25	0.776	13.30
	(0.0240)	(0.60)	(0.0229)	(0.55)	(0.0184)	(0.32)
N	1434		1506		1533	

Table 3. Tobit regression results for CABSCM surveys

	Trees	Building Efficiency
	Tobit results for ln(MWTP)	
Mean	1.7458	0.5390
(s.e.)	(0.0993)	(0.1405)
Sigma	0.765	1.0934
(s.e.)	(0.0789)	(0.1013)
N	61	61
	Marginal WTP	
Median	5.73	1.71
(95% CI)	(4.72, 6.96)	(1.30, 2.26)

Table 4. Multinomial logit regression results for DABSCM

	Multinomial Logit Regression	
	Parameter Estimate	
MU Trees	0.5371	
(s.e.)	(0.1383)	
MU Efficiency	0.2152	
(s.e.)	(0.0424)	
MU Money	-0.1312	
(s.e.)	(0.0291)	
N	188	

	Marginal WTP	
	Trees	Building Efficiency
Median	4.09	1.64
(95% CI)	(2.62, 5.90)	(1.3, 2.14)

Economic Welfare Effects of Recreation Site Closure on Multiple Destination Visitors Using a Random Utility Model: The Case of Yellowstone Snowmobiling

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Abstract

Economic Welfare Effects of Recreation Site Closure on Multiple Destination Visitors Using a Random Utility Model: The Case of Yellowstone Snowmobiling

A key assumption of the Travel Cost Method in general, and Random Utility Model variants is that the trip be for a single purpose to a single destination. The assumption of single purpose and single destination in the recreation demand model avoids the issue associated with joint travel cost in a multiple destination trip. Often times multiple destination visitors are dropped from the sample before model estimation due to the joint travel cost problem.

The multiple destination visitor goes to more than one destination while on a trip away from home. The question becomes how do visitors allocate visits to multiple destinations in a particular area while on a single trip away from home? Because what the researcher usually observes is the total cost of the trip away from home, little evidence exists as to how price per destination may be assigned or more importantly how site allocation is affected while on the trip.

The purpose of this paper is to develop a modeling approach that explains site choice in a multiple destination trip and provides welfare change estimation for this type of visitor given a site closure. We draw upon economics, tourism and economic geography literature to develop a tractable and theoretically consistent framework with which to model the *multiple destination* segment. This modeling approach is then applied to Yellowstone National Park, a snowmobile recreation site that is frequented by a significant number of multiple destination visitors and which faces uncertainty as to snowmobile access. This model is statistically significant in explaining behavior and parameter estimates are consistent with theory. Welfare estimates associated with site closure are provided for the sample of multiple destination visitors. This modeling approach's strengths, its limitations and suggestions for further efforts are then discussed. It is expected this multi-state work makes a contribution to the literature as it relates to estimating the economic value of changing recreational access, a specific objective of the W-1133 regional research project.

Introduction

Valuing the environment through the use of recreation demand models has been a topic of much research. A typical approach is the Travel Cost Method (TCM) (Haab and McConnell 2002). The cost of the trip is used as a proxy for price to a destination, and the quantity demanded is defined as the number of trips to the site in question with TCM. Consumer surplus is then calculated from the estimated demand function. A key assumption of this method is that the trip be for a single purpose to a single destination (Loomis, Yorizane and Larson 2000). Smith and Kopp (1980) point out there are spatial limits to the TCM, and that after a certain distance the assumption of a single purpose trip becomes questionable at best.

The assumption of single purpose and single destination in the recreation demand model avoids the issue associated with joint travel cost in a multiple destination trip. Often times multiple destination visitors are dropped from the sample before model estimation due to the joint travel cost problem (Walsh, Johnson and McKean 1988). When the number of visitors to a site that are of the "multiple destination" category are small, potentially little information is lost if they are eliminated from the researcher's sample.

The multiple destination visitor goes to more than one destination while on a trip away from home. The question becomes how do visitors allocate visits to multiple destinations while on a single trip away from home? Because what the researcher usually observes is the total cost of the trip away from home, little evidence exists as to how price per destination may be assigned or more importantly how site allocation is affected while on the trip. Hanson (1980) criticizes the assumptions made in most choice models and states "when examined, [these assumptions] yield a rather poor approximation of actual choice behavior, particularly in the context of destination choice on multistop or multipurpose journeys (p. 246)."

Given the difficulties associated with modeling multiple destination visitors, policy analysis for locations frequented by this visitor type becomes problematic. What are the implications of a policy that proposes closure of a unique destination when a significant portion of that site's visitors is of the multiple destination kind? Welfare estimates may very well be inaccurate if multiple destination visitors are dropped from the sample or assumed to behave as single destination visitors in the face of the joint travel cost issue. Modeling behavior so as to allow for substitution to other destinations seems a logical approach, particularly for this type of visitor. The purpose of this paper is to develop a modeling approach that explains site choice in a multiple destination trip and provides welfare change estimation for this type of visitor given a site closure.

The remainder of this paper will first review relevant literature pertaining to multiple destination visitors and modeling their behavior. A potential model is then proposed based on this literature and relevant economic theory. This modeling approach is then applied to a snowmobile recreation site that is frequented by a significant number of multiple destination visitors and which faces uncertainty as to snowmobile access. Welfare estimates associated with site closure are provided for the sample of multiple destination visitors. This modeling approach's strengths, its limitations and suggestions for further efforts are then discussed.

Selected Travel Research Relating to Multiple Destination

Wall (1978) uses parking lot intercept interview data to delve into single versus multi-destination trip tourists at Mammoth Cave National Park and Carter Cave state park, Kentucky. The author concludes that both types of visitors frequent both sites and assumptions cannot be made about types of visitors frequenting one site over another. The author also concludes that the two types of recreational visitation should be modeled separately.

Hanson (1980) defines the assumptions of the spatial choice models of that time and provides criticisms as to why those assumptions are not accurate of all behavior. The author examines data from several intraurban travel studies and estimates descriptive statistics, and she concludes that multipurpose and multi-destination trips must receive more attention in the research literature.

Hwang and Fesenmaier (2003) study multi-destination travel using the 1995 American Travel Survey household data. Destinations are broken down by state and purpose in their results for domestic travel only. The authors state that the importance of spatial characteristics in the multi-destination travel decision is closely related to the idea of economic rationalism and explains travelers' choice as a strategy for minimizing travel cost. The authors conclude that multi-destination travel can be characterized as an en route pattern, but base camp travel is dominant when travelers visit only one additional destination. Base camp travel occurs when visitors go to a destination away from home and then take shorter trips from that destination to other sites before returning home. Enroute travel occurs when visitors go to a number of destinations along their roundtrip route before returning home.

Economic Research Relating to Multiple Destination

Smith and Kopp (1980) argue that the typical TCM results from necessary assumptions when estimating a zonal TCM to represent the individual's demand for a given recreational site's services. The most important of these assumptions is that the objective of the trip to the recreational site is for recreational use and not multiple objectives. The authors propose a test for estimating the stability of the estimated demand functions' parameters be used to define the spatial limits of the model. The authors use Forest Service data to estimate the demand for an area in California that had recently been burned. Their test results (the BDE cusum statistic) indicate that at 672 miles the model becomes unstable. The authors re-estimate the model without the data past 672 miles and results are different for both parameter and welfare estimates. The important contribution of this article is the suggestion that TCM assumptions may become untenable at far distances, particularly the assumption of single purpose and single destination trips.

The results of Smith and Kopp (1980) motivated a number of economic researchers to investigate alternative TCM specifications to address diversity in visitors (Kerkvliet and Nowell 1999). One approach by Parsons and Wilson (1997) presents several theoretical utility maximization models regarding incidental (side) trips and joint consumption recreation trips, and they estimate several empirical models to test the theoretical models. Empirically the model uses a binary variable for multiple purpose or destination and then interacts that variable with both travel cost and travel time as well as several other variables. The authors use Maine fishing trip data sets to test their model. Their results suggest a small bias when incidental trips are not dealt with in both the model and welfare estimation. They conclude that omitted variable bias exists in empirical models if incidental jointness is not accounted for.

Loomis, Yorizane and Larson (1999) extend the work of Parsons and Wilson (1997) with a more general TCM to allow for inclusion of multi-destination visitors in a single pooled equation for whale watching. The authors conclude that omitting multi-destination visitors results in underestimation of benefits which could be policy relevant, but the benefit estimates from the primary purpose model and the model including incidental and joint trips were not significantly different. Both of these papers provide a framework for addressing multiple destination visitors when looking at benefit estimates for a single site, but the issue of site allocation amongst possible substitute sites is not addressed by this approach.

Mendelsohn et al. (1992) present a model, which uses a system of inverse demand equations to account for multiple destination recreation trips. Combinations of multiple destinations are essentially treated as “unique” destinations in this system. The demand system focuses on single destination and multiple destination trips for Bryce, Grand Canyon, Las Vegas and Arches National Park. One of the model’s contributions is that it is based on demand theory and forces symmetry on the system. Results indicate that consumer surplus estimates that don’t include multiple destination demands underestimate the value of a site. The authors conclude this is an important step toward using travel cost models in complete valuation of sites. While this approach is theoretically consistent, it requires bundling of sites into a unique destination and variables such as cost and site attributes must somehow be aggregated to represent the “unique” multiple site bundle. Moreover, if a choice set has a large number of sites this approach becomes difficult as permutations of which sites should or should not be bundled becomes large, and bundled site equations pose a potential aggregation bias.

Bell and Leeworthy (1990) argue that traditional TCMs, which typically assume one day trips, are not applicable to travelers coming long distances as per Smith and Kopp (1980). They develop a recreation demand model for beach days based on past literature which posits that trip length is positively related to travel cost, i.e., the more dollars spent on total trip cost, the longer the number of days spent recreating. Utility is defined as a function of beach days recreated over a specified time (BDAYS) and q is a composite good or all other goods and services. BDAYS is also defined as a composite good containing recreational attributes such as swimming, sunning, and or fishing. Their assumption is that utility is additively separable in the recreational activity, all other income, and all other leisure time. “Tourists” as defined by the authors face two distinct types of costs, travel cost per trip, and price on-site cost per day, in the consumption of beach days per trip. They posit that TCPT and BDAYST (beach days per trip) are positively related. They conclude that as TCPT increases economic agents will take less trips but the individual trips will be longer in days. The authors gather data using an intercept sampling and interview method at all major highways and airports as visitors leave the state of Florida. Empirical models were significant, and the key results were that price on site was significant and negative in sign while travel cost per trip was positive and significant. This supported the authors conclusion that cost to come to the region was in fact positively correlated to trip length while on-site cost negatively affected days demanded on site. The authors use a bias adjustment in their welfare calculation and estimate a final consumer surplus figure of $33.91/person/day for "tourists" using beach resources in Florida.

Hof and King (1992) provide a theoretical model suggesting that Bell and Leeworthy's (1990) model is consistent with theory used to derive the TCM. They argue, however, that what Bell and Leeworthy (1990) propose is powerful theoretically but sometimes difficult to estimate depending on the resource and empirical data available. The authors provide an empirical example to support their conclusions.

Shaw (1991) in another comment applauds Bell and Leeworthy (1990) for taking on the issue of "tourists" and the spatial limits of the single-site TCM but raises several concerns with their approach. He argues that there are likely three stages to the decision process for tourists that relate to the estimation of demand for beach days in Florida and these stages are not accounted for adequately in their model. Shaw (1991) recommends an approach of developing a likelihood function to estimate demand conditioned on decisions in the described stages given available data. Second, Shaw points out a potential endogeneity issue in the demand equation as the dependent variable (BDAYS) as price is prorated on total annual expenditures on Florida beach recreation by the percentage of each day spent on the beach. Simultaneity between price and BDAYS exists as modeled by Bell and Leeworthy (1990). Shaw also indicates a potential problem with not including individual beach site characteristics in estimating the demand for BDAYS.

Kerkvliet and Nowell (1999) do a TCM for trout fishing in Yellowstone National Park. The authors point out that the spatial limits of TCM is related to stability of parameter estimates in the model and use the BDE cusum statistic as proposed in Smith and Kopp (1980) to estimate the model's parameters' stability. The authors use the on-site travel cost model as proposed by Bell and Leeworthy (1990) where days is the dependent variable and long distance travel cost and on-site cost are broken out separately. The authors take into account the heterogeneity of visitors by defining costs differently and incorporating binary variables to shift the intercept using a normal visitor as the base. The authors make a contribution as they delve into how travel costs should be handled for different visitor types, thereby extending the on-site TCM.

The above literature points to several important issues when modeling multiple destination visitors. First, traditional TCM modeling is inadequate to explain behavior and estimate benefits for visitors other than the single purpose, single site visitors. Second, there are different types of multiple destination visitor behavior such as incidental, enroute or base camp behavior, which is likely affected by purpose of trip and the spatial nature of available destinations. Third, the potential for substitute sites or activities is important. How costs are defined for multiple destination visitors is important and dependent on the type of visitor being modeled. Important components of cost are those relating to the long distance traveled to get to the area of destination and the cost associated with the individual site. A modeling approach that addresses these issues should make an important research contribution.

Theory and General Model

The general framework of the Random Utility Model (RUM) seems to provide a basis to address several important issues laid out in the literature above. First, the RUM allows for decision making of the type described by Shaw (1991) where decisions are made in stages such as come to the region or not, participate in the recreation activity of interest or not, and site choice among a number of alternative sites. More specifically a repeated nested logit model allows these different decision stages to be modeled while addressing the Independence of Irrelevant Alternatives (IIA) assumption (Morey 1999; Chen, Lupi, and Hoehn 1999). The RUM is also theoretically consistent with utility maximization and benefit estimates are easily calculated from the model once estimated.

Random utility theory poses that individuals will choose the destination or recreation option, on a given decision period, that will provide them with the greatest utility given their constraints (Louviere, Hensher and Swait 2000). The utility function for an individual then contains both a deterministic component (*V*) and a component that is unobservable to the researcher or stochastic (ε). This is represented in equation 1.

(1) $U = V + \varepsilon$

where V is the indirect utility function and can be characterized as follows:

(2) $V_i = \beta_k X_i$

For this function (2) X is a vector of k attributes associated with alternative i and β is a coefficient vector. The error terms for the nested logit specification are assumed to be generated by a generalized extreme value (GEV) distribution as proposed by McFadden (1978).

As Hwang and Fesenmaier (2003) point out multiple destination visitors seem to be cost minimizers when it comes to overall trip costs, i.e., rather than make a number of expensive trips to visit each site individually they bundle destinations together that are spatially close. This is congruent with Bell and Leeworthy's (1990) findings that length of trip is positively related to total trip cost. Thus, one would expect that multiple destination visitors investing in a long distance single-trip away from home, would tend to maximize total trip utility. This simply occurs when the visitor equates the ratios of the marginal utilities to prices across sites once in the region.

What becomes important for our model is how price per destination is defined. Following Bell and Leeworthy (1990) and the concept of the on-site travel cost model, individual site or destination price has two components. We define the two components as that portion of the long distance trip cost associated with getting to the area or region where sites or destinations are bundled, which can be attributed to a specific site or destination, and the variable cost of getting to the site once in the area where site choice occurs. This total site cost can be represented as follows:

(3) $SC_i = \tau_i \text{ LDTC} + VC_i$

SC_i is defined as the total site cost for destination or site *i*. τ_i is scalar or proportion by which the long distance trip cost (LDTC) to the region is multiplied by for site or destination *i*. The specifics of how this is calculated will be discussed when we discuss the data and estimation of the model. VC*i* is the variable cost associated with getting to site or destination *i* once the visitor is in the region where sites or destinations are bundled.

Our approach assumes the multiple destination visitor is most likely of the base camp type discussed by Hwang and Fesenmaier (2003). τ_i provides the ability of LDTC to be assigned along a continuum which might allow for several of the visitor types discussed by Kerkvliet and Nowell (1999), however. For example, if the person makes a side trip enroute that does not add to total long distance trip cost, τ is assigned a zero, and the only cost associated with the visit is the variable cost associated with that site. At the other end of the spectrum, the single destination and purpose visitor could have a τ that equaled one, if the different components of cost could be identified as described above. Obviously, in such a case the SC variable would mimic the normal travel cost variable used in the TCM for a single destination trip.

The indirect utility functions for each potential site or destination within a region has a vector of site attributes and an SC unique to that individual and site. Our site cost (SC) variable includes components of both travel cost to come to the region and variable cost to get to the site from the base camp destination. Recall that Bell and Leeworthy's (1990) travel cost per trip (TCPT) is the total roundtrip cost to the aggregate site in the on-site travel cost model. This variable is only appropriate in our model when $\tau = 1$ and all travel costs can be assigned to one site. Indirect utility functions for participating in other activities or deciding to come to the region or not could be modeled as well with our approach, given the available data as per Shaw's (1991) suggestions.

Our approach differs from the on-site travel cost model as proposed by Bell and Leeworthy (1990) in that the dependent variable becomes visits to each destination within the bundle of available sites rather than days spent on site. Moreover, number of days spent in the region, now becomes opportunities for more choice occasions to visit destinations within the site bundle region. Thus, as travel cost per trip as defined by Bell and Leeworthy (1990) increases we assume the number of choice occasions to visit sites within the destination region increases. Given the RUM formulation, we then assume, that on a given choice occasion, an individual site, which is available on the trip to the region, will be chosen when the utility from that site is greater than the other sites given the visitor's constraints. This approach allows visitors to visit a site as many times as they prefer up to the maximum number of choice occasions they have while in the region from their base camp destination.

The next step is to test our approach. Will this approach explain site allocation amongst multiple destination visitors in a manner consistent with theory? Can welfare estimates be obtained from this approach for a proposed site closure within the potential bundle of destinations?

Application of Model to a Unique Snowmobile Recreation Site

Now that we have laid out the basics of our modeling approach for multiple destinations, it is important understand the case in which we are applying it. More specific details of the model are dictated by the particular problem and data it is being estimated for.

In response to environmental issues, a preferred winter use management alternative of banning the use of snowmobiles in Yellowstone National Park (YNP), Grand Teton National Park (GTNP), and the John D. Rockefeller, Jr., Memorial Parkway (JDRMP) was proposed in an environmental impact statement (EIS) during the spring of 2000 (National Park Service 2000). Various changes in that policy have taken place since its proposed adoption as a result of federal administration turnover and court decisions stemming from appeals (Sullivan 2002; Black 2004). The future of snowmobile recreation inside the boundaries of YNP and GTNP continues to be uncertain, but the fundamental question of where snowmobilers will recreate, if these parks are closed, remains. This question has implications regarding the change in nonmarket benefits to snowmobilers and potential economic impacts faced by communities within the states surrounding the park.

Given the fact that numerous snowmobile sites exist in Wyoming, Idaho and Montana, the issue of substitutability is central to the estimation of benefit changes and economic impacts in the region surrounding these national parks. It has been proposed by a number of businesses in the region that a significant number of YNP visitors come to the region for a winter vacation and visit a number of sites while in the region (Lipsher 2004). In the face of a park closure to snowmobiles, what would the welfare impact be on these multiple destination visitors should the park be closed to snowmobiling? Given the potential for visitors to visit other snowmobile sites in the region, this case provides a natural experiment to apply our modeling approach to.

Data Collection

Data collection for this project involved intercept sampling and a follow up mail survey sent to YNP snowmobile recreators agreeing to participate in the project. Intercept sampling occurred on thirty-three days between December 15, 2001 through February 28, 2002. Recreators agreeing to participate were then asked to fill out a card with their mailing address, and they were informed that a questionnaire would be sent to them the first part of March. Moreover, each contact was given a one-page trip record sheet with a map on the reverse side for listed sites and asked to keep a log of their trips and the sites they visited between December 15, 2001 and February 28, 2002. Twice during the winter season survey participants were sent postcard reminders asking them to keep their trip record sheets up to date and to remind them this information would be important for filling out the survey they would receive in March. During the intercept sampling procedure the refusal rate was 9.5% and the final number of contacts in the database was 1162. Of those 1162 respondents, several addresses were removed due to bad addresses, foreign mailing addresses in Canada, and contacts that were professional guides. The final database for the first mailing had 1148 addresses.

Survey

The mail survey followed a modified Dillman (1978) design to insure an adequate response rate. The finalized survey was mailed to respondents March 4th. The response rate was 701 returns out of 1148 (61 percent).

The questionnaire is divided into seven sections. Section one asks basic questions about the respondent's snowmobile experience and days snowmobiled during the season. Section two asks for specific trip information during the December through February period. Specifically the revealed preference question provided a table with 28 different sites from Wyoming, Idaho and Montana allowing respondents to list the number of trips and days spent at each site during the specified survey period. Respondents were asked to refer to their trip record sheet or place the trip record sheet in the survey upon returning it for this question. Respondents were also given the opportunity to list "other" sites for each state that they recreated at and were asked to list the name of the site. An additional 20 sites were added to the choice set as a result of this question, bringing the total sites in the choice set to 48. This format was used to allow respondents to more accurately define the relevant choice set.

Much work has been done suggesting ill-defined choice sets for RUMs can produce biased results and welfare estimates (see Parsons and Kealy 1992; Parsons and Needleman 1992; Feather 1994; Karou et al. 1995; Haab and Hicks 1997; Parsons and Hauber 1998; Parsons, Plantinga and Boyle 2000). The aforementioned research has implications for choice set definition in this project. First, aggregation seems to have serious consequences on model and welfare estimation. As such, sites are not aggregated, but rather trail systems are presented as alternatives to sample respondents in this study. It is expected that individual trails within the identified systems are homogeneous enough in characteristics that this should not pose a problem. Moreover, given the large distances snowmobiles can cover within a day, trail systems seem to be the relevant site alternative for decision purposes. If an error has been made in choice set definition, it has likely been to include too many sites. The above research suggests this has less serious consequences on welfare estimates than narrow choice set definition. Questions were not included in the survey asking familiarity with all sites in the defined choice set as suggested by Hicks and Strand (2000) other than a map showing the geographic location of the listed sites and specifics about YNP characteristics due to concerns regarding questionnaire length.

Section three asks specific questions about their most recent trip to YNP including hours snowmobiled per day, number in party, etc. Section four asks respondents for information about their expenditures in and out of the YNP region on their most recent snowmobile trip. Section five asks several questions about their opinions regarding the potential phase out of snowmobile use in the park. Section six asks questions designed to elicit preferences for site and trip attributes. Section seven asks for demographic information about the respondent.

Additionally, data regarding average snow depth by site for both the 2000-2001 and 2002-2003 seasons for all 48 sites in respondents' choice set, and other site attributes such as miles of groomed trail, services within five miles of the trail head, and high and low elevation along the trails for each site were recorded.

Econometric Estimation and Model Specifics

Initial analyses using descriptive statistics, t-tests and chi-square tests indicated two distinct groups within the sample. One of the two groups was comprised of snowmobilers who visited multiple snowmobile sites during a single trip to the region (WY, ID, MT) surrounding YNP. This group comprised 40% of the sample. The other group could be categorized as people taking multiple snowmobile trips to a single site per trip, i.e., the classic single purpose and destination visitor. After controlling for item nonresponse in the questionnaire for model estimation and removing the single destination visitors there were 254 individuals representing

1,075 site visits taken in the three state region surrounding and including YNP and GTNP that will be used for this investigation in multiple destination trip modeling.

Table 3.1 Descriptive Statistics for Multiple Destination Segment - Selected Variables N=254.

Question	Yes	No	No Answer
Q8. Taken Snowmobile Trip to YNP before	49.21%	50.00%	0.79%
Q13. YNP primary destination of most recent trip	81.89%	17.72%	0.39%
Q17. Snowmobiling primary purpose of most recent trip to YNP	96.06%	3.94%	0.00%

Table 3.1 indicates that 96.06% of the snowmobilers that came to YNP on their most recent trip did so as their primary purpose and 81.89% of these visitors indicated YNP was the primary destination of their most recent trip. On the surface it would seem that modeling these individuals as single destination and purpose visitors would make sense. However, additional descriptive statistics indicate that these visitors made a single trip from home, and visited multiple sites while in Wyoming, Idaho and Montana visiting YNP. Moreover, these visitors traveled farther on average than the classic single destination portion of the sample. Our results seem to be consistent with past research. Borrie et al. (1999) found that 52 percent of all winter visitors sampled also recreated in other areas outside YNP on their trip while 84 percent stayed within the vicinity of YNP during their trip. Given these results, our approach to modeling these visitors assumes “base camp” behavior. That is, given that snowmobiling was the primary purpose of the trip for the vast majority of these visitors and YNP was their primary destination, we assume these visitors come to the region surrounding YNP and then make primarily additional snowmobile trips from one community.

During the intercept sampling process, data was coded with study participants as to which gate they were contacted at. We assume for purposes of this model that the community closest to the gate where contact was made is the base camp destination of the multiple destination respondents. For example, if the respondent is coded as being intercepted at the west entrance, West Yellowstone, MT is assumed to be that respondent's base camp destination. Travel distances and travel times using ground transportation for each respondent to the base camp destination from their home zip codes, and from the base camp destination to each of the 48 snowmobile sites were estimated using PC-Miler by ALK Technologies.

As discussed previously, these visitors are modeled in a RUM framework. Unfortunately, questions specific to decisions about coming to the region or not were not included in the survey. Thus, we model the decision to participate or not in snowmobiling once in the region, and subsequently the site choice decision is modeled if the visitor chooses to snowmobile. Nonparticipation in this model assumes they use a choice occasion while in the region to do something other than snowmobile. The choice to participate or not, along with site choice lends itself to the two level nested logit specification (Morey 1999; Chen, Lupi, and Hoehn 1999). The decision to come to the region or not is exogenous to our model. Figure 3.1 diagramatically depicts our modeling approach for this problem.

The probability of choosing a specific site in this two-level nested-logit model is depicted in Morey (1999) as follows:

$$\text{(3)}\quad \text{Prob(ni)} = \frac{\exp(s_n V_{ni})\left[\sum_{j=1}^{Jn}\exp\left(s_n V_{nj}\right)\right]^{(1/s_n)-1}}{\sum_{m=1}^{M}\left[\sum_{j=1}^{Jm}\exp\left(s_m V_{mj}\right)\right]^{1/s_m}}$$

where, for our model, M has two elements (nonparticipation or participation in snowmobiling once in the region). Dimension J has 48 sites. In this notation $n \in M$, and $i \in J$. For this notation and our estimation, which follows Morey (1999), $s=1/(1-\sigma)$ in McFadden's (1978) notation, or $s=1/\theta$ in Kling and Herriges (1995) where they refer to θ as the dissimilarity coefficient.

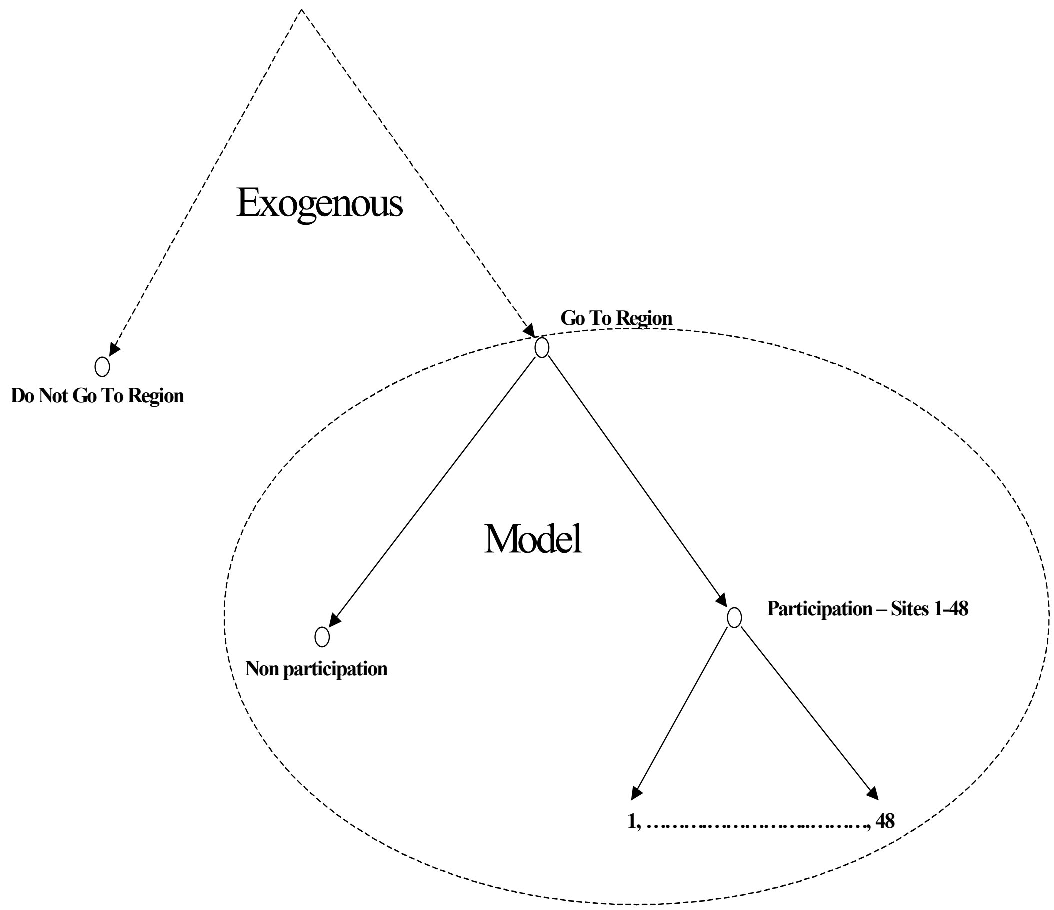

Figure 3.1. Depiction of two-level nested-logit model regarding site choice on multiple destination trip.

Per-choice occasion expected maximum utility is

(4) U = ln D + 0.57721 (Euler's constant),

where

$$(5)\ D = \sum_{m=1}^{M}\left[\sum_{j=1}^{Jm}\exp\left(S_m V_{mj}\right)\right]^{1/Sm}$$

Typical RUMs are linear in income, thereby imposing a constant marginal utility of income. For our model we assume zero income effects, i.e., constant marginal utility of income across all respondents. Herriges and Kling (1999) investigate the sensitivity of welfare estimates to nonlinear income effects in a Random Utility Model. They find that for most of their models the assumption of underlying error distribution has more impact on welfare estimates than nonlinear income effects. The authors point out these results may be somewhat sample specific, but the overall results point to the relative robustness of the linear income nested logit model. Moreover, computational burden is quite large for some of the techniques used by the authors. Thus, for this paper we do not deal with income effects in our model. Moreover, this is likely acceptable because our constant marginal utility of income only need hold locally, at the range of our compensating variation estimates, not globally at the full range of household income.

Given our assumption of zero income effects, compensating variation (CV) for site closure is calculated by the following:

$$(6)\quad CV = \left(\frac{1}{\mu}\right)\left(\ln D^{1} - \ln D^{0}\right)$$

where D^1 is defined as the expected maximum utility per choice occasion after site closure, and D^0 is the expected maximum utility per choice occasion before site closure. The change in expected maximum utility is obtained by multiplying by the inverse of the constant marginal utility of money ($1/\mu$). This is the absolute value of the parameter estimate of the price or SC variable for our model.

As with any econometric model, specification of and estimation procedure for the RUM can affect model performance and the resulting welfare estimates. Pendleton and Mendelsohn (2000) conclude that functional form in the RUM is important (linear versus quadratic in this case). Kling and Thomson (1996) and Morey (1999) suggest that Full Information Maximum Likelihood (FIML) has several advantages over sequential estimation. Larger welfare estimates were obtained by Kling and Thomson (1996) with sequential estimators compared to FIML estimators. Thus, our model was estimated using GAUSS and FIML. The use of a quadratic term for price (SC) was investigated.

Attribute variables and functional form were chosen based on theory, apriori expectations and goodness of fit criteria for the model. It was hypothesized that sites immediately surrounding YNP and GTNP could comprise a separate nest in the model. The three-level specification would not converge after trying a number of start values indicating the two-level nested-logit was the appropriate specification for the model. Moreover, goodness of fit criteria indicated the quadratic term on price was the appropriate specification.

Variables in the indirect utility equations for each site included a site cost variable (SC2). Recall from our previous discussion this cost had two components, which included a portion of the long distance trip costs to come to the region and the variable cost associated with traveling to the site from the base camp destination. The survey asked respondents for total trip costs by category and expenditures by category in Wyoming, Idaho and Montana. Long distance trip costs were assumed to be those costs that were incurred just to come to the region (WY, ID, and MT). These were based on individual costs such as lodging, gas, trip repairs and airfare if traveled by air on a per person basis. Expenditures for these categories within the region were subtracted from the total trip costs in these categories. This difference comprised the long distance trip costs which were apportioned to each site. The proportion (τ) of LDTC assigned to each site was estimated based on roundtrip travel time to get to the site, plus actual or average on-site time. This site time estimate was converted to days by dividing by 10 (i.e., 10 hours per recreation day was assumed). This site time in days was then divided by total days in the region for an estimate of τ. Thus, the more time it took to get to and from a site the more of the long distance trip costs were assigned to that site. The variable cost to get to the site was based on roundtrip distance to the site from the base camp destination multipled by a standard mileage rate of $0.2185/mile (rate based on AAA estimate SUV pulling trailer with one or two snowmobiles in 2001 dollars). These two components were summed to estimate site cost for each individual to each of the 48 sites in the choice set.

The value of travel time to the site was not included in site cost or as a separate variable to avoid potential collinearity or simultaneity problems given our site cost variable. There continues to be debate as to how travel time and on-site time should be valued (see McConnell 1992; Feather and Shaw 1999; Shaw and Feather 1999; and Berman and Kim 1999). The remainder of the variables included in the indirect utility functions for each site beside SC were site specific attributes such as length of trail (Stelng), an interaction between length of trail and trail grooming (Stetlgm), a binary variable indicating if 50% or more of the trail is groomed (Stegrm), a binary variable indicating if services were either on the trail or within five miles of the trailhead (Stesrv), the difference between the high and low point in elevation on the trail (Steeldf), and the average snowpack from snotel sites on the trail system for January and February of 2002 (Sn02ste). A binary variable was also included to capture the potential unique amenities of YNP and GTNP as compared to the other sites (Steamn) where YNP and GTNP were coded as 1 and other sites were not. The dependent variable for each site equation is the respondent's trips taken to that site for their choice occasions between December 15, 2001 and February 28, 2002.

The indirect utility equation for nonparticipation includes a constant and a variable for the respondent's level of education (Educ). The final variable included in the nonparticipation equation is based on the respondent's number of years of snowmobiling experience (yrssnow). The number of choice occasions for individuals in this segment of the data is based on the number of days available to snowmobile, i.e., number of days in the region during the specified dates in the trip record sheet, on their single trip to the region. Nonparticipation was estimated as number of choice occasions minus total trips or site visits taken according to the trip record sheet.

Model Results and Welfare Estimate

As can be seen in Table 3.2 the model is highly significant in explaining site choice behavior for our multiple destination segment of the data according to the model chi-square statistic. The pseudo or McFadden's r^2 of 0.2533 suggests the fit is reasonably good, especially for these types of models. The scale parameter is greater than one and significant indicating the model is globally well behaved (Morey 1999).

All of the variables in the model are significant at the α=0.10 level, and many meet with apriori expectations regarding sign. First, and foremost the cost variable (SC2ste) is highly significant and negative indicating the probability of choosing a site decreases as price increases. The quadratic term on price is positive and significant as well. The majority of the site attributes are also as expected. Results indicate that length of trail (Stelng), grooming (Stegrm), services

Table 3.2 Model Results for Single Trip to Region and Multiple Sites Visited Segment –N=254.

Variable	SC2 2NL Quadratic
SC2ste	-0.1288
	(0.0055)
$SC2ste^2$	0.0043
	(0.0058)
Stelng	0.0034
	(0.0664)
Stetlgm	-0.0068
	(0.0165)
Stegrm	0.0677
	(0.0303)
Stesrv	0.0939
	(0.0093)
Steeldf	0.0061
	(0.0882)
Steamn	0.1946
	(0.0062)
Sn02ste	0.0027
	(0.0071)
Constant	0.4587
	(0.0362)
Educ	-0.0775
	(0.0144)
Yrssnow	-0.0150
	(0.0004)
s – scale	11.5906
	(0.0058)
McFaddens R^2	0.2533
LL	-3953.3830
LL – Constant	-5294.5030
Model χ^2	2682.2400
Critical $\chi^2_{\alpha=0.05}$	21.026

* Probabilities reported in parentheses for asymptotic t-statistics.

on or near the trail head (Stesrv), elevation difference which could be a proxy for roughness (Steeldf), and average snowpack (Sn02ste) are all positive and significant. These variables indicate that the probability of taking a trip to the site increases as these attributes either are present or are relatively higher in quantity relative to other sites in the choice set.

An interesting result is the interaction term between grooming and trail length (Stetlgm), which is negative in sign and significant at the $\alpha = 0.05$ level (Table 3.2). This suggests that as there is more groomed trail at a site the probability of visiting the site decreases. This may very well suggest these snowmobile recreators prefer trails that are less developed or maintained. This variable could also be a proxy for congestion, in that you would expect more snowmobilers, and perhaps more novice snowmobilers, at more developed and better maintained trail sites. The site amenities variable (Steamn) is positive and significant indicating the unique amenities of YNP and GTNP do increase probability of this segment snowmobiling at this site. This could be an artifact of the sampling frame, but RUMs estimated for the other segment (single destination segment) of the data did not suggest this variable added to the explanatory of the model. Overall, this may suggest that YNP and GTNP is very much a draw for this visitor segment to snowmobile in this region on their winter vacation.

The indirect utility function for nonparticipation has some interesting results. As expected, years of snowmobiling experience (yrssnow) is significant and negatively related to nonparticipation (Table 3.2). As snowmobile experience increases in this visitor type, the probability of not snowmobiling once in the region decreases. The variable related to education is significant and also negative, suggesting the more education this visitor type has the more likely they are to snowmobile once in the region. This variable may very well be acting as a pseudo proxy for income.

Using Model to Estimate Loss in Benefits from Snowmobile Ban in YNP & GTNP

The compensating variation for this group was estimated by evaluating D^0 at the means of all the variables for the sample, and D^1 was estimated by forcing the price of YNP and GTNP to essentially go to infinity or where trip share probability for these two sites went to zero. This essentially simulates a ban on snowmobiling in the two parks. The estimates were adjusted for the scaling in price (i.e., multiplied by 100), which was done to keep parameter estimates near the same magnitudes during model estimation. The per choice occasion CV for this segment of the sample is estimated to be a loss of \$15.65. The annual CV estimate is based on an average of nearly seven choice occasions per individual in the sample during the season. This puts the estimated annual loss to multiple destination visitors in this sample at \$105.45 if YNP and GTNP are closed to snowmobiling. Even though there are number of sites available for this visitor segment to go to in the region, the closure of YNP and GTNP still results in an estimated welfare loss to them. Assuming visitors to YNP and GTNP are similar to our sample proportions, approximately 33,288 visitors per year would lose a total of \$3.5 million in benefits annually. The magnitude of estimated loss suggests ignoring or dropping these visitors from the sample would likely bias welfare loss estimates for snowmobilers.

Table 3.3 Predicted Change in Welfare or Compensating Variation (CV) Trips with Site Closure.

	CV Estimate
Per Choice Occasion CV	-\$15.65
Annual Change in CV	-\$105.45

Discussion

A key assumption of most recreation demand models used in nonmarket valuation is that each trip taken is for a single purpose and to a single destination. The assumption of single purpose and single destination in the recreation demand model avoids the issue associated with joint travel cost in a multiple destination trip. Often times multiple destination visitors are ignored in many policy analyses because of the difficulties they pose. This practice would provide inaccurate welfare estimates and policy informationj in our case study of banning snowmobiles from Yellowstone and Grand Teton National Parks. The purpose of this paper has been to illustrate a modeling approach that explains site choice in a multiple destination trip and provides welfare change estimation for this type of visitor given a site closure.

Our approach builds on concepts in the travel literature as well as the economic literature. This approach extends the concepts used in the on-site travel cost models, but uses trips or site visits as the dependent variable rather than days on site. This approach better addresses site allocation and the potential for substitution than traditional on-site travel cost models. Price is modeled as a sum of two components, a proportion of the long distance travel cost to come to a region where bundling of sites occurs and the variable cost associated with visiting an individual site in the region destination. This approach seems to address a number of concerns expressed in the literature with the on-site TCM. The model seems to perform relatively well, and the results are consistent with theory in explaining site choice for a sample of multiple destination visitors faced with the potential loss of a unique snowmobile recreation site. Welfare estimates are also relatively easily obtained from this approach.

We argue this approach makes a contribution to the research literature as it stands, but it is certainly not without its limitations. As with any model several simplifying assumptions were made to make the model tractable and estimable. First, given data limitations, the decision to come to the region of interest where the potential sites were bundled was assumed to be exogenous to the model. Greater insight into multiple destination behavior would likely be gained by including this decision stage in the model. Gathering more information in the survey instrument focused on this decision could allow this decision stage to be modeled. The visitors in our sample were assumed to behave in a "base camp" fashion. Thus, they were assumed to come to one destination in the region from which all snowmobile trips originated. While we believe this is a reasonable assumption for this particular data set, this type of assumption is a limitation when applying this approach to a broad range of policy relevant problems. Finally, we believe the long distance travel cost (LDTC) represents an investment to come to the region and is important to apportion to individual site cost. Research that investigates whether site cost modeled solely as the variable cost to get to a site once in the region performs similarly both in model and welfare estimation would be beneficial.

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Stated Preferences for Great Lakes Coastal Wetland Programs

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ABSTRACT

Coastal wetlands represent unique and biologically important ecosystems in the Great Lakes region (Canadian Wildlife Service, 2002). Despite their ecological value, Great Lakes coastal resources are increasingly under pressure and threatened by urban sprawl, coastal development, beach grooming, invasive species, hydrologic changes, and environmental degradation. The purpose of this research was to learn about public preferences for different Great Lakes coastal wetland preservation and restoration programs, as well as to gain information on residents' knowledge and use of Great Lakes coastal wetlands. By addressing critical information needs for ecosystem management and by estimating the public's willingness to make trade-offs, the research addresses W1133 research theme number 1: Estimate the economic benefits of ecosystem management of forests and watersheds.

A mail survey was used to gather the needed data from a random sample of Michigan residents twenty-one years or older. To collect information on the public's wetland program preferences, the survey also included a structured stated choice question asking respondents to make trade-offs between attributes of Great Lakes coastal wetland programs. The three program attributes in the stated choice question were: the ecological service which would be the "priority" of the program; the program's "mix" of effort between preservation and restoration activities; and the "tool" used for land acquisition. This later attribute is especially important in light of the policy need for conservation contracting. In making a selection between the alternative programs, respondents revealed their preferences for the various attributes. A logit model revealed that:

- Among possible program priorities, respondents preferred programs placing a priority on *Water Quality and Flood Control* or *Biodiversity* to the other priorities examined.
- Respondents significantly prefer programs with a priority on *Waterfowl Habitat* to those providing *Open Space near Cities*, but a priority of *Waterfowl Habitat* was of lesser importance than a priority of *Biodiversity* or *Water Quality and Flood Control*.
- Programs prioritizing *Fish Habitat*, *Non Game Species Habitat* or *Open Space Near Cities* were not significantly different from each other and were of lower importance to respondents than *Biodiversity* or *Water Quality and Flood Control*.
- Respondents preferred wetland protection programs with higher levels of effort devoted to preservation as opposed to restoration, and wetland protection programs with 72% of their effort focused on preservation were the most preferred.
- Respondents preferred programs acquiring land thru *Purchase of Property* to those using *Permanent Easements* which was preferred to the use of *Ten Year Contracts.*

The study results demonstrate that the citizens of Michigan have a varied understanding of Great Lakes coastal wetlands. The research also reveals that the public has definite preferences about the relative attractiveness of programs for Great Lakes coastal wetland protection. Because public support of coastal wetland programs can make them more successful, it is important to address the public's understanding and preferences in the design and implementation of wetland protection programs. This research is one step towards understanding people's preferences for wetland protection/restoration programs and informs ecosystem management of watersheds.

INTRODUCTION

Great Lakes coastal wetlands represent unique and biologically important ecosystems in the Great Lakes region (Canadian Wildlife Service, 2002). Despite their ecological value, Great Lakes coastal resources are increasingly under increasing pressures from urban sprawl, coastal development, beach grooming, invasive species, hydrologic changes, and environmental degradation. Great Lake coastal wetlands provide a variety of environmental services including the support of non-game species; provision of open space; protection of water quality; flood control; provision of fish and waterfowl habitat; as well as maintaining biodiversity.

More information about the public preferences for wetlands is a critical need (Mitsch and Gosselink, 2000; Environment Canada, 2002). Increasingly, policymakers and scientific experts see restoration activities as central for maintaining and improving natural resources and ecosystems. In the Great Lakes region, U.S. Senators recently introduced federal legislation to fund large-scale restoration activities that includes a significant component focused on Great Lakes wetlands (GLA 2005, GLERA 2005). Decision making concerning GL coastal ecosystems can benefit from incorporating public preferences for coastal wetlands and wetland services. Public input is critical for success of coastal wetland protection and restoration efforts.

The reported research asked people about their experience with Great Lakes coastal wetlands and asked them to make trade-offs between wetland programs with different protection foci, levels of preservation and restoration effort, and land acquisition methods. The research provides a first step towards a better understanding of what the public values about Great Lake coastal wetlands and those programs designed to protect and restore them.

METHODS

Survey Questionnaire Design & Pretesting

The stated choice approach (Louviere et al, 2000) was used to elicit preferences for wetland program characteristics using a mail survey. The survey questionnaire was designed to be "user-friendly;" easy for respondents to understand and follow. The first section of the questionnaire was designed to gather information on respondents' knowledge of and experience with Great Lakes coastal wetlands. Questions also collected information on respondents' knowledge of the types of programs associated with wetland protection and restoration. These questions led to a "stated choice question," which will be explained in detail later. Briefly, the stated-choice question was designed to force respondents to make trade-offs between alternative wetland programs so that the researchers could gain information on respondents' preferences for the characteristics of Great Lakes coastal wetland programs.

Stated choice survey instruments typically go through pre-testing as part of the design and development process (Kaplowitz et al. 2004). Pre-testing helps to ensure questionnaire language is understandable, and questions are realistic and meaningful to respondents. For the Great Lakes coastal wetland survey, two types of pre-testing were used. First, pretest interviews were conducted using intercept interviews with participants randomly selected in public venues. For this, the researchers used two different "food courts" at shopping malls and successfully completed 20 pre-testing sessions. Interviewers approached individuals in the food court areas, and asked them if they would be interested in filling out a "public policy" survey. Potential participants were told that they would receive an honorarium of $10 for participating. After participants filled out the draft survey instrument, they were asked a series of questions pertaining to the survey, its design, and their opinion of it. The questions asked of respondents during the pre-test interviews were designed to determine if respondents understood the information and questions in the questionnaire. They were also designed to evaluate whether the stated choice question worked as intended.

The second pretest interviews were conducted using the telephone recruitment of randomly selected individuals in mid-Michigan to invite them to the Michigan State University campus for scheduled individual interviews. Two sessions of individual pre-test interviews were held, the first on November 20, 2003 and the second on December 10, 2003. Each person randomly contacted by phone was asked if they would be interested in participating in an interview on public policy at Michigan State University. They were told that they would be asked to complete a survey questionnaire and then discuss their answers. Potential participants in the on-campus pretest interviews were offered a $20 honorarium. Like the intercept pretest interviews, on-campus interviewees were asked about their experience with the survey instrument. In total, 23 on campus pretest interviews took place, with each interview lasting about 20 minutes. Based on the two sets of pre-testing interviews, the survey questionnaire was modified and revised to clarify items and improve its design.

Implementation

The initial survey sample consisted of 1,650 individuals, randomly drawn from a list of names and addresses obtained from the Michigan office of the Secretary of the Sate. The list was made up of Michigan residents, twenty-one years or older, who possess a valid drivers license or State of Michigan identification card. A stratified random sample was drawn, with sample strata that corresponded to the seven most populous counties in Michigan (Gibson). The strata ensured that specific counties with large percentages of Michigan's population were accurately represented, so as not to over or under sample them. The seven counties and their sample percentages are: Genesee, 4.3%; Ingham, 2.9%; Kent, 5.6%; Macomb, 8.2%; Oakland, 12.2%; Washtenaw, 3.4%; and Wayne, 20.2%. The eighth strata contained all other counties in Michigan and represented 43.2% of the sample.

The survey was implemented from March to May, 2004 through the mail using the tailored design method (Dillman, 2000). The mail survey consisted of five contacts: a pre-notice letter, a survey booklet, a reminder postcard, a replacement questionnaire, and a final contact and replacement questionnaire. To the extent possible, each contact was personalized. All letters were addressed directly to respondents and printed on high quality, watermark paper. Letters and postcards were hand signed, and the large format questionnaires were printed in color on glossy paper.

Of the 1,650 persons in the initial sample, 413 had invalid addresses (i.e., at least one notification that the address was not correct was received). Removing invalid cases yielded a sample with 1,237 valid addresses. In total, 540 completed survey questionnaires were returned yielding an overall response rate for the survey of 43.65%. These response rates are determined using the methods outlined by the American Association for Public Opinion Research (2004). Of the 540 surveys completed, only 539 were returned in time for model estimation; hence, results in the subsequent sections are based on those 539 completed surveys.

Demographic Characteristics of the Sample

This section presents the general characteristics of the group of citizens that participated in the survey, followed by sections that present the responses to the questionnaire. The information contained in the Table 1 was generated from the returned questionnaires and the 2000 Population Survey (U.S. Census Bureau, 2000). Table 1 shows that the demographic characteristics of the survey sample are reasonably similar to those of Michigan's general population.

Table 1. Comparison between Survey Respondents and Census Results for Michigan

	Survey Sample	State of Michigan
Average Household size	2.76	2.56[3]
Average age	49.8	46.4[4]
Household Median income	$42,500	$46,986[5]
Education		
High school graduate or higher	63.7%	61.6%[6]
Bachelor's degree or higher	30.7%	21.8%
Ethnicity		
White	89.3%	80.7%[7]
African American	4.7%	13.0%
Hispanic, Latino or Spanish	1.2%	2.7%
Female	52.4%	51.8%[8]

The average household size of respondents is slightly larger, and not substantially different than the State of Michigan Average (2.76 and 2.56 persons respectively). The average age of respondents in the survey is above the State average (49.8 compared to 46.4 years). Household median income of survey respondents ($42,500) is slightly below the State's median ($46,986). Looking at educational attainment, a slightly higher percentage of individuals responding to the survey have a high school degree or higher, compared to Michigan's

[3] U.S. Census Bureau, Census 2000. Table DP-1 Profile of General Demographic Characteristics: 2000. Geographic area: Michigan.
[4] Computed from: U.S. Census Bureau, Population Estimates Branch, "Estimated Population of States by Age Group and Sex, 2000-2003" as released by Census Bureau on March 10, 2004; for population over 20 years.
[5] U.S. Department of Commerce, Economics and Statistics Administration. U.S. Census Bureau. Money Income in the United States: 2000, page 12; for population 25 years and over.
[6] Educational information obtained from U.S. Bureau of the Census, Census 2000. Table DP-2 Profile of Selected Social Characteristics: 2000. Geographic area: Michigan; for population 25 years and over.
[7] U.S. Bureau of the Census. Census 2000. Table PL4. Hispanic or Latino and Not Hispanic or Latino by Race for the population 18 years and over [73] - Universe: Total population 18 years and over. Data Set: Census 2000 Redistricting Data (Public Law 94-171) Summary File. http://factfinder.census.gov/.
[8] U.S. Bureau of the Census. Census 2000. Table DP-1.Profile of General Demographic Characteristics: 2000. Data Set: Census 2000 Summary File 4 (SF 4). Summary File. Geographic Area: Michigan. For population 18 years and over. http://factfinder.census.gov/

population (63.7% and 61.6% respectively), and a larger percentage of respondents, 30.7%, hold a Bachelor's Degree or higher when compared to comparable figure of 21.8% for the state.

Most of the respondents identify themselves as 'white', followed, in much smaller percentages, by 'African Americans' and 'Hispanic, Latino or Spanish origin'. Other minority groups were, 'Hawaiian or other Pacific Islander' (0.6%), 'Asian' (0.8%), 'American Indian or Alaska native' (0.6%) and 'other' (2.9%). The more survey respondents identify themselves as 'white' (89.3%) than is the case for the state (80.7%). Overall, the sample of survey respondents compares reasonably well to the census data for Michigan, though it under-represents minorities.

What People Say About Wetlands

The survey collected information on respondents' coastal wetland knowledge and use as well as information on coastal wetland program preferences. The knowledge and use questions revealed, among other things that:

- 52% of the respondents visited a Great Lakes coastal wetland within the last year and an additional 17% have ever been to a Great Lakes coastal wetland.
- Of respondents that visited a wetland last year, 22% fished or hunted, 27% watched birds, and 62% enjoyed the outdoors.
- Among recreational activities that wetlands support, respondents reported the highest level of importance of wetlands for fishing (60%) and bird watching (61%).
- When queried about the importance of various ecological services of wetland, between 93% and 99% of respondents rated the services as "extremely important" or "somewhat important."
- Respondents identified shoreline development (71%) and urban expansion (70%) as "extremely serious" threats to wetlands.

As an overall measurement of respondent's perception of wetlands importance, two questions were raised in the survey booklet: one question asked about the importance of knowing that wetlands are there (an existence value), and a second one asked about the importance of knowing that wetlands will be there for future generations (a bequest value). In answering these questions the vast majority of the respondents indicated that wetlands are from 'extremely important' to 'somewhat important', supporting the idea that the public recognizes existence value and future bequest value of wetlands. Of the respondents 61.1% believe that it is 'extremely important' to know what wetlands are there, and an additional 30.3% believe it is 'somewhat important'. Even more people, 70.7% believe it is 'extremely important' to know that wetlands will be there for future generations, with an additional 22.8% believing that it is 'somewhat important'.

STATED CHOICE MODEL

A stated choice questionnaire was designed to elicit the preferences of Michigan residents over alternative coastal wetland programs. Stated choice methods develop statistical relationships between people's choices and the attributes of the alternatives they choose among (Adamowitz et al, 1994, 1998; Louviere et al, 2000; Lupi et al, 2002). The wetlands programs included in the stated choice questionnaires had features that varied in the environmental services, the mix of preservation and restoration activities, and the tools used for acquiring land preservation and restoration.

The stated choice question asked each respondent to choose one of two alternative programs. Each program alternative contained three attributes: the ecological services that the program would focus on as a program "priority"; the "mix" of effort divided between preservation and restoration of coastal wetlands; and the "tool" used for land acquisition. The program alternatives were presented side by side for easy comparison of the attributes. The choice question was a binary discrete question that asked for a yes/no type of answer. Respondents were asked to choose whether they preferred program A or program B, based on the attributes given. Table 2 depicts the general scenario given to respondents.

In answering the choice question, respondents must make tradeoffs in selecting a program. They evaluate the features of a program and select the program with the bundle of features that they prefer. By making a selection, respondents are choosing a program based on

Table 2: Example Survey Page Showing One Version of the Stated Choice Question (One Choice Scenario)

WHICH PROGRAM WOULD YOU PREFER?

The two programs described below take different approaches to coastal wetland protection. Please compare the two programs before answering Question 8.

	PROGRAM A	PROGRAM B
Of the many features coastal wetlands provide, which is the program's highest priority?		
Primary Focus	**Water Quality and Flood Control**	**Non-Game Species**
How the program effort and resources are divided		
Preservation of high quality coastal wetlands	**40% Preservation**	**60% Preservation**
Restoration of coastal wetlands in poor condition	**60% Restoration**	**40% Restoration**
How the program gets coastal wetland sites from volunteers		
Pays for purchase, permanent easement, or ten-year contract	**Purchase Property**	**Permanent Easements**

8. If the state had to choose one of these two programs for protecting coastal wetlands, which of these programs would you prefer?
(Circle one response)

a. Program A
b. Program B

how they make these tradeoffs. By varying the program features across respondents, we can estimate how the choices respond to the features of the program. That is, we can estimate respondents' preferences for the attributes of wetland programs.

Experimental Design of the Stated Choice Question

The experimental design of a stated choice question refers to the method for combining the attribute levels into alternative programs, and how these programs are then combined to create the choice scenarios to be presented in the survey. For example, the two columns on the right hand side of Table 2 represent "alternatives" in the choice question. Together, the alternatives form a choice "scenario." The rows present information on the "level" of a program "attribute," and by comparing columns respondents can see how the attribute levels may differ across the alternative programs in a choice scenario.

Table 3. Program Priority, Mix, and Tool Attribute Levels

A

Priority:
Non Game Species
Open Space Near Cities
Water quality & flood control
Fish Habitat
Waterfowl Habitat
Biodiversity

B

Mix:
10 % Preservation, 90% Restoration
25 % Preservation,75% Restoration
40 % Preservation, 60% Restoration
50 % Preservation, 50% Restoration
60 % Preservation, 40% Restoration
75 % Preservation, 25% Restoration
90 % Preservation, 10% Restoration

C

Tool:
Purchase Property
Permanent Easements
Ten Year Contracts

In our survey, three attributes were offered in each of the two programs (Table 3). Each attribute was made up of various levels. In Table 3, "Priority" refers to the six different program priorities presented in the programs. It is the priority offered to respondents as the programs primary focus. An individual has two programs to choose between, and each program has a priority, that can be any one of the six. The specific level of an attribute that appears in a given scenario is pre-determined by the experimental design of the choice model. "Mix" refers to the split between preservation and restoration offered in each program. The programs vary between the seven levels. It shows how program resources would be split between the two activities. “Tool” refers to the approach used for acquiring the acreage for coastal wetland preservation or restoration. It is how the program gets coastal wetland sites from volunteers.

The levels are the possible values that an attribute might take in any choice scenario. The attribute for the primary focus of a program, “priority,” contained six levels. The attribute for the “mix” of effort devoted to preservation or restoration activities contained seven levels. The attribute for the “tool”, or the method used to acquire land for the program, had three levels. Column A of Table 3 shows the different wetland “priorities”; column B of Table 3 shows the preservation/restoration “mix”; and column C of table 3 shows the three different “tools” for implementing the program utilized by the survey. The attribute levels vary across alternatives within choice scenarios as well as across choice scenarios. Respondents must make tradeoffs between these levels of attributes when making a program selection and their selection forms the basis for estimating preferences.

In order to estimate the response of the choice probability to the programs features (the attribute levels), we need variation in the attribute levels across alternatives and across choice scenarios. Hence, a method is needed to combine the possible attribute levels into alternatives and choice scenarios in a manner that provides sufficient variation in the attributes (Louviere et al. 2000). One approach uses a full factorial design in which every level of every attribute is combined with every level of all other attributes. In our case, the factorial design would result in $6^2 X 7^2 X 3^2 = 15{,}876$ combinations (choice scenarios). Because this number of combinations is too large, a main effects design was utilized. A main effects plan represents a set of choice scenarios consisting of the fewest number of combinations of attributes that will still ensure independence of the main effects of the attributes within and across alternatives. With the main effects design our attributes and levels led to a design with 96 alternatives combined into 48 choice scenarios.

The Model

In order to estimate preferences from the stated choice question, we use the random utility model approach. We briefly present the random utility theory before presenting the statistical model used to estimate preference parameters. First, the random utility model is based on the standard economic assumption that individuals will try to maximize their utility, U. Put differently, it is assumed that individuals will pick the alternative they like best. That is, an individual, i, will choose alternative a over alternative b if:

$$U_{ai} > U_{bi}. \tag{1}$$

The subscripts a and b refer to alternative a and alternative b in the choice experiment, and U_{ai} is the utility of the a^{th} alternative for the i^{th} individual (Louviere et al. 2000). The model also assumes that U_{ai} has two components, a systematic or 'representative utility' component, V_a, which is deterministic, and an additive random component, ε_a, which is the stochastic term.

$$U_{ai} = V_a + \varepsilon_a \quad \text{for alternative } a\text{, and} \quad U_{bi} = V_b + \varepsilon_b \quad \text{for alternative } b. \tag{2}$$

V_a, the representative utility component, is an expression in terms of the attributes of an alternative in the choice question, a vector of all attributes in an alternative (X). The usual specification is followed by writing V as a linear-in-parameters function of the attributes (Louviere et al. 2000) as follows:

$$V_a = \beta X_a \qquad \text{and} \qquad V_b = \beta X_{b,} \tag{3}$$

where β is the vector of the preference parameters associated with the attributes, X, that make up alternatives a and b. The preference inequality can be used to specify the probability that option a is chosen over option b,

$$\text{Prob}(U_a > U_b) =,\text{Prob}\ (\beta(X_a - X_b) + \varepsilon_a - \varepsilon_b > 0) = P_a, \tag{4}$$

where P_a equals the probability that alternative *a* is preferred to *b*.

To achieve the desired goal of estimating the β's, an assumption about the errors must be made. A common approach involves assuming that the errors, ε's, are independent and identically distributed from a type I extreme value distribution which yields the logit form for the choice probabilities as follows:

$$P_a = \text{F}(\beta X) = 1 / (1 + e^{-(\beta X)}), \tag{5}$$

with $X = X_a - X_b$ in our model. This logit form is the basic choice model that was estimated here and is a widely used form of the random utility model for stated choice data.

Estimation of the Model

The model is estimated by maximum likelihood estimation, the estimation method most commonly used for logit models (Wooldridge, 2000; Louviere et al. 2000). The exact specification of the model in terms of the specific variables is given by:

$$\begin{aligned} V = \beta X = \ & \beta_1 \textit{Non Game Species} + \beta_2 \textit{Water Quality and Flood Control} + \\ & \beta_3 \textit{Fish Habitat} + \beta_4 \textit{Waterfowl Habitat} + \beta_5 \textit{Biodiversity} + \\ & \beta_6 \textit{Purchase Property} + \beta_7 \textit{Permanent Easements} + \\ & \beta_8 \textit{Percent Preservation} + \beta_9 \textit{Percent Preservation}^2 \end{aligned} \tag{6}$$

The specific variables in equation (6) are all defined in Table 4. The goal was to estimate the β's, which indicate the effect that each of the variables has on utility, and consequently, through equation (5), relate the probability that individuals prefer one program to another given the attributes of the two programs.

Table 4. Variables Used in the Estimation of the Choice Probability.

	Variable	Variable Definition
"Priority"	*Non Game Species*	A dummy variable indicating whether *Non Game Species* is the program's top priority.
	Water Quality and Flood Control	A dummy variable indicating whether *Water Quality and Flood Control* is the program's top priority.
	Fish Habitat	A dummy variable indicating whether *Fish Habitat* is the program's top priority.
	Waterfowl Habitat	A dummy variable indicating whether *Waterfowl Habitat* is the program's top priority.
	Biodiversity	A dummy variable indicating whether *Biodiversity* is the program's top priority.
	Open Space Near Cities	A dummy variable indicating whether *Open Space near Cities* is the program's top priority. Since it is the baseline for comparison of the priority variables, it is not reported in Table 5.
"Tool"	*Purchase Property*	A dummy variable indicating whether or not *Purchase Property* was the approach used to acquire wetland acreage.
	Permanent Easements	A dummy variable indicating whether or not *Permanent Easements* was the approach used to acquire wetland acreage.
	Ten Year Contracts	A dummy variable indicating whether or not *Ten Year Contracts* was the approach used to acquire wetland acreage. Since it is the baseline for the tool variables, it is not reported in Table 5.
"Mix"	*Percent Preservation*	A continuous variable representing the percentage of program effort devoted to preservation.
	Percent Preservation^2	A continuous variable representing the percentage of program effort devoted to preservation, squared, to show the non-linear effects.

To estimate the model, the levels for the "priority" and "tool" variables were converted to binary variables, due to the fact that they were not continuous (see Table 4). Because the "priority" and "tool" variables were binary variables, one level of each of these attributes served as the baseline in the logit regression. This meant that the effect of the remaining levels of the "priority" and "tool" attributes must be interpreted relative to the levels of the variable that served as the baseline. *Open Space near Cities* was the level omitted from the regression for program priorities, and was therefore the baseline for program priorities. Coefficients for the remaining program priorities are interpreted as the effect on the level of utility, or the choice probability, relative to the effect on the choice probability that *Open Space near Cities* has. *Ten Year Contracts* was the variable omitted from the regression for program tools, and was likewise the baseline for program tools. All remaining attribute levels for program priorities and program tools were included as variables, and their estimated parameters must be interpreted as the effect they have on utility relative to the omitted attribute of their group.

The attribute "mix" (see Table 4) was represented by the continuous variable, *Percent Preservation*. *Percent Preservation* is based solely on the preservation level of the mix attribute because the percent preservation and percent restoration levels for a program always add to 100%. The variable *Percent Preservation* takes on seven levels, ranging from 10% to 90% (see Table 3). To examine possible non-linear effects for this variable, a squared term called *Percent Preservation*^{2} was included in the estimated model.

Estimation Results

The estimation of the logit choice model was based on the 512 observations that had valid responses for the choice question. The estimation results for the logit model are presented in Table 5. The estimated coefficients (the β's) associated with each of these variables (the attributes of *X*) indicate the effect the variable has on the choice probability (the utility level). A positive β indicates that, holding other variables constant, the variable has a positive effect on the choice probability.

Table 5. Estimated Parameters from the Stated Choice Model

Variable (*X*)	Coefficient (β)	t-stat	p-value
Purchase Property	0.682	3.897	0.0001
Permanent Easement	0.353	2.153	0.0313
Percent Preservation	0.043	3.868	0.0001
Percent Preservation Squared	-0.0003	-3.052	0.0023
Non Game Species	0.184	0.887	0.3751
Water Quality and Flood Control	0.902	3.582	0.0003
Fish Habitat	0.237	0.955	0.3396
Waterfowl Habitat	0.498	2.101	0.0357
Biodiversity	0.833	3.397	0.0007

Though not shown in Table 5, one way to assess the logit model performance is to examine the percent correctly predicted. This classification compares the actual choice (program A or Program B) with the predicted choice, using the estimated parameters. The percent correctly predicted classification refers to the percentage of times in the actual data that the predicted choice corresponds with what the respondent actually selected. For the estimated logit model, the percent correctly predicted classification is 67% overall and its performance is well-balanced for both Program A and Program B predictions. Moreover, another statistical test reveals that when compared to a chance explanation of choices, the overall model is highly significant (Gibson).

For each estimated parameter, Table 5 also presents the t-values and p-values for the hypothesis test that the parameter is equal to zero. Seven of the nine variables are statistically significant at the 5% level (that is, they have p-values smaller than 0.05). Only *Non Game Species* and *Fish Habitat* are not statistically significant. The low statistical significance of *Fish*

Habitat and *Non Game Species* does not mean that they do not have an effect on the probability of selecting A. It just means that they do not have a statistically different effect on the choice probability than does the baseline level for program "priority", *Open Space near Cities*. These three priorities are not statistically different from each other in their effect on choice probabilities.

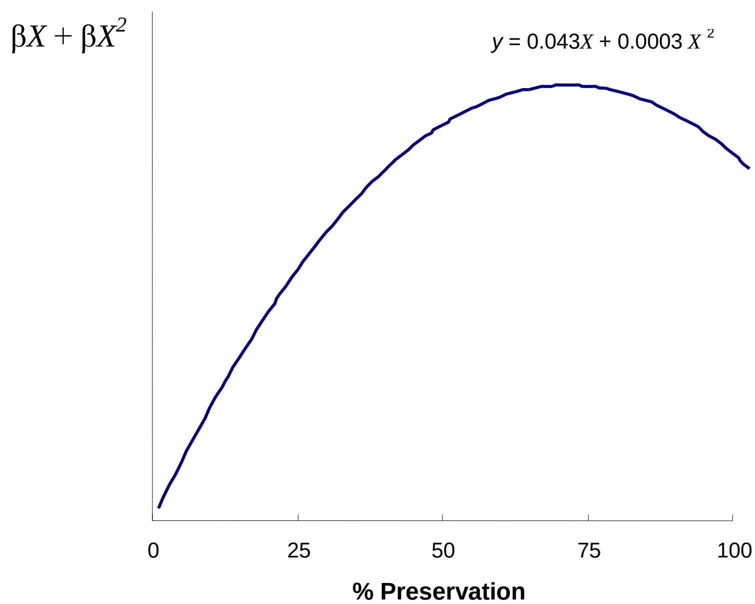
A positive coefficient indicates the variable has a positive effect on the representative utility function, which affects the probability of program A being selected. Both *Purchase Property* and *Permanent Easement* have positive coefficients, 0.682 and 0.353 respectively. The positive coefficients imply that each variable has a positive effect on the choice probability, compared to the baseline tool of *Ten Year Contracts*, holding all other variables constant. *Non Game Species, Water Quality and Flood Control, Fish Habitat, Waterfowl Habitat,* and *Biodiversity* all have positive coefficients of 0.184, 0.902, 0.237, 0.498, and 0.833 respectively. Their positive coefficients imply that each variable has a positive effect on the choice probability, compared to the baseline priority of *Open Space near Cities*, holding all other variables constant.

Percent of effort devoted to preservation, *Percent Preservation*, has a positive coefficient of 0.043, implying a positive effect on the choice probability, holding all other variables constant. Increasing the *Percent Preservation* has a positive effect on the choice probability. People prefer preservation over restoration, and tend to vote for programs that will provide for more preservation of Great Lakes coastal wetlands, but only up to a point.

Percent Preservation^2 is a nonlinear form of the variable *Percent Preservation*. It is used to capture the potentially different marginal effects of preservation effort, over our range of preservation effort levels (10% to 90%). *Percent Preservation* is graphed in Figure 1, to show

how the percent of program effort devoted to preservation has positive utility, reaches a peak at 72%, and begins to diminish at levels beyond 72%. Every level of preservation is preferred to 100% restoration, but the most preferred level of preservation is 72%. Beyond 72% preservation, the positive effect on the choice probability begins to decline (yet it is still positive). Preservation levels of 100% and 44% were equally preferred by respondents. Below a 44% preservation level, 100% preservation would be preferred; however, 100% preservation would not be preferred to levels of preservation between 44% and 100%.

Figure 1. The Nonlinear Effect that Percent Preservation has on Estimated Utility



How do the variables compare? Because *Open Space Near Cities* and *Ten Year Contracts* are the "base line" for their respective attributes, and because all their respective remaining levels have positive coefficients, the two base lines are of the lowest ranking order; however, variables that are not significantly different from them may also be of the lowest ranking order.

All "tool" variables are significantly different from each other, and can be ranked based on their effect on the choice probability. *Purchase Property* is most preferred as a program tool, giving respondents the most utility, followed by *Permanent Easements*, then *Ten Year Contracts*.

The order for "priorities" is complicated by the fact that several of the variables are not significantly different from each other (Gibson). *Water Quality and Flood Control* and *Biodiversity* are the two top program priorities. *Water Quality and Flood Control* and *Biodiversity* are significantly better than *Non Game Species, Fish Habitat*, and *Open Space near Cities* as program priorities. *Water Quality and Flood Control* is also significantly better than *Waterfowl. Waterfowl*, next in order of preference, is significantly better than *Water Quality and Flood Control*, and *Open Space near Cities* as a program priority. However, *Waterfowl* is not significantly different than *Biodiversity, Fish Habitat*, and *Non Game Species* in its effect on the choice probability. *Fish, Non Game Species*, and *Open Space near Cities*, would be next in order of preference, based solely on their attribute levels coefficient; however, they are not significantly different from each other, so no exact order can be made among the three. They all have the lowest effect on the choice probability. The low significance levels of *Fish* and *Non Game Species* imply they are not statistically different from the priority *Open Space near Cities*, it does not mean their effect on the choice probability is not significant when compared to other possible priorities.

CONCLUSIONS

The public does have preferences regarding programs for protection of Great Lakes coastal wetlands. Understanding these preferences, as well as the public's knowledge and understanding of Great Lakes coastal wetlands may make the design and implementation of coastal wetland programs more successful. The reported research is one set of data on what

Great Lakes residents understand about their coastal wetlands and what they wish to prioritize in protecting and restoring these ecosystems.

The research estimated respondents' preferences for wetland protection programs using the stated choice method. Results from the choice model demonstrate that, when respondents had to choose between wetland programs, respondents prioritize *Water Quality and Flood Control* as well as *Biodiversity* as the most important coastal wetland services. The results show that these two sets of services are significantly more important to respondents as a program priority than are programs that place a priority on the provision of *Non Game Species, Fish Habitat*, and *Open Space near Cities* as priorities. Although the results indicate that *Waterfowl Habitat* is not as preferred as a program priority as *Water Quality and Flood Control* or *Biodiversity*, *Waterfowl Habitat* is significantly preferred as a program priority to *Open Space near Cities* but not significantly different than priorities of *Fish Habitat* or *Non Game Species*. Programs that prioritized *Fish Habitat*, *Non Game Species* or *Open Space near Cities* were of lowest importance to respondents, and were not significantly different from each other in their effect on the choice probability.

The results also demonstrate that respondents preferred wetland programs that *Purchased Property* for protection or restoration instead of wetland protection programs that acquired land through *Permanent Easements* or *Ten Year Contracts*. Furthermore, the results show that respondents prefer programs using *Permanent Easements* to protect and restore coastal wetlands to those using *Ten Year Contracts*.

Finally, coastal wetland programs that have a "mix" of preservation and restoration activities were seen to be preferred to those that focus on one or the other. However, the results show that coastal wetland programs that have more preservation activity in their "mix" were preferred by respondents to those programs with more restoration in their “mix” (72% preservation is the most preferred level).

These research results provide a foundation for the development of specific wetland conservation or restoration projects and programs for protecting Great Lakes coastal wetlands. Designing programs in line with public preferences will result in the implementation of coastal wetland programs that meet with wide-spread public support.

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A latent-class model of angler preferences for Green Bay: estimated jointly with attitudinal data and stated preference-choice data

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Abstract

A latent-class model of environmental preference groups is developed and estimated using both the answers to stated-preference (SP) choice questions and the answers to 15 likert-scale attitudinal questions about Green-Bay fishing characteristics. Characteristics include boat fees, catch rates by species, and fish consumption advisories (FCA) by species. Both the responses to the attitudinal questions and the SP choices are used to estimate (1) the number of preference groups/classes, (2) the probability that an individual belongs to a particular class (3) the parameters in each classes's conditional, indirect-utility function for a Green Bay fishing day, and (4) for each attitudinal question, the probability that an individual in a particular class will give a particular

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answer. Estimation is with the E-M (expectation-maximization) algorithm, a technique new to environmental economics that can be used to do maximum-likelihood estimation with incomplete information. The missing piece of information in latent-class models is class membership; the researcher cannot observe it. FIML (full-information maximum likelihood) estimates are obtained by finding those values of the parameters in the model that maximize the likelihood of observing both the attitudinal and choice data. Deriving this likelihood function, developing an algorithm to find the values of the parameters that maximize it, and implementing that algorithm are the main accomplishments of this paper. It is also possible to estimate the parameters in the model sequentially. In this case, one first uses either the attitudinal or choice data to esimate some of the parameters in the model; then, conditional on those parameter estimates, one estimates the remaining parameters using the other type of data.

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Surveys often include a significant number of attitudinal questions. Consider an example Likert-scale attitudinal question from a survey of Green Bay anglers:

> On a scale from 1 to 5 where 1 means "Not at all Bothersome" and 5 means "Very Bothersome", answer the following question. For the fish you would like to fish for in the waters of Green Bay, how much would it bother you, if at all, if PCBs resulted in the following fish consumption advisory: "Do not eat".

Environmental economists generally do not view answers to attitudinal questions as data one uses in an econometric model to estimate preferences. Instead, they often view these questions as a "warm-up" exercise or use the answers to support the econometric results. But, attitudinal data can provide significant information about the existence and composition of different preference groups.

In this paper, we assume that the answers to attitudinal questions are expressions of exogenous well-behaved preferences: individuals can rank states of the world. Preferences are latent/ unobserved, and both choices (actual and hypothetical) and answers to attitudinal questions are manifestations of those unobserved preferences.

A latent-class model of environmental preference groups and the preferences of each group is developed and estimated. Group membership is latent/unobserved. The intent is to identify and estimate preference heterogeneity for environmental amenities in terms of a small number of preference groups. The application is to preferences over the fishing characteristics of Green Bay, a large bay on Like Michigan, one of the Great Lakes. Anglers answered a number of attitudinal questions, including the importance of boat fees, species catch rates, and fish consumption advisories on site choice.[1] Anglers also answered a set of SP-choice questions of the type: Would you rather fish Green Bay under conditions A or B?. Latent-class models are common in the social sciences but not in environmental economics.

[1]Between the late 1950s and the mid-1970s, local paper companies released PCBs into the Lower Fox River of Wisconsin which were later redistributed into the Lower Fox River and Green Bay (Sullivan et al., 1983). PCBs bio-accumulate in fish and wildlife. Possible FCA levels are a "do not eat", a "eat no more than once a month", and a "eat not more than once a week". They vary across species.

Standard references include Titterington et al. (1985), Bartholomew and Knott (1999), and Wedel and Kamakura (2000).

Both the responses to the attitudinal questions and the SP choices are used to estimate (1) the number of groups/classes, (2) the probability that an individual belongs to class c, (3) the parameters in each classes's conditional, indirect-utility function for a Green Bay fishing day, and (4) for each attitudinal question, the probability that an individual in class c will answer level s to question q. We find that Green Bay anglers separate into a small number of distinct classes with varying preferences and willingness to pay for a PCB-free Green Bay.

Estimation is with the E-M (expectation-maximization) algorithm, a technique new to environmental economics that can be used to do maximum-likelihood estimation with incomplete information (Bartholomew and Knott (1999), Dempster et al. (1977)).The E-M algorithm is seeing increased use in economics (Arcidiacono and Jones (2003)).[2] The missing piece of information in latent-class models is class membership; the researcher cannot observe it.

The basic idea of the E-M algorithm is that one replaces unobserved information with its expected value and then conducts maximum likelihood estimation as if these expectations were correct. The maximum likelihood estimates can be then used to update the original expectations. The E-M algorithm consists of two steps: an expectation step and a maximization step. In the expectation step, one calculates the expected value of the unobserved information. In the maximization step, one conducts maximum likelihood estimation as if the true value of the unobserved information was the expected value of the unobserved information. Based on the results of the maximization step, one then updates the expected value of the unobserved information. The process continues until the change in the log-likelihood

[2]Estimates can also be obtained using the Newton-Raphson method. Compared to the Newton-Raphson method, the E-M algorithm converges more slowly. However, unlike the Newton-Raphson method, convergence to at least a local optimum is guaranteed. An additional strength of the E-M algorithm for this model is that there closed form solutions for some of the parameters. The E-M algorithm is typically used more frequently than the Newton-Raphson method (Wedel and Kamakura (2000)).

function becomes very small.

We build on previous work, both by us and by others. Morey et al. (2005) estimate a latent-class model of angler preferences for Green Bay using only the answers to the attitudinal questions - a LC_A model.[3] Environmental economists generally do not view answers to attitudinal questions as data one uses in an econometric model to estimate preferences. We believe that answers to attitudinal questions are manifestations of preferences and have a significant role to play in the estimation of preferences. One of our goals in this paper was to demonstrate "how far one can get" with only attitudinal data. We found that all Green Bay anglers would prefer a reduction in PCBs, but there is a lot of variation in the magnitude of that preference.

While an LC_A model can tell one a lot about preferences, many in the field equate estimating preferences with estimating the values of preference parameters in utility functions or, in discrete-choice models, the parameters in conditional-indirect utility functions. The LC_A model we developed does not do this.

Using only the choice data, one can estimate the parameters in the conditional, indirect-utility function for a Green Bay fishing day, conditional on class membership. Denote this a LC_C model, which is estimated only with choice data. One assume some number of classes, c, of Green Bay anglers and specifies a conditional, indirect-utility function of a Green Bay fishing day (real or hypothetical) that allows the preferences parameters to vary by class. The choice data is used to estimate the number of classes, the probability of class member as a function of covariates of the individual, and the preference parameters in each class's conditional, indirect-utility function. No attitudinal data is used. Provencher et al. (2002) and Scarpa and Thiene (2005) are the two environmental applications of LC_C models.

Boxall and Adamowicz (2002) have estimated a latent-class site-choice model using both attitudinal data and choice data but with a fundamentally different assumption than we are prepared to make. Here, we assume that what people do and say are manifestations

[3] LC denotes "latent class" and the subscript(s) denote what type or types of data are used to estimate the model.

of underlying stable preferences. That is, revealed preference data, stated preference data, stated-frequency responses, votes, and expressions of attitudes are manifest variables. These types of data each provide insights and information about underlying latent preferences. We assume that group membership is exogenous and that the probability of giving a particular response to an attitudinal or choice question is a function of one's group. In contrast, Boxall and Adamowicz (2002) assume that the probability that an individual belongs to a particular preference group is a function of his answers to the attitudinal questions; that is, they make group membership a function of how one answers the questions. This is a subtle but important distinction between their work and ours. Given our assumption, not their's, that expressed attitudes are a manifestation of latent, exogenous preferences, the causality arrow in Boxall and Adamowicz (2002) goes the wrong direction. Like us, causality from preferences to responses/choice is assumed by Provencher et al. (2002) and in a non-environmental application by Ben-Akiva et al. (2002).

We denote the model estimated in this paper a LC_{AC} model, where estimation is with both attitudinal and choice data. FIML (full-information maximum likelihood) estimates are obtained by finding those values of the parameters in the model that maximize the likelihood of observing both the attitudinal and choice data. Deriving this likelihood function, developing an algorithm to find the values of the parameters that maximize it, and implementing that algorithm are the main accomplishments of this paper.

It is also possible to estimate the parameters in the model sequentially. In this case, one first uses either the attitudinal or choice data to esimate some of the parameters in the model. Then, conditional on those parameter estimates, one estimates the remaining parameters using the other type of data. Parameter estimates obtained this way are consistent but not efficient. For example, one could use the attitudinal data alone to estimate an individual's probability of class membership and her response probabilities. This is what we did in Morey et al. (2005)). These results can be used to estimate, for each angler in the sample, the probability that the individual is in class c conditional on his or her answers to the attitudinal questions. The choice data can then be used to estimate the parameters in the conditional-indirect utility function for each class, taking as given the conditional class probabilities estimated at the first stage. Put simply, the results in Morey et al. (2005) can be viewed at the results of the first stage of a sequential estimation. Estimates obtained sequentially are consistent and can be used as starting values for FIML estimation.

Since the number of groups is estimated and no restrictions are placed on membership probabilities, latent-class models allow for a wider range of preference heterogeneity without imposing a restrictive functional form on the distribution of the preference parameters. For example, one does not have to assume the parameters are normally distributed or or vary only deterministically as a function of observable characteristics of the individual.

A latent-class model of choice and attitudinal data

Assume the population consists of C different preference groups, $c_1, c_2, ..., C$. An individual's preference group is latent. The researcher observes, for each individual, the data $(\mathbf{x}_i, \mathbf{y}_i)$; $\mathbf{x}_i$ is the set of individual i's answers to the attitudinal questions (the individual's attitudinal response pattern) and $\mathbf{y}_i$ represents individual i's answers to the SP Green Bay choice pairs. The individual's *type*, t_i is also observed where type is defined in terms of a finite number of observable discrete characteristics (covariates) of the anglers. For example, if type is assumed a function of boat ownership and gender, there are four types of anglers: $t = 1, 2, 3, 4$. N_t is the number of anglers of type t such that $N = N_1 + ... + N_T$.

In constrast, angler i's *class*, c_i, is an unobservable, discrete-random variable. Type can influence the probability of belonging to a class.

With complete generality, the likelihood function for the sample can be written

$$L = \prod_{i}^{N} Pr\left(\mathbf{x}_i, \mathbf{y}_i, c_i : t_i\right), \tag{1}$$

The colon in the joint-density function, Equation 1, should be interpreted as "given". In contrast, a $|$ will denote "conditional on".

Since group membership is unobserved/latent, the best one can do is to model:

$$L = \prod_i \left[\sum_{c=1}^{C} \Pr(c : t_i) \Pr(\mathbf{x}_i, \mathbf{y}_i | c) \right] . \tag{2}$$

where $\Pr(c : t_i)$ is the unconditional probability that angler i belongs to class c; it is a function of his type. $\Pr(\mathbf{x}_i, \mathbf{y}_i | c)$ is a conditional probability and represents the probability of observing the individual's attitudinal and stated preference responses, conditional on belonging to class c. The latency of group membership causes the response patterns of individuals from the same group to be more correlated with each other than with individuals in other groups; individuals of the same class answer and behave similarly. That is, each angler's answers and SP choices are correlated with one another because of memberhip in a preference class. Latent-class models assume that once one has conditioned on class, an individual's answers to all of the stated-choice and attitudinal questions are independent of one another. Accepting this assumption, the likelihood function can then be written:

$$L = \prod_i \left[\sum_{c=1}^{C} \Pr(c : t_i) \Pr(\mathbf{x}_i | c) \Pr(\mathbf{y}_i | c) \right] , \tag{3}$$

where

$$\Pr(\mathbf{x}_i | c) = \prod_{q=1}^{Q} \prod_{s=1}^{S} (\pi_{qs|c})^{x_{iqs}} \tag{4}$$

and

$$\Pr(\mathbf{y}_i | c) = \prod_{k=1}^{K} \prod_{j=1}^{J} P_{ijk|c}^{y_{ijk}} \tag{5}$$

$\pi_{qs|c}$ is the probability that an individual in group c answers level s to attitudinal question q and $x_{iqs} = 1$ if individual i's answer to attitudinal question q is level s and 0 otherwise. $P_{ijk|c}$ is the probability that individual i chooses alternative j in SP-choice pair k, conditional on being a member of class c and $y_{ijk} = 1$ if individual i choose alternative j in choice pair k.

Substituting Equations 4 and 5 into Equation 3, the likelihood function can be written, in terms of most of the parameters, as:

$$L = \prod_i \left[\sum_{c=1}^{C} \Pr(c : t_i) \prod_{q=1}^{Q} \prod_{s=1}^{S} (\pi_{qs|c})^{x_{iqs}} \prod_{k=1}^{K} \prod_{j=1}^{J} P_{ijk|c}^{y_{ijk}} \right]. \tag{6}$$

At this point is is appropriate to wonder what all of the above has to do with estimating the parameters in conditional-indirect utility functions. The answer is that the $P_{ijk|c}$ are functions of the parameters in the class-specific conditional-indirect utility functions, the β_c parameters. That is, $P_{ijk|c}$ is a probit or logit probability of choosing Green Bay alternative j from SP-choice set k, conditional on being a member of class c. If a logit model is assumed, the probability of choosing alternative j is

$$P_{ijk|c} = \frac{\exp(\beta_c^{'} \mathbf{z}_{ijk})}{\sum\limits_{j=1}^{J} \exp(\beta_c^{'} \mathbf{z}_{ijk})} \quad c = 1, 2, ..., C. \tag{7}$$

where $\mathbf{z}_{ijk}$ is the vector of Green Bay's fishing characteristics that individual i sees in alternative j of choice-pair k. For example, in this application these characteristics include catch rates by species, FCAs, travel-costs, etc.

Alternatively, assuming probit where the random component on each Green-Bay alternative in each alternative and choice pair is an independent random draw from a normal distribution with zero mean and variance σ_ε^2, the probability of choosing alternative 1 is

$$P_{i1k|c} = \Phi((\beta_c^{'} \mathbf{z}_{i1k} - \beta_c^{'} \mathbf{z}_{i2k}) / \sqrt{2}\sigma_\varepsilon) \tag{8}$$

where $\Phi(.)$ is the CDF of the standard normal.

The goal of estimation is to find the C β_c, the $(Q \times S \times C)$ $\pi_{qs|c}$ and the $(C \times T)$ $\Pr(c : t_i)$ that maximize Equation 6.

Two conditional group membership probabilities will be useful for estimating the parameters in Equation 6. The first is the probability that an angler is a member of class c given her type and conditional on her answers to the attitudinal questions. By Bayes Theorem, this probability is:

$$\Pr(c : t_i \,|\mathbf{x}_i) = \frac{\Pr(c : t_i) \prod_{q=1}^{Q} \prod_{s=1}^{S} (\pi_{qs|c})^{x_{iqs}}}{\Pr(\mathbf{x}_i : t_i)}, \tag{9}$$

where

$$\Pr(\mathbf{x}_i : t_i) = \sum_{c=1}^{C} \Pr\left(c : t_i\right) \Pr(\mathbf{x}_i | c) = \sum_{c=1}^{C} \Pr(c : t_i) \prod_{q=1}^{Q} \prod_{s=1}^{S} (\pi_{qs|c})^{x_{iqs}} \tag{10}$$

The second useful probability, the probability that an angler is a member of class c given their type and conditional on **both** their answers to the attitudinal questions and their answers to the SP choice questions, is

$$\Pr(\mathbf{x}_i, \mathbf{y}_i : t_i) = \frac{\Pr(c : t_i) \prod_{q=1}^{Q} \prod_{s=1}^{S} (\pi_{qs|c})^{x_{iqs}} \prod_{k=1}^{K} \prod_{j=1}^{J} P_{ijkc}^{y_{ijk}}}{\Pr(\mathbf{x}_i, \mathbf{y}_i : t_i)}. \tag{11}$$

where $\Pr(\mathbf{x}_i, \mathbf{y}_i : t_i)$ is individual i's contribution to the likelihood function (the bracketed term in Equation 3).

1 Simultaneous estimation of the attitudinal/sp latent-class model parameters

The following is an application of the E-M algorithm.

1. Guess or estimate the $N \times C$ initial values of $\Pr(c : t_i \,|\mathbf{x}_i, \mathbf{y}_i)$, denoted $\Pr(c : t_i \,|\mathbf{x}_i, \mathbf{y}_i)^{\{0\}}$ where ${}^{\{d\}}$refers to iteration d. These initial guesses at the conditional probabilities, Equation 11, could be from a sequential estimation of the parameters in the model. Sequential estimation is discussed below.

2. Use the $\Pr(c : \mathbf{z}_i \,|\mathbf{x}_i, \mathbf{y}_i)^{\{0\}}$ to calculate the unconditional membership probabilies, $\Pr(c : t_i)^{\{1\}}$, for each of the T types of anglers. It is obtained by maxmizing the likelihood function and solving the first order conditions.

$$\Pr(c : t) = \frac{1}{N_t} \sum_{i_t=1}^{N_t} \Pr(c : t \,|\mathbf{x}_{i_t}, \mathbf{y}_{i_t}) \tag{12}$$

The right-hand side of Equation 12 is simply the average of the conditional group-membership probabilities for group c for all the anglers of type t, If there were only one type of individual, Equation 12 would simplify to $\Pr(c) = \frac{1}{N}\sum_{i=1}^{N}\Pr(c\,|\mathbf{x}_i, \mathbf{y}_i)$. So, at this point one has calculated $\Pr(c : t_i)^{\{1\}}$ for each angler in the sample, conditional on the $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)^{\{0\}}$.

3. Then use the $\Pr(c : t)^{\{1\}}$, the $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)^{\{0\}}$and the attitudinal data to calculate the $\pi_{qs|c}^{\{1\}}$. The formula, obtained by maxmizing the likelihood function and solving the first order conditions, is

$$\pi_{qs|c} = \frac{\sum\limits_{i=1}^{N}\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)x_{iqs}}{\sum\limits_{t=1}^{T}\Pr(c : t)N_t}. \tag{13}$$

In explanation, the denominator in Equation 13 is an estimate of the number of anglers in class c; it is also an estimate of the number of times question q is answered by anglers in class c. The numerator, $\sum\limits_{i=1}^{N}\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)x_{iqs}$, is the number of times individuals in the sample answered level s to question q, the x_{iqs}, each weighted by the conditional probability that the individual is in c. That is, the numerator is an estimate of the number of times individuals in class c answer level s to question q. The ratio is therefore an estimate of the proportion of times anglers in class c answer level s to question q.

4. Now use the $(\pi_{qs|c})^{\{1\}}$ and Equation 4 to calculate the $\Pr(\mathbf{x}_i|c)^{\{1\}}$.

Summarizing to here, based on our initial "guesses" for the $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)$ and the data, we have come up with the estimates of the $\Pr(c : t_i)^{\{1\}}$**and the** $\Pr(\mathbf{x}_i|c)^{\{1\}}$. Steps $2.-3.$ are an application of the E-M algorithim. One is finding the values of the $\Pr(c : t_i)$ and the $\pi_{qs|c}$ that maximize the expectation of the joint likelihood function. It is an "expected" likelihood function because one is using the expected values of the conditional membership probabilities, the $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)^{\{d\}}$, as if they were the true values.

5. Plugging in the $\Pr(c : t_i)$ and $\pi_{qs|c}$, the likelihood function, conditional on these estimates, is

$$\begin{aligned} L_r^{\{1\}} &= \prod_i\left[\sum_{c=1}^{C}\Pr(c : t_i)^{\{1\}}\Pr(\mathbf{x}_i|c)^{\{1\}}\Pr(\mathbf{y}_i|c)\right] \qquad (14) \\ &= \prod_i\left[\sum_{c=1}^{C}\Pr(c : t_i)^{\{1\}}\prod_{q=1}^{Q}\prod_{s=1}^{S}(\pi_{qs|c}^{\{1\}})^{x_{iqs}}\prod_{k=1}^{K}\prod_{j=1}^{J}P_{ijk|c}^{y_{ijk}}\right] \end{aligned}$$

Use a maximization algorithm (such as Optimum or Maxlik in Gauss) to maximize $\ln L_r$ in terms of the β_c. Denote these parameter estimates $\beta_c^{\{1\}}$. The subscript r indicates that the likelihood function is conditioned/restricted.

6. Now plug the $\beta_c^{\{1\}}$, the $\Pr(c : t_i)^{\{1\}}$, the $(\pi_{qs|c}^{\{1\}})$, along with the attitudinal and choice data into Equation 11 to calculate $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)^{\{1\}}$. $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)^{\{1\}}$ is an expected value. This is the end of iteration 1.

Return to step 1 but start with new best estimate of the $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)$, the $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)^{\{1\}}$. Continue iterating until the conditional likelihood function, Equation 14, increases by by less than some predetermined amount.

As with most maximum-likelihood problems, local maximum can be an issue. To guard against mistaking a local maximum for the global maximum one can repeat the the above, iterative algorithm, but start with different guesses for the $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)^{\{0\}}$, using, in the end, the parameter estimates that result in the largest value for the likelihood function.

2 Sequential estimation

Sequential estimation can be viewed as an alternative to FIML estimation or a first step to get initial estimates of the conditioanl class membership probabilitites, $\Pr(c : t_i\,|\mathbf{x}_i, \mathbf{y}_i)$.

Sequential estimation, as defined here, first obtains maximum likelihood estimates of the $\Pr(c : t_i)$ and the $\pi_{qs|c}$ using only the attitudinal data. These estimates are not as efficient as the FIML estimates because not all of the information/data is used in their estimation. Denote these estimates $\Pr(c : t_i)^{s1a}$ and $\pi_{qs|c}^{s1a}$ where the superscript "$s1a$" denotes stage 1 estimates based solely on the attitudinal data. These can then be plugged in to Equation 9 to obtain stage 1 maximum likelihood estimates of the conditional group-membership probabilities, $\Pr(c : t_i\,|\mathbf{x}_i)$. Denote these $\Pr(c : t_i\,|\mathbf{x}_i)^{s1a}$.

At stage 2 one obtains the maximum likelihood estimates of the β_c, taking as given the $\Pr(c : t_i\,|\mathbf{x}_i)^{s1a}$, and using only the SP-choice data. At the end of sequential estimation one has esimates of all of the parameters in the joint model (the $\Pr(c:t_i)$, $\pi_{qs|c}$ and β_c) but these estimate are only consistent. They are not efficient because none were estimated using all of the data. Put simply, they are not the parameter estimates that maximize the joint likelihood function, Equation 6.

In more detail, consider first the likelihood function for the attitudinal data. It is:

$$L_a(\Pr(c:t_i), \pi_{qs|c}) = \prod_i \left[\sum_{c=1}^{C} \Pr(c:t_i) \prod_{q=1}^{Q} \prod_{s=1}^{S} (\pi_{qs|c})^{x_{iqs}} \right]. \tag{15}$$

This likelihood function is developed, estimated and explained in Morey et al. (2005). One maximizes Equation 15 to obtain the $\Pr(c:t_i)^{s1a}$ and $\pi^{s1a}_{qs|c}$. These estimates are then used to calculate conditional group-membership probabilities using Equation 9. Note these conditional probabilities are conditional on only the attitudinal data and are a vector of numbers.

The likelihood function for the β_c parameters, taking as given the $\Pr(c:t_i\,|\mathbf{x}_i)^{s1a}$, and using only the SP-choice data, is

$$L_{sp}(\beta_c) = \prod_i \left[\sum_{c=1}^{C} \Pr(c:t_i\,|\mathbf{x}_i)^{s1a} \prod_{k=1}^{K} \prod_{j=1}^{J} P_{ijk|c}^{y_{ijk}} \right] \tag{16}$$

That is, each individual's probabilty of choosing alternative j in choice-pair k, conditional on being a member of class c, is weighted by the stage 1 best estimate of the probability that the individual is in class c. The estimated stage 2 estimates of the β_c, β_c^{s2sp} are obtained by using Gauss to maximize $\ln(L_{sp}(\beta_c))$.

Note that one can use the sequentially estimated $\Pr(c:t_i)^{s1}$, $\pi^{s1}_{qs|c}$and β_c^{s2} along with all of the data in Equation 11 to obtain initial estimated values for the conditional membership probabilities, $\Pr(c:t_i\,|\mathbf{x}_i, \mathbf{y}_i)$. Denote these $\Pr(c:t_i\,|\mathbf{x}_i, \mathbf{y}_i)^{\{0\}}$ because they can be used to as initial estimates for $\Pr(c:t_i\,|\mathbf{x}_i, \mathbf{y}_i)$ in the first step in in the first iteration of FIML estimation.[4]

Further note that there are other ways to sequentially estimate the $\Pr(c:t_i)$, $\pi_{qs|c}$ and β_c. For example, one could in a first stage obtain maximum likelihood estimates of the $\Pr(c:t_i)$

[4]As an aside, note that one could alternatively use the $\Pr(c:t_i\,|\mathbf{x}_i)^{s1a}$ as initial estimates of the $\Pr(c:t_i\,|\mathbf{x}_i, \mathbf{y}_i)$ in the first step in the first iteration of FIML estimation.

and β_c using only the SP choice data. The likelihood function is

$$L_{sp}(\Pr(c:t_i),\beta_c) = \prod_i \left[\sum_{c=1}^{C} \Pr(c:t_i) \prod_{k=1}^{K} \prod_{j=1}^{J} P_{ijk|c}^{y_{ijk}} \right] \tag{17}$$

Denote the estimates of the $\Pr(c:t_i)$ and β_c, $\Pr(c:t_i)^{s1sp}$ and β_c^{s1sp} where the superscript denotes stage 1 estimates obtained using only the SP data. These could then be used to obtain stage one estimates of the conditional group-membership probabilities $\Pr(c:t_i\,|\mathbf{y}_i)^{s1sp}$ where,

$$\Pr(c:t_i\,|\mathbf{y}_i) = \Pr(c:t_i\,|\mathbf{x}_i,\mathbf{y}_i) = \frac{\Pr(c:t_i)\prod_{k=1}^{K}\prod_{j=1}^{J} P_{ijk|c}^{y_{ijk}}}{\Pr(\mathbf{y}_i:t_i)}, \tag{18}$$

and

$$\Pr(\mathbf{y}_i:t_i) = \sum_{c=1}^{C} \Pr(c:t_i) \prod_{k=1}^{K} \prod_{j=1}^{2} P_{ijk|c}^{y_{ijk}}$$

Then at the second stage one takes as given the $\Pr(c:t_i\,|\mathbf{y}_i)^{s1sp}$ and uses only the attitudinal data to find the maximimum likelihood estimates of the $\pi_{qs|c}$. The likelihood function is

$$L_a(\pi_{qs|c}) = \prod_i \left[\sum_{c=1}^{C} \Pr(c:t_i\,|\mathbf{y}_i)^{s1sp} \prod_{q=1}^{Q} \prod_{s=1}^{S} (\pi_{qs|c})^{x_{iqs}} \right]$$

Denote these stage 2 estimates of the $\pi_{qs|c}$, $\pi_{qs|c}^{s2a}$ where the superscript denotes stage 2 estimates obtained with the attitudinal data.

Application: preferences of Green Bay anglers

The goal is to characterize the preferences, and heterogeneity in those preferences, of Green Bay anglers for the fishing characteristics of Green Bay. The site characteristics examined are catch rates by species, FCA levels by species, and launch fees.

The target population is active Green Bay anglers who purchase Wisconsin fishing licenses in eight Wisconsin counties near Green Bay; most Green Bay fishing days are by these anglers. A three-step procedure was used to collect data from a random sample of individuals in the target population. First, a random sample of anglers was drawn from lists of 1997 license holders in the eight counties. Second, a telephone survey was completed in late 1998 and early 1999; telephone contact was attempted with 4,597 anglers; 3,190 anglers completed the telephone survey for a 69% response rate. Anglers who had participated in open-water fishing in the Wisconsin waters of Green Bay in 1998 (the target population) were recruited for a follow-up mail survey: 92% of the open-water Green Bay anglers agreed to participate in the mail survey (the third and final survey wave). Of the 820 anglers who were mailed the survey, 647 (79%) completed and returned the survey. Seven individuals who did not answer any of the attitudinal questions were dropped, leaving a sample size of 640. In terms of the socioeconomic information collected during the phone survey, the Green Bay anglers who completed the mail survey do not differ significantly from those who did not.

The answers to 15 attitudinal questions are used in the estimation. The actual questions are included in the appendix. The four species examined were perch, walleye, bass, and trout/salmon. The 640 anglers in the sample also each answered 8 SP-choice pairs. These questions essentially asked, "Would you prefer to fish Green Bay under conditions A or B?" An example choice question is in the appendix.

2.1 Sequential estimation

2.1.1 Stage one

We start with sequential estimation because we will use the sequential estimates to calculate initial conditional class-membership probabilities for the FIML estimation. To keep things simple, since this is our first attempt at implementing the above FIML algorithm, we assume only two classes and no covariates (all anglers are of the same type). This simplification simplies the notation: t and t_i drop out of all of the equations, summations that were over N_t are over N, and $\Pr(class\ 2) = 1 - \Pr(class\ 1)$. The first stage estimates of the $\Pr(1)^{s1a}$ and $\pi^{s1a}_{qs|c}$ are obtained by maximizing Equation 15. The results are reported in Morey et al. (2005) and only summarized here. As noted above, class 1 can be characterterized as a PCB group and class 2 as a a Perch/Walleye group. The probability of class membership for group 1 usng only the attitudinal data, $\Pr(1)^{s1a}$, is 0.29; that is, 29% of Green Bay anglers are predicted to be in the PCB group (71% for the Perch/Walleye group); this estimate is imposed as an assumption at the second stage of sequential estimation.

Figure 1 reports the average responses to the attitudinal questions for the anglers most likely to belong to each group. One sees that those in the FCA group are "more bothered" by FCA levels than those in the Perch/Walleye group, and that those in the FCA group stated that the FCA levels for all species were the most important factors in their choices, while those in the Perch/Walleye stated that the most important factors for them were the catch and FCA levels for Perch and Walleye.

The 124 estimated $\pi^{s1a}_{qs|c}$ are combined with the the class membership probabilities and each individual's attitudinal data to estimate each angler's class membership probability conditional on his answers to the attitudinal questions, $\Pr(1\,|\mathbf{x}_i)$, Equation 9.[5] Most of these conditional estimates of membership put each individual into one of the groups with high probability (the maximum of the probabilities for the two groups is 90% or greater for 89% of the sample and effectively 100% for 69% of the sample). Interestingly, the maximum of these two conditional probabilies was lower than .71 (the larger of the two unconditional probabilities for 24 of the 648 anglers, indicating that their responses to the attitudinal questions made it more difficult to predict their class. For the rest, the added information makes the class membership prediction more accurate.

[5]There were 14 questions with 4 estimated levels and 1 question with 6 estimated levels, $\times$ 2 classes.

Figure 1: Average Response to Attitudinal Questions by Group

Two Groups

	FCA	Perch/ Walleye
Attribute Importance (5=Very Important)		
Catch:Bass	3.49	3.00
Catch:Perch	3.63[a]	3.54[a]
Catch:Trout/Salmon	3.25	2.60
Catch:Walleye	3.82	3.40
FCA:Bass	4.47	2.39
FCA:Perch	4.69	3.35
FCA:Trout/Salmon	4.43	2.61
FCA:Walleye	4.87	3.29
Fee	3.2[a]	3.07[a]
Amount Bothered (5=Very Bothersome)		
FCA: 1/week	4.02	2.71
FCA: 1/month	4.47	3.49
FCA: Don't eat	4.82	4.33
Agreement (5=Strongly Agree)		
WTP Higher Fees: Higher Catch	2.82[a]	2.85[a]
WTP Higher Fees: No PCBs	3.68	3.20
Comparison to Other Sites (7=Green Bay Much Better)		
Green Bay Quality	3.93	4.10

[a] Not a significant difference (5%) between FCA & Perch/Walleye
[b] Not a significant difference (5%) between FCA and Catch & Fee
[c] Not a significant difference (5%) between Walleye/Trout and Fee/Low Interest
[d] Not a significant difference (5%) between Walleye/Trout and Perch/Walleye
[e] Not a significant difference (5%) between FCA and Fee/Low Interest
[f] Not a significant difference (5%) between Perch/Walleye and Fee/Low Interest

2.1.2 Stage two

To estimate the second stage, assume the functional form of the deterministic part of the conditional-indirect utility function for a Green Bay fishing day for members of class c is:

$$\begin{aligned} \beta_c^{'}\mathbf{z}_{ijk} &= \beta_{p|c}p_{ijk} + \beta_{w|c}w_{ijk} + \beta_b b_{ijk} + \beta_s s_{ijk} \\ &+ \sum_{f=2}^{9} \beta_{f|c} FCA_{fiijk} \\ &+ \beta_m (y_i - TC_i - fee_{ijk}), \end{aligned} \tag{19}$$

where p_{ijk} is the time it takes, on average, to catch a perch in alternative j, Green Bay choice-pair k, as seen by individual i; w is the walleye catch time, b is bass catch time and s is salmon catch time. Note the catch parameters on bass and salmon are assumed, for simplicity, to not vary by class.

In the Green Bay SP-choice pairs there were 9 possible configurations of FCA levels. Each specified the level (”do not eat”, ”once a month”, ”once a week”, no advisory”) for each of the four species: FCA_{fiijk} equals 1 if the FCA level is level f in alternative j, choice pair k as experienced by individual i, and zero otherwise. Level 1 indicates PCB levels sufficiently low such that all species may be eaten in unlimited quantities; there is no health risk from consumption. Level 9 is the most restrictive: trout/salmon, walleye, and bass should not be eaten, and a perch meal should be consumed once a month at most. Level 4 corresponds to current conditions on Green Bay. With one exception, as one moves up through the nine levels, the FCA becomes more severe.[6]

The variables y_i and TC_i are choice-occasion income and the cost of fishing GB, excluding any fees. The variable fee is a charge imposed to fish Green Bay. The marginal utility of money, β_m, is assumed a constant. Income not spent on fishing GB, $(y_i - TC_i - fee)$, is spent on the numeraire. Since income and travel costs do not vary across Green-Bay alternatives or choice pairs for an individual, y_i and TC_i play no role in estimation.

[6]The exception is in moving from level 4 to level 5 and from level 5 to level 6 with the consumption of some species becoming more restricted and others less restricted. This anomalie is reflected in the parameter estimates.

Table 1: Indirect utility parameter estimates

	FCA Group			Perch and Walleye Group		
Parameters	**Estimates**	**Est/S.E.**	**Prob**	**Estimates**	**Est/S.E.**	**Prob**
Perch	−0.2953	−3.286	0.0005	−0.6310	−11.822	0.0000
Walleye	−0.0319	−4.456	0.0000	−0.0381	−9.499	0.0000
FCA 2	−0.5220	−4.387	0.0000	−0.0597	−0.876	0.1905
FCA 3	−0.5954	−4.879	0.0000	−0.1398	−2.102	0.0178
FCA 4	−1.0402	−8.711	0.0000	−0.2811	−4.213	0.0000
FCA 5	−1.3687	−10.685	0.0000	−0.4317	−6.254	0.0000
FCA 6	−1.0307	−8.456	0.0000	−0.2757	−4.234	0.0000
FCA 7	−1.4749	−11.729	0.0000	−0.5506	−8.454	0.0000
FCA 8	−1.9424	−13.783	0.0000	−0.7996	−11.600	0.0000
FCA 9	−2.0994	−15.137	0.0000	−0.8986	−12.784	0.0000

	Both Groups		
Parameters	**Estimates**	**Est/S.E.**	**Prob**
Salmon	−0.0279	−7.865	0.0000
Bass	−0.0315	−9.325	0.0000
Fee	−0.4770	−15.326	0.0000

The second-stage esimates of the β are reported in Table 1. These estimates are very consistent with the first stage results. In terms of the estimated β, those in the Perch/Walleye group care more about the Perch and Walleye catch rates than do those in the FCA group. And, at every FCA level, the FCA group is more concerned about that FCA level than is the Perch/Walleye group. Note that for both groups the parameters on FCA levels increases monotonically as one moves from level 1 to level 9, with the exception of the increase from level 5 to level 6. As noted in footnote 6, every increase in level leads to an unambigous increase in the severity of FCA levels, except for the change from level 5 to level 6.

At this point, one could stop: one has consistent estimates of all of the parameters and they could be used to obtain expected compensating variations for changes in FCA levels. However these estimates are not efficient, because all of the information/data was not used to estimate all of the parameters.

With estimates of all of the parameters and the attitudinal and choice data one can now calculate conditional membership probabilities, conditional on all of the parameters and all of the data; that is, one can calculate $\Pr(1 : t_i \,|\mathbf{x}_i, \mathbf{y}_i)$ for each angler using Equation 11. It is of interest to compare these to the $\Pr(1 \,|\mathbf{x}_i)$ estimated after the second stage. To be added.

2.2 FIML estimation

To be added.

A Attitudinal questions

1. On a scale from 1 to 7 where 1 means "Much Worse" and 7 means "Much Better", how do you rate the quality of fishing on the water of Green Bay compared to other places you fish?

2. On a scale from 1 to 5 where 1 means "Not at all Bothersome" and 5 means "Very Bothersome", answer the following question. For the fish you would like to fish for in the waters of Green Bay, how much would it bother you, if at all, if PCBs resulted in the following fish consumption advisories:

   (a) Eat not more than one meal a week.

   (b) Eat not more than one meal a month.

   (c) Do not eat.

3. On a scale from 1 to 5 where 1 means "Strongly Disagree" and 5 means "Strongly Agree", how do you feel about each of the following statements about boat launch fees? If you don't fish from a boat, please think of the daily boat launch fee as a fee you would have to pay to fish the waters of Green Bay.

   (a) I would be willing to pay higher boat launch fees if catch rates were higher on the waters of Green Bay.

   (b) I would be willing to pay higher boat launch fees if the fish had no PCB contamination.

4. On a scale from 1 to 5 where 1 is "Not at all important" and 5 is "Very Important", when you were making your choices in $Q15$ through $Q34$, how important were each of the following?

   (a) The average catch rate for yellow perch

   (b) The fish consumption advisory for yellow perch

   (c) The average catch rate for trout/salmon

   (d) The fish consumption advisory for trout/salmon

   (e) The average catch rate for walleye

   (f) The fish consumption advisory for walleye

   (g) The average catch rate for smallmouth bass

   (h) The fish consumption advisory for smallmouth bass

   (i) Your share of the boat launch fee (or daily access fee if not fishing from a boat)

Figure 2: Example choice question

Figure 5-1
Example Choice Question

If you were going to fish the waters of Green Bay, would you prefer to fish the waters of Green Bay under Alternative A or Alternative B? *Check one box in the last row*

	Alternative A ▽	Alternative B ▽
Yellow Perch		
Average catch rate for a typical angler.....................	40 minutes per perch	30 minutes per perch
Fish consumption advisory.......	No more than one meal per week	No more than one meal per week
Trout and Salmon		
Average catch rate for a typical angler.....................	2 hours per trout/salmon	2 hours per trout/salmon
Fish consumption advisory.......	Do not eat	No more than one meal per month
Walleye		
Average catch rate for a typical angler.....................	8 hours per walleye	4 hours per walleye
Fish consumption advisory.......	Do not eat	No more than one meal per month
Smallmouth bass		
Average catch rate for a typical angler.....................	2 hours per bass	2 hours per bass
Fish consumption advisory.......	No more than one meal per month	Unlimited consumption
Your share of the daily launch fee............................	Free	$3
Check the box for the alternative you prefer..	❑	❑

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A Empirical Framework for Evaluating the Welfare Gains and Losses

from Credence Attribute Labeling

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A Empirical Framework for Evaluating the Welfare Gains and Losses

from Credence Attribute Labeling

Abstract

The analysis develops a theoretically rigorous framework for evaluating the benefits and costs of credence product labeling in major food markets. Credence attributes are features that cannot be directly determined by a consumer, but require some sort of special labeling, such as dolphin-safe, organic, and pesticide-free products. Consumers may be willing to pay more for the credence product, but, without labeling, they are unable to differentiate products by the presence and absence of the credence attribute. Certified labeling vertically separates a single pooled market into separate credence and conventional markets. The empirical results show that the net benefits of costless labeling are positive, but the gains and losses are highly asymmetric across the credence and conventional subsectors. Given the asymmetry, labeling policies trigger new equilibria that are Pareto non-comparable, so that implementing a labeling policy is certain to make some subsectors worse off than they are without labeling. Informed policy choices require a careful ex ante analysis of the magnitude of actual benefits and costs, knowledge of the fraction of consumers willing to pay the credence product premium, and tradeoffs across the empirical gains and losses of consumers and producing subsectors.

A Empirical Framework for Evaluating the Welfare Gains and Losses from Credence Attribute Labeling

There is substantial public and private interest in labeling food products for non-nutritional, credence attributes (Golan et al., 2001). Credence attributes are product features that cannot be directly experienced by consumers (Darby and Karni, 1973). Without labeling, consumers are unable to identify products with and without the credence attribute, and market prices fail to reward firms that produce credence goods. Labeling allows consumers to match their demands to the product that best suits their preferences and budget. It also allows markets to reward firms with price premiums that match their product attributes. Notable examples of credence goods include dolphin-safe tuna (Teisl, Roe, and Hicks, 2002) and the National Organic Program (Agricultural Marketing Service, 2003b); origin labeling (Agricultural Marketing Service, 2003a), absence of pesticide residues (Ott, Huang, and Misra, 1991), genetically modified content (Caswell, 1998; Zedalis, 2001), and hormone-free labeling (Kleiner, 1994).

Previous research shows that the net economic benefits of credence labeling are theoretically ambiguous. In terms of consumers, theory is unable to determine whether there is a net gain across consumers of the credence and non-credence goods. Some consumers gain while other consumers lose (Giannakas, 2002; Giannakas and Fulton, 2002). When producer effects are considered, net benefits and costs are also *a priori* ambiguous (Fulton and Giannakas, 2004; Sedjo and Swallow, 2002). These theoretical analyses are helpful in understand the structure of gains and losses, but they cannot tell us the size of the benefits and costs, by whom these benefits and costs are experienced, and whether, on balance, costs exceed benefits or benefits exceed costs. The latter issues are central to the analysis of specific labeling policies (Freeman, 1998). Given asymmetric gains and losses, labeling policies generate Pareto non-comparable equilibria. Hence, policy makers will not be able to appeal to Pareto efficiency as a normative criteria for guiding labeling policies. Alternatively, the potential compensation criterion may provide a basis for policy decisions. However, this criterion requires ex-ante approximations of net-benefits.

The present analysis develops an analytical and empirical model to assess credence good labeling and it's affect on both the magnitude and distribution of benefits and costs. The analytical framework uses a general equilibrium model of demand and supply for the credence and non-credence subsectors. In the case without labeling, consumers are unable to distinguish the credence product from the conventional products, so a single market price emerges for a market good that is a mixture of credence and non-credence goods. Subsector supplies for the credence and non-credence goods are inelastic, so marginal costs to rise and fall with production levels and both credence and conventional firms are present in non-labeling equilibrium. This unlabeled, pooled equilibrium is consistent with data showing that, in the United States, one-third of retail fruits and vegetables are pesticide-free (Agricultural Marketing Service, 2001), two-thirds of corn production uses seed that is not genetically engineered (National Agricultural Statistics Service, 2002), and two-thirds of dairy cows produce milk without using growth hormones (Barham and Foltz, 2002).

When labeling is introduced, the single pooled market is partitioned into distinct subsector markets for the credence and non-credence goods. Consumer demand in the credence subsector shifts upward in a manner consistent with the empirical literature on the willingness to pay for credence attributes (Blend and van Ravenswaay, 1999; Buhr and et al., 1993; Henson, 1996; Loureiro, McCluskey, and Mittelhammer, 2002; Misra, Huang, and Ott, 1991; Rousu et al., in press). Firms enter and leave each sector depending on profits offered by subsector participation. Both production sectors are characterized by increasing costs of production and the infra-marginal producer surpluses are equal to zero in both sectors. Consumers decide to purchase the credence or non-credence good based on the good that offers the greater net consumer surplus at given market prices. Given sufficient consumers willing to pay for the credence good, separate equilibrium prices emerge for the credence and non-credence goods. However, if the quantities demanded of the credence good are small relative to supply, the credence good market can be saturated and the overflow is sold to consumers who do not have a separate valuation of the credence attribute. In the market saturation case, separate credence and non-credence prices do not emerge.

We develop an empirical model that can generate estimates of producer and consumer surplus using estimates of supply and demand parameters that exist in the literature. Our results, for example, draw on existing estimates of market share, elasticity, and willingness to pay parameters. Results show that costless labeling unambiguously improves aggregate net welfare. However, the incidence of gains and losses is highly asymmetric, with large gains to the credence subsector and large losses to the conventional subsector. Net gains from labeling are rather small. Mean net gains become negative with labeling costs of less than 5 percent of the initial pooled price. Also, simple rule-of-thumb welfare measures, such as multiplying consumer willingness to pay times baseline quantities, are highly misleading, failing to identify net loss policies and overstating positive net benefits by many times.

The pattern of gains and losses shifts marked in the market saturation case. The saturation case results in a single market price for credence and non-credence products, since there are not enough consumers who place a positive value on the credence attribute. The credence subsector loses to the extent it incurs labeling costs, and the conventional subsector stands to gain market share as the credence subsector is disadvantaged by labeling costs. Credence consumers gain since the single market price fails to reflect the influence of credence consumers' willingness to pay for the credence attribute.

The analysis is developed in the following manner. The next section describes the demand and supply conditions underlying the pooled and separating equilibria. The third section presents the market and benefit-cost simulations. The last section presents concluding comments.

Conceptual Model

The market analysis incorporates consumers, a subsector producing the credence product, and a subsector producing the conventional product. In the initial pooled market equilibrium without labeling, information about product quality is not revealed at the level of individual purchases. Consumers have only a market level conjecture about the proportions of credence and conventional goods in the average pooled market purchase. Certified labeling allows consumers to differentiate the credence product from the conventional product. Labeling partitions the single, pooled market into two, separate subsector markets, each with the potential for determining distinct prices and quantities.

The credence and conventional production subsectors have different cost structures, but each is an increasing cost industry. Increasing subsector costs imply inelastic supply. Increasing costs mean that a sector may expand in response to higher market prices or contract in response to lower market prices. Increasing costs may arise from an input supplied inelastically, such as land, dairy herd size, climate, or specialized labor. Credence firms may have a cost advantage in using the fixed input under certain conditions, while low-credence firms may be cost advantaged by different conditions. For example, fruit producers in arid climates may have an advantage in producing fungicide-free fruits, while fungicide-using firms may be more cost advantaged by humid climates. Hence, the supply functions for the credence and non-credence subsectors may intersect at some point, and at the equilibrium quantity produced by a subsector, marginal costs are equal to market price.

Consumers are represented by aggregate demands, but the way these demands are realized is different in the pooled and separating markets. To derive the realized demands, we begin with underlying latent demands for the pure credence and conventional products. Latent demands are so-called since they correspond to pure credence and conventional products that may not be available in an existing market. In the pooled market, the pooled product is a mixture of both the credence and conventional products, so realized demand is a pooling of the latent demands for the two goods. In the separating market, realized conventional demand analysis is latent demand, reduced by the quantity of the credence product purchased.

When only the conventional product is available to consumers, aggregate demand for the conventional good, q_c, at a given price, r_c, is

$$\textbf{(1)} \qquad \begin{aligned} q_c &= q_c(r_c) \\ &= \beta_0 - \beta_2 r_c \end{aligned}$$

where β_0 is a demand intercept and $\beta_2 > 0$ is the absolute value of the demand slope. It is also useful to write the price of the conventional product as a function of quantity by rearranging equation (1). This reservation price schedule, $r_c(q_c)$, is the mathematical inverse of equation (1),

$$\textbf{(2)} \qquad \begin{aligned} r_c &= r_c(q_c) \\ &= \gamma_0 - \gamma_2 q_c \end{aligned}$$

where $\gamma_0 = \beta_0/\beta_2$ and $\gamma_2 = 1/\beta_2$.

When only the credence product is available, aggregate demand for the credence product, q_g, at the credence price, r_g, is

(3)
$$\begin{aligned} q_g &= q_g(r_g) \\ &= \beta_0 + \beta_1 - \beta_2 r_g \end{aligned}$$

where the term $\beta_1 > 0$ is a shifter that shifts latent credence demand rightward relative to latent conventional demand. The corresponding reservation price schedule for the credence product, $r_g(q_g)$, is

(4)
$$\begin{aligned} r_g &= r_g(q_g) \\ &= \gamma_0 + \gamma_1 - \gamma_2 q_g \end{aligned}$$

where $\gamma_1 = \beta_1/\beta_2 > 0$. The latent credence and conventional reservation price schedules, equations (4) and (2), respectively, differ only by a fixed intercept shifter, γ_1. The shifter γ_1 is willingness to pay for the credence attribute per unit of the credence product demanded.

Within each sector, production functions at the firm-level are constant returns to scale. However, as output rises, input prices increase, so that subsector supplies are inelastic for both the credence and conventional products. The relationship between firm-level marginal costs and the quantity supplied by the conventional sector is $mc_c = \mu_0 + \mu_1 q_c$ where $\mu_0 > 0$ is an intercept term and $\mu_1 > 0$ is the slope of marginal costs within the conventional sector with respect to sector output.

The relationship between marginal cost and the quantity supplied by the credence sector is $mc_g = \delta_0 + \delta_1 q_g + \tau$ where $\delta_0 > 0$ is an intercept, $\delta_1 > 0$ is the slope of marginal cost in market share, and τ is a fixed per unit cost of labeling in the separating equilibrium. Labeling costs are zero in the pooled equilibrium, so $\tau = 0$ in the pooling case. In a separating equilibrium with costly labeling, the credence subsector may incur a certification cost, so $\tau \geq 0$.

A Pooled Market

Demanders in a pooled market are unable to match their willingness to pay to a pure conventional or pure credence product. The pooled market quantity is a mixture of credence and conventional products. Consumers formulate a conjecture about the proportions of credence and conventional products contained in the pooled product. The conjectured proportion of credence product in the market mixture is α, $0 < \alpha < 1$. Pooled market demand is conditioned on the conjecture. Realized pooled market demand, $Q_\alpha(r_\alpha)$, is a α-weighted sum of the latent credence and conventional demands,

(5)
$$\begin{aligned} Q_\alpha &= Q_\alpha(r_\alpha) \\ &= (1-\alpha)q_c + \alpha q_g \\ &= \beta_0 + \alpha\beta_1 - \beta_2 r_\alpha \end{aligned}$$

A pooled market equilibrium equates quantity supplied with quantity demanded at a single price. The total market quantity, Q, is the sum of the credence and conventional quantities, $Q = q_c + q_g$. Consumers perceive the α-mixture, Q_α. For purposes of defining an equilibrium, the conjecture may be inconsistent with the actual market mix. The only restriction is that the market clears, so that aggregate quantity demanded, Q_α, equals aggregate quantity supplied, $Q = q_c + q_g$. Thus, the unlabeled, pooled market equilibrium is a single market price, p_α^p, that clears the market given the α-conjecture,

$$
\textbf{(6)} \qquad \begin{aligned} q_c^p + q_g^p &= Q(p_\alpha^p) \\ p_\alpha^p &= mc_c(q_c^p) \\ p_\alpha^p &= mc_g(q_g^p) \end{aligned}
$$

Equation (6) defines a pooled market equilibrium using, respectively, subsector supply conditions and aggregate market supply conditions. These pooled equilibrium conditions provide the baseline conditions for evaluating the economic and welfare consequences of certified labeling.

Figure 1 illustrates the supply and demand structures underlying the pooled equilibrium. Panel A shows the credence and conventional subsector supply schedules. Aggregate market supply in Panel B is the horizontal sum of credence and conventional supplies in Panel A (Friedman, 1962). Market supply is kinked where one of the subsectors is unable to compete at prices lower than the vertical level of the kink. Equation (6) describes aggregate market supply for pooled prices above the vertical height of the kink. Market supply below the kink is the supply schedule for the remaining subsector.

The market reservation price schedule, $r_\alpha(Q_\alpha)$, in Panel B of Figure 1 is the alpha-weighted sum of the latent credence and conventional reservation price schedules, respectively, $r_g(q_g)$, and $r_c(q_c)$. Aggregate demand is shown as a solid line and the latent demands are shown as dashed and dotted lines. The vertical distance between the latent reservation price schedules is willingness to pay, γ_1. The vertical distance between the credence and aggregate reservation price schedules is $(1-\alpha)\gamma_1$, and the vertical distance between the aggregate and conventional reservation price schedules is $\alpha\gamma_1$.

The equilibrium aggregate quantity and pooled priced are determined by the intersection of aggregate supply and the aggregate reservation price schedule in Panel B. The pooled market price is consistent with the non-zero subsector quantities supplied shown in Panel A, as long as pooled price is greater than the subsector supply intercept, μ_0. In the illustrated case, the credence subsector supplies the aggregate quantity at pooled prices less than μ_0.

A Separating Equilibrium with Certified Labeling

Once certified labeling is introduced, consumers can distinguish the credence product from the conventional product. The single pooled market is replaced with separate markets for the credence and conventional products. Consumers buy either the credence or conventional product. The credence demand and reservation price schedules realized in the separated market are the latent schedules. The realized conventional schedules are the latent schedules reduced to account for credence purchases, reduced in the sense that once a buyer purchases a unit of the credence product, demand for that unit is lost to the conventional market.

The realized conventional residual reservation price schedule shifts downward with the purchase of the credence product. The amount of the shift downward is equal to the slope of the conventional reservation price schedule, $-\gamma_2$, times the credence quantity demanded in the separating equilibrium, q_g^s. The net effect is that the intercept of realized conventional reservation price schedule shifts downward by $-\gamma_2 q_g^s$, so it is endogenous to the outcome of the separating equilibrium. Algebraically, the realized conventional reservation price schedule, $\tilde{r}_g(q_c|q_g^s)$, is

$$
\begin{aligned}
\tilde{r}_c &= \tilde{r}_c(q_c|q_g^s) \\
&= r_c(q_c) - \gamma_2 q_g^s \qquad \textbf{(7)} \\
&= r_g(q_g^s) - \gamma_1 - \gamma_2 q_c
\end{aligned}
$$

The third line in equation (7) follows by adding and subtracting γ_1 to the second line and then substituting the reservation price for the marginal consumer of the credence. In this latter form, the intercept for the conventional reservation price schedule is the marginal reservation price for the credence product adjusted downward by the incremental willingness to pay for the credence product, γ_1. In the latter form, the intercept of the conventional reservation price schedule equals the marginal credence reservation price, $r_g(q_g^s)$, less willingness to pay for the credence characteristic, γ_1. Hence, the conditional intercept for the conventional good is endogenous to the separating equilibrium.

Some previous research divides consumers into two fixed and distinct consumption groups in specifying a separating equilibrium (Sedjo and Swallow, 2002). However, we follow Giannakas, and Giannakas and Fulton, and make the choice of the credence and conventional products an economic decision, dependent on consumer valuations and prices. A consumer chooses the product that yields the largest relative gain in individual welfare given credence and conventional market prices. Net consumer surplus is the money metric of welfare, as measured by the realized reservation price less the market price for a particular product. The realized reservation price schedules are equation (4) for the credence product and equation (7) for the conventional product.

In purchasing a product, a consumer compares the net consumer surplus gain of a credence purchase with its opportunity cost, the net consumer surplus of a conventional purchase. If the gain is greater than the opportunity cost, the consumer makes the credence purchase. If it is not, the consumer makes a conventional purchase. The marginal credence purchase remains in the credence market only as its net consumer surplus is greater or equal to the net consumer surplus forgone by a conventional purchase. The infra-marginal conventional purchase remains only as its net consumer surplus is greater or equal to the net consumer surplus from a marginal credence purchase.

A separating market equilibrium with certified labeling is a set of prices for the credence and conventional products such that consumers are unable to improve their welfare and firms are unable to improve their profits by entering or leaving a subsector. This is a Nash equilibrium with competitive behavior. The conditions for a Nash equilibrium are

$$
\begin{aligned}
r_g(q_g^s) - p_g^s &= \tilde{r}_c(0|q_g^s) - p_c^s \\
p_g^s &= mc_g(q_g^s) + \tau \\
p_c^s &= mc_c(q_c^s) \\
p_c^s &= \tilde{r}_c(q_c^s|q_g^s)
\end{aligned}
\tag{8}
$$

where the first line of equation (8) is the net surplus condition that leaves the marginal consumer unable to improve welfare by switching to purchases from one market to the other. The second line of equation (8) requires the credence market to clear at a price where the marginal product earns zero marginal rent. The third and fourth lines of equation (8) set prices and quantities so that the conventional markets clear where price equals marginal costs. The third line ensures that marginal rent is also zero in the conventional market.

Labeling separates the pooled market into separate markets for pure credence and conventional products. Figure 2 describes the separating market equilibrium. Panel A in Figure 2 represents the credence market and Panels B shows that conventional market. The realized credence reservation price schedule is the schedule that remained latent in the pooled equilibrium, $r_g(q_g)$. The separated market allows consumers to express their full valuation for the credence product.

Figure 2 shows how demands in the two markets are interrelated through the realized reservation price schedule for the conventional product. The realized conventional reservation price schedule, $\tilde{r}_c(q_c|q_g^s)$, represents demand in Panel B, but its derivation begins in Panel A. The latent conventional reservation price schedule, $r_c(q_c)$, is the dashed and dotted line in Panel A. The credence quantity purchased in the separated market is q_g^s. The segment of the latent conventional reservation price schedule above the credence quantities purchased–above the interval $[0,q_g^s]$–is lost to the separated conventional market. Instead of intersecting the vertical axis at γ_0, the realized conventional reservation price schedule in Panel B intersects the vertical axis at $\tilde{r}_c(0|q_g^s) = r_g^s - \gamma_1$.

The equilibrium conditions of equation (8) require prices to be equal to marginal costs in both markets. This occurs at credence price p_g^s for a credence quantity q_g^s, and at conventional price p_c^s for a conventional quantity q_c^s. Substituting the third line of equation (7) into the first line of equation (8) shows that the difference between credence and conventional prices is equal to willingness to pay, γ_1.

The equilibrium conditions also require net consumer surplus to be equal for the marginal credence purchase and the infra-marginal conventional purchase. Marginal net surplus for the credence product is $r_g(q_g^s) - p_g^s$ in Panel A, and $\tilde{r}_c(0|q_g^s) - p_c^s$ is the net surplus for the infra-marginal purchase of the conventional product, so the latter two vertical distances are equal in Figure 2. In addition, the geometry of Panel B implies that these net surpluses are equal to $\gamma_2 q_c^s$.

Figure 2 is helpful in illustrating the absence of incentives for changing purchases or production levels in the Nash equilibrium. The marginal consumer entering into the credence market is the infra-marginal consumer in the conventional market who has the highest willingness to pay. When the price differential in the two markets is equal to willingness to pay, this infra-marginal consumer cannot make herself better off by switching to the credence market. Firms seeking to switch from one market to the other have costs just greater than the marginal firm in each market. Since equilibrium prices are equal to marginal costs, there is no incentive in the separating equilibrium for a firm to switch from one product to the other. Neither consumers nor producers can make themselves better off by changing their behavior given the equilibrium behaviors of other market actors.

Labeling and Market Saturation

A second type of labeling equilibrium is where there is an insufficient number of consumers willing to pay for the credence attribute. Market saturation occurs when the maximum quantity demanded by credence consumers–consumers willing to pay the extra amount γ_1 for the credence attribute--is less than the quantity necessary for the equilibrium amount q_g^s. In Figure 2, this market saturation level is shown as the amount τ. Panel B in Figure 3 illustrates the significance of the threshold τ for demand. Willingness to pay for per unit of the credence good to the left of τ is γ_1. For quantities of the credence good in excess of τ, consumers do not care about the credence good and willingness to pay for it is zero. Market saturation seems a possibility in products such as organic foods where supply grows by as much as 20 percent per year and the organic market itself is less than 2 percent of retail food sales (Greene and Dimitri, 2003).

With market saturation and the supplies shown in Panel A of Figure 3, the portion of demand relevant to price determination is the conventional demand curve, $r_c(q_c)$. Credence demand potentially affects on the first τ units, while the market equilibrium occurs at Q^p. Only conventional demand is relevant at Q^p, so the equilibrium quality demanded and price is the same with and without labeling when labeling is costless. However, there is a benefit with labeling even with market saturation–consumers who care about the credence attribute are able to identify and purchase the credence good. Thus, even though firms in the credence subsector go unrewarded, consumers are able to benefit from being able to match their demands with the product that they value more highly. Credence consumers therefore gain by the change in their reservation price to $r_g(q_g)$ in the equilibrium with labeling from $r_\alpha(Q_\alpha)$ in the pooled equilibrium.

With costly labeling, the supply function for the credence product shifts upward, so in Figure 3 the credence subsector supply in Panel A would lie to the northeast of mc_c and the aggregate supply in Panel B would lie to the northeast of mc. Aggregate supply would cross aggregate demand to the left of Q^p. Thus, the equilibrium price would be slightly higher than the initial pooled market price with costly labeling. The increase in costs for the credence subsector would also put it at a small cost disadvantage relative to the conventional subsector at the initial equilibrium. Hence, in the labeling equilibrium with saturation, the market share of the conventional subsector would be larger and that of the credence subsector would be smaller with costly labeling. Overall, credence consumers and the conventional production subsector would gain from labeling with market saturation and credence consumers and conventional consumers would lose.

Empirical Model and Results

Numeral simulations were carried out to examine the quantitative changes that may occur in agricultural markets with the introduction of certified labeling. Eight thousand combinations of parameter values were selected randomly from the set of ranges. This section details the parameter range selection and the simulation results.

Baseline Conditions and Parameters

Table 1 lists the baseline market conditions and parameter ranges used in the simulations. The baseline prices and quantities were selected from the range of prices and quantities in wholesale markets for the five largest non-citrus fruit crops in the United States. These crops, in order of quantities sold, are apples, grapes, strawberries, peaches, and pears (Economic Research Service, 2003). The sales in 2001 for these five crops range from 547 to 2,771 thousand tons. Price per ton varies from $364 to $1,514 per ton.

Conjectures were set equal to the credence market share in the initial, pooled equilibrium. Baseline credence market shares were selected to parallel conditions found in agricultural markets. The lower endpoint was 2 percent and was based on the market share of organic produce prior to the organic program (Greene, 2001). The upper endpoint was 40 percent.

Demand parameters were based on research literature (Brown and Lee, 2002; Huang and Lin, 2000; You, Epperson, and Huang, 1998). The demand elasticity range was based on econometric research showing that recent fruit and vegetable elasticity estimates varied from just less than -.3 to a little over -1.1. The formula for price elasticity was used to calculate the slope of the reservation price schedule for randomly drawn combination of demand elasticity, price, and quantity. Willingness to pay values were selected to incorporate mean estimates, as well as to examine the somewhat higher willingness to pay values that may be found in limited segments of a market (Blend and van Ravenswaay, 1999; Buzby, Ready, and Skees, 1995; Hammitt, 1990; Ott, Huang, and Misra, 1991).

The supply elasticity range from 0.2 to 1.2 was selected to represent the ranges found in the empirical literature on aggregate supply response. For instance, Nerlove's seminal study estimated supply elasticities that ranged from 0.09 to 0.93 (Nerlove, 1956). A review of supply response studies two decades after Nerlove's article found 190 studies and almost 400 estimates of agricultural supply response. Almost 90 percent of these 400 estimates were less than 1.2 (Askari and Cummings, 1977). A recent study estimated elasticities ranging from 0.13 to 1.11 for major agricultural subsectors (Shumway and Lim, 1993). Supply elasticity estimates for organic lettuce range from 0.23 and 0.56, depending length of the time period allowed for adjustment (Lohr and Park, 1992).

The cost of certified labeling was based on slotting fees charged for placing branded and bagged vegetable in supermarkets. A recent study reports that typical slotting fees range from one to eight percent(Calvin et al., 2001). Given these data, labeling costs were set within a range from zero to five percent, so as to determine the sensitivity of the simulation results to modest cost levels.

The simulations were developed by randomly selecting 8,000 sets of baseline conditions and parameters from the ranges in Table 1. The selection process used a uniform distribution on each range so that each parameter value with the range had an equal probability of being selected for one of the 8,000 simulations. The selected values were used to compute quantities, prices, and surpluses for the pooled and separating equilibrium. Two different sets of separating equilibria were generated for each of the 8,000 sets of values; the first for costless labeling, $\tau = 0$, and the second with costly labeling, $\tau > 0$.

Price and Quantity Results

The bottom portion of Table 1 describes the quantity and price effects of costless and costly labeling. Labeling performs exactly as anticipated in Propositions 1 and 2. Costless labeling results in a one-thousand ton increase in the mean aggregate quantity, resulting from a 46-thousand ton mean decrease in conventional production and a 47-thousand ton mean increase in credence production. At the mean, credence market share rises three points to 24 percent in the separating equilibrium from 21 percent in the pooled equilibrium. The mean conventional price is six percent less than the pooled equilibrium and the mean credence price is 22 percent greater in the separating equilibrium than in the pooling equilibrium. The mean credence price premium is 27 percent of the initial pooling price, consistent with Proposition 2. The range of price and quantity effects vary with the parameter values. For instance, change in the conventional quantity may be almost zero in some cases and over 300 thousand tons in other cases.

Costly labeling differs from costless labeling in two important ways. First, the mean aggregate quantity in a separating equilibrium is less than that of the pooling equilibrium. This suggests that the welfare effect for conventional consumers may be negative, at least at the mean when labeling is costly. Second, the mean credence and conventional prices in the separating equilibrium with costly labeling are slightly higher than the prices in the costless labeling simulations. Since only credence production experiences the direct costs of labeling, the higher prices for conventional producers may reduce their certain loss. The mean credence price increase is not enough to offset mean labeling costs, so labeling costs reduce credence producer surplus.

Benefits and Costs of Labeling

Benefits and costs were computed using the welfare differences listed in Table 2. The welfare change equations were derived by taking the differences between the consumer and producer surpluses realized in the pooled and separating equilibrium. Table 3 lists the welfare change results computed using the welfare change equations. A positive dollar value represents a benefit and a negative value is a cost. Benefits and costs were calculated for each of the 8,000 simulated pairs of pooled and separating equilibria. Table 3 reports the results as the mean and range across the 8,000 differences for each of the welfare measures.

Costless labeling has a positive impact on aggregate, but the incidence of gains and losses is highly asymmetric, especially across production sectors. The aggregate market mean is a net benefit of $7.4 million with a range from approximately zero to $83 million. The mean effects on credence and conventional consumers are $0.6 million and $1.1 million, but the losses from costless labeling range as great as $122 million for conventional consumers and $82 million for credence consumers. Conventional producers are certain to lose with labeling. They mean loss is $65 million, and ranges from almost zero to $486 million. Credence producers are the certain gainers from labeling, with a mean benefit of $71 million and a range from $1 million to $530 million.

Using data from willingness to pay studies, it may seem appropriate to estimate the welfare consequences of labeling using mean willingness to pay times the market quantities affected. One such rule-of-thumb estimate multiplies willingness to pay times the initial pooled credence quantity, resulting in benefits of $89.5 million. This latter estimate is more than 12 times the correct aggregate market impact of $7.4 million. Alternatively, one might assume that the labeled credence product applies to the entire market, so the benefit estimate would be willingness to pay times the aggregate pooled quantity. This latter procedure results in a more misleading estimate. Thus, benefit measures that use only mean willingness to pay and initial market conditions provide a misleading benefit assessment. They also fail to identify the situations where the net impact is negative.

The costly certification simulations included unit labeling costs for credence producers that ranged from zero to five percent of the initial pooling price. With this modest level of costs, the mean aggregate impact is negative and the range of aggregate welfare impacts widens to include a significant negative region. The results across the different groups remain similar to costless labeling, but the ranges for each group become slightly more negative. Even credence producers may be worse off in some costly labeling scenarios.

Labeling gives the credence production sector routine incentives to realize gains as the expense of other market groups. In all cases where the credence producer impact is positive, the net impact on consumers and conventional producers is negative. Correlation analysis indicates that the conflict in interests was strongest between credence and conventional producers, and relatively weak between credence producers and credence consumers. The Pearson correlation coefficient for the credence and conventional producer impacts was -0.9, while it was only -0.15 between credence producers and conventional consumers and -0.16 between credence producers and credence consumers.

Credence producers may also realize a gain from costly labeling when the overall market impact is negative. This creates an incentive to seek adoption of certified labeling even when it is economically inefficient. An inspection of individual cases showed that credence producers have a positive gain with a net market loss in about 60 percent of the simulations with costly labeling.

Labeling with Market Saturation

When market saturation occurs with labeling, consumers are able to match their preferences to the pure good they prefer, but price is determining by demanders who do not have a willingness to pay for the credence attribute. The latter consumer group is indifferent between the conventional and green goods. Hence, price is equalized across the two markets. With costless labeling, green consumers experience a welfare improvement welfare gain without paying a price premium or a higher price.

Table 4 lists the welfare consequence of labeling with and without market saturation. As a point of reference, the column labeled "None" lists welfare changes at the mean level of the initial conditions in Table 1, but with no market saturation. The two other columns report welfare changes with saturation at five and ten percent of the pooled aggregate quantity.

The results for costless certification and labeling highlight the impact of market saturation. Without market saturation, conventional producers lose \$53.6 million in surplus with labeling while green producers gain \$57.6 million. The aggregate impact is a net gain of \$4 million. Green and conventional consumer welfare is unaffected by costless labeling since the equilibrium price and quantity remain unaffected by the green consumers' shift in demand. With market saturation, there are too few green consumers to affect market price. With market saturation, green consumers gain \$13 million, with no welfare costs to conventional consumers, conventional producers, and green producers. Costless labeling with market saturation simply allows green consumers to match their preferences with the appropriate product.

Costly labeling changes the results once again, and somewhat paradoxically. Certification costs increase supply costs for green producers. However, with market saturation, no price premium emerges to compensate for the additional costs. Green and conventional producers compete at a price determined by demand for the conventional product. Higher costs in the green subsector result in a loss of market share for green producers and a higher price for the conventional and green product. Conventional producers gain from the higher price and greater market share.

Green consumers gain from matching their preferences to the green product, while paying only a portion of the cost of certification. Conventional consumers lose due to the increase in price. As long as market saturation occurs, green consumer welfare rises linearly with the percentage of green consumers. Of course, at some point the number of green consumers would reach a point where there is no market saturation and the equilibrium would shift to one without market saturation.

Conclusion

The analysis developed a theoretically rigorous framework for evaluating the benefits and costs of credence labeling. The framework can be readily adapted to specific markets and labeling policies. All that is needed are the baseline prices and quantities in the pooled market, demand and supply elasticities, and willingness to pay for the credence attribute. In addition, the analysis shows that it is critical to know how willingness to pay is distributed across consumers and their quantities demanded. The distribution of willingness to pay is the critical factor in determining the market consequences of labeling; that is, whether labeling supports two separate markets or credence subsector sustains the cost of labeling without a concomitant price premium.

The analysis shows that neither average willingness to pay in excess of average labeling costs, nor anticipated gains to credence producers, are reliable indicators of the net benefits of labeling. Average willingness to pay is only one of the factors that determines price and net benefits. Gains for credence producers do not predict general efficiency gains. The net welfare effects of labeling may be negative even when credence producer surplus is large and positive. As in Spence (1973), credence producers may have an interest in inefficient signals.

Certified labeling can cut deeply into the economic returns of a market subsector. Net welfare gains of labeling are small relative to gross gains and losses. When sizable gains and losses are likely to occur, compensatory strategies may be appropriate. Informational strategies other than labeling may prove to be more benign. For instance, if consumer conjectures are incorrect, a market-level information policy about the level of the credence attribute in the pooled market may reduce deadweight loss without disrupting returns to producers.

Paradoxically, costless labeling is free of adverse impacts when the market saturation occurs. Market saturation occurs when credence production exceeds the credence quantity demanded by those consumers who care about the credence attribute. With market saturation, certified production is priced at the margin by consumers who are *not* willing to pay for the credence characteristics. A price premium fails to emerge and those who care about the credence attribute get the credence good at the conventional good price. The net welfare effect of labeling is positive as long as certification costs are not too high. However, the asymmetric in gains and losses still occur. Credence producers and conventional consumers lose while conventional producers and credence consumers gain.

The results suggest a pragmatic and cautious approach to certified labeling proposals in agricultural markets. Empirical analysis of the market consequences of credence labeling requires good estimates of the supply and demand elasticities, in addition to willingness to pay for labeled products. Moreover, while willingness to pay research is well established, market segment research is needed on the distribution of willingness to pay across consumers, since willingness to pay at the margin of price determination is crucial in determining the size and distribution of benefits and costs. In the end, labeling provides no Pareto superior market outcome given the asymmetry of gains and losses. Informed policy choices require a explicit tradeoff of the estimated gains and losses across consumers and producing subsectors.

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Table 1. Initial Conditions and Results for Simulated Separating Equilibria[a]

Market Quantities	Mean	Range
*Baseline Market Conditions and Parameter*s		
Aggregate quantity, 1,000 tons	1,655	547 to 2,771
Price per ton, $	944	364 to 1,514
Credence market share, %	21	2 to 40
Demand elasticity	-0.7	-0.2 to -1.2
γ_1 as percent of pooled price	27.4	5 to 50
Conventional supply elasticity	0.7	0.2 to 1.2
Credence supply elasticity	0.7	0.2 to 1.2
Certification cost as a percent of price, %	2.5	0 to 5
Costless certification, separating equilibrium		
Aggregate quantity, 1000 tons	1,656	537 to 2,839
Change in conventional quantity, 1000 tons	-46	-318 to ~0
Change in credence quantity, 1000 tons	47	~0 to 326
Credence market share, %	24	2 to 51
Conventional price per ton, $	889	280 to 1,509
Credence price per ton, $	1,147	389 to 2,235
Costly certification, separating equilibrium		
Aggregate quantity, 1000 tons	1,653	536 to 2,828
Change in conventional quantity, 1000 tons	-42	-318 to -10
Change in credence quantity, 1000 tons	44	-5 to 326
Credence market share, %	24	2 to 51
Conventional price per ton, $	892	283 to 1,510
Credence price per ton, $	1,150	389 to 2,235

a. The simulations were based on 8,000 sets of parameters drawn from the range of parameters listed as initial conditions. The costless certification results reset each of the unit cost parameter to zero, while the costly certification results left unit certification costs at the randomly drawn values. Initial quantities and prices were representative of annual data for five largest non-citrus fruit crops in 2001 (Economic Research Service, 2003).

Table 2: Welfare Differences between the Separating Equilibrium with Certified Labeling and the Pooling Equilibrium[a]

Market Groups	Welfare Differences: Surplus in Separating Equilibrium Minus Surplus in Pooling Equilibrium
Credence	
Producers	$\Delta ps_g = \delta_1(q_g^s - q_g^p)q_g^p + 0.5\delta_1(q_g^s - q_g^p)^2$
Consumers	$\Delta cs_h = -\delta_1(q_g^s - q_g^p)q_g^s + (1-\alpha)\gamma_1 q_g^s - \tau q_g^s$
Credence market	$\Delta s_g = (1-\alpha)\gamma_1 q_g^s + 0.5\delta_1(q_g^s - q_g^p)^2 - \tau q_g^s$
Conventional	
Producers	$\Delta ps_c = -\mu_1(q_c^p - q_c^s)q_c^s - 0.5\mu_1(q_c^s - q_c^p)^2$
Consumers	$\Delta cs_c = 0.5\gamma_2[q_c^{s2} - (Q_\alpha^p - q_g^s)^2]$
Conventional market	$\Delta s_c = -\mu_1(q_c^p - q_c^s)q_c^s - 0.5\mu_1(q_c^s - q_c^p)^2 + 0.5\gamma_2[q_c^{s2} - (Q_\alpha^p - q_g^s)^2]$

a. The equations are derived for the situation where market saturation does not occur. The welfare differences for market saturation are available upon request to the authors.

Table 3. Welfare Impacts of Costless and Costly Certified Labeling[a]

Welfare Measure	Welfare Change due to Certified Labeling in Millions of Dollars			
	Costless Certification		Costly Certification	
	Mean	Range	Mean	Range
Aggregate market	7.4	0 to 83	-1.9	-61.9 to 71.2
Consumers				
Credence	0.6	-82 to 107	-0.8	-88 to 100
Conventional	1.1	-122 to 163	-1.9	-133 to 147
Producers				
Credence	70.8	1 to 530	62.8	-3 to 306
Conventional	-65.0	-486 to -1	-62.0	-481 to -1
Rules-of-Thumb				
$q_g^p(\gamma_1 - \tau)$	89.5	1 to 693	81.2	0 to 668
$Q^p(\gamma_1 - \tau)$	427.4	16 to 1,972	388.0	1 to 1,893

a. The welfare measures for costless and costly labeling were computed using the 8,000 pairs of simulated pooled and separating equilibria. The initial conditions, price, and quantity results are described Table 1. The costless certification results reset each of the unit cost parameters to zero, while the costly certification results left unit certification costs at the randomly drawn values.

Table 4. Welfare Gains from Certification with Certification Costs and Market Saturation, Millions of Dollars

Cost Levels and Market Subsector	Market Saturation Level		
	None	At 5%	At 10%
Costless Certification			
Conventional Producers	-53.6	0.0	0.0
Conventional Consumers	0	0.0	0.0
Green Producers	57.6	0.0	0.0
Green Consumers	0.0	13.0	25.9
Aggregate	*4.0*	*13.0*	*25.9*
Certification Cost at 5% of Pooled Price			
Conventional Producers	-47.3	6.5	6.5
Conventional Consumers	-6.3	-7.8	-7.4
Green Producers	41.4	-14.5	-14.5
Green Consumers	-1.9	12.5	25.1
Aggregate	*-14.1*	*3.2*	*9.8*
Certification Cost at 10% of Pooled Price			
Conventional Producers	-41.0	13.0	13.0
Conventional Consumers	-12.7	-15.5	-14.6
Green Producers	25.7	-28.4	-28.4
Green Consumers	-3.6	12.1	24.3
Aggregate	*-31.6*	*18.8*	*-5.8*

a. When market saturation occurs, the welfare results for conventional producers, conventional consumers, and green producers do not vary with the level of saturation, only the level of certification costs.

Figure 1. Pooled Market Equilibrium Price and Quantities

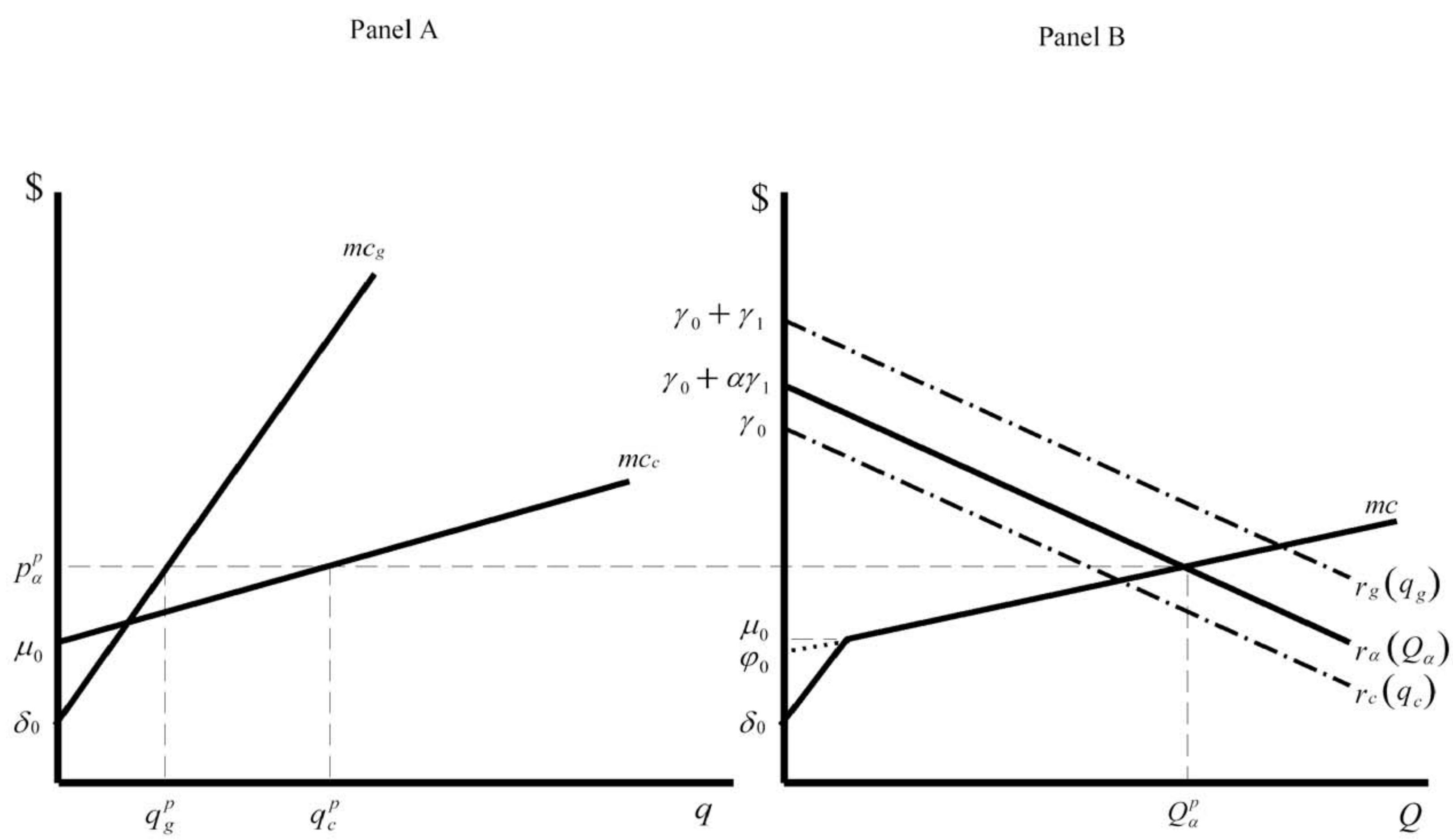


Figure 2. Prices and Quantities in a Separating Market Equilibrium

Panel A

Panel B

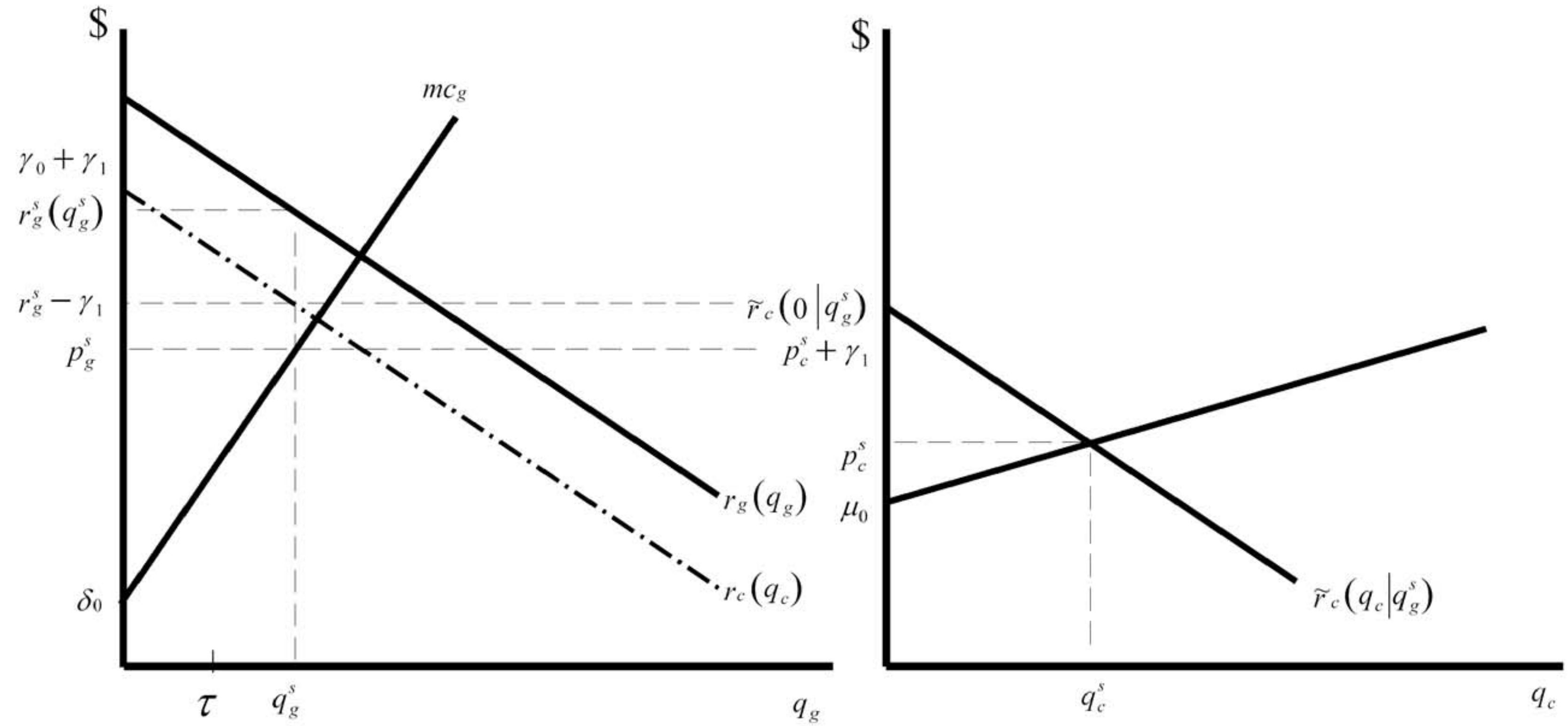
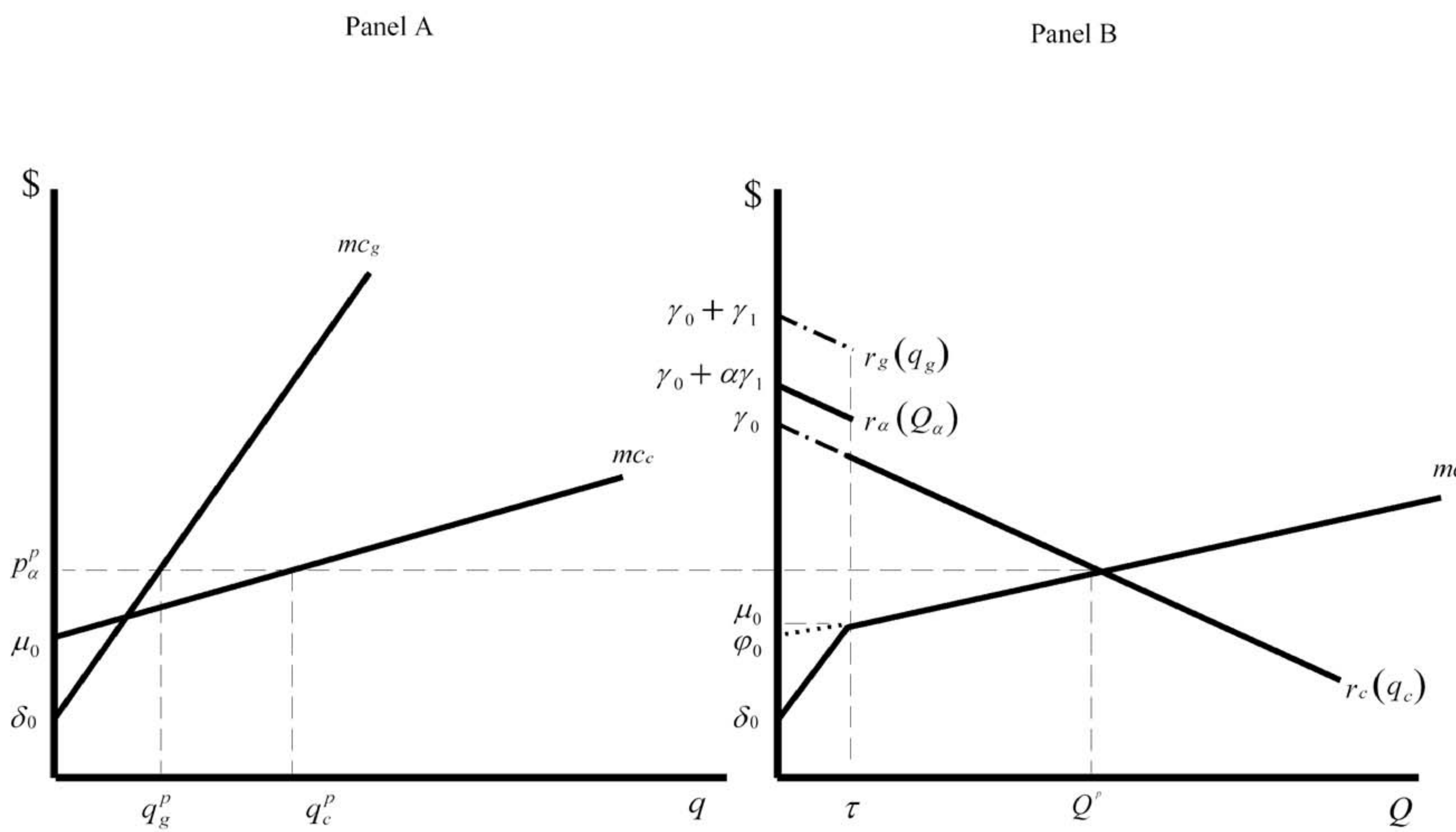


Figure 3. Market Saturation



User Fees and the Demand for OHV Recreation

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Abstract

The recent boom in the demand for off-highway vehicle (OHV) recreation has created an important policy issue for public land managers who are concerned with the impacts of OHV use on environmental quality. Within the past few years, the U.S. Forest Service has recognized the need for greater authority in managing these recreation areas and has proposed to amend OHV regulations. However, not much is known about the demand for OHV recreation or how various policy tools might be applied to improve the management of OHV sites. One means of protecting environmental quality and restoring areas damaged by unauthorized OHV use is to make use of funds collected through the recreational user fee program to restore and maintain OHV areas. A second method would be to make use of volunteers from OHV clubs and other riders to help protect OHV sites. To help address and evaluate these issues, data were collected at three OHV sites in North Carolina. The demand for OHV recreation was estimated using standard and simulation-based, random parameter count data models. Econometric results from the random parameter models indicated that the most avid OHV riders did not think that user fees were an appropriate method to manage OHV recreation. In contrast, riders who volunteer to maintain trails and OHV areas are more avid riders. Consequently, it seems

that the encouragement of volunteer effort and labor could be a viable and productive means to improve trail maintenance and environmental protection at OHV sites.

1. Introduction

Off-highway vehicle (OHV) use on public lands is becoming a major policy issue for the U.S. Forest Service and other land management agencies. The demand for OHV use on public land is not new - motorcycles have been used off-road for almost a century (Havlick 2002). Because dirt bikes are relatively difficult to ride, the demand for this type of recreation is relatively stable. However, the change in technology from two-wheeled to four wheeled vehicles has dramatically altered the demand for OHV use. This is evident in the boom in popularity for four-wheel drive (4WD, SUV) and all-terrain vehicle (ATV) use on public lands.

OHV recreation has become an important policy issue on public lands because these vehicles can have negative impacts on the environment by increasing soil erosion, decreasing water quality and impairing wildlife and visual aesthetics. Attempts to regulate OHV use on public lands are not new. Executive Orders E.O. 11644 (1972) and E.O. 11989 (1977) addressed safety and environmental concerns with OHVs by authorizing the Forest Service to manage OHV use so as to protect the land as well as the safety of all users of those lands. Within the past few years, however, the Forest Service has recognized the need for greater authority in managing these recreation areas and has proposed to amend the OHV regulations in an attempt to mitigate unacceptable environmental damage to Forest Service lands (USDA Forest Service 2004).

One means of protecting environmental quality and restoring areas damaged by unauthorized OHV use is to make use of funds collected through the recreational user fee program authorized in 2004. This program gives federal agencies the authority to collect user fees at certain sites and invest the revenues at the site where they were collected. Collected fees could be used to close trails where environmental impacts are unacceptable, or to perform trail improvements that would help protect environmental quality.

Another approach to protecting environmental quality and restoring areas damaged by unauthorized OHV use is to collaborate with trail riding clubs and organizations that provide volunteers for trail maintenance. Because people who use OHV trails have a stake in maintaining access to those areas, trail riding organizations have traditionally participated in protecting the quality of, and access to, the riding environment.

We are unaware of any published studies that evaluate the economic demand for, or value of, OHV use on public lands. In this paper, we present analysis of OHV demand and consumer surplus at three Forest Service sites in North Carolina. Empirical estimates are obtained using standard and simulation-based random parameter count data models in order to evaluate respondent heterogeneity. We are particularly interested in understanding how the avidity of OHV users (as proxied by the number of OHV trips) is related to two key policy variables: (1) whether or not the collection of user fees is an appropriate way to manage OHV recreation, and (2) whether or not the respondent has ever volunteered to conduct trail maintenance.

The paper is organized as follows. In section 2, we describe the study area and the data collection method. In section 3, we describe the empirical methods we used. In section 4, we present our results and in section 5 we present the conclusions of our study.

2. Study Area and Data Collection

The three study sites are all located in the National Forests of North Carolina and allow opportunities for trail bikes, ATV and 4WD use. Two of the sites are in the mountains of western North Carolina and the third site is in the Piedmont physiographic region. The Upper Tellico is a premier regional site located in the Nantahala National Forest. This site is highly scenic and the steep, rugged trails are designed for use by experienced riders only. The other mountain site, Brown Mountain, is located in the Pisgah National Forest, contains less severe terrain and offers recreational opportunities for beginning to advanced riders. The third site, Badin Lake, is located in the Uwharrie National Forest. Although not as high in elevation as the other two sites, Badin Lake contains an abundance of steep, rocky terrain and opportunities for all classes of riders.

Data were collected using a paper and pencil survey that was administered on-site to riders as they were exiting the trail system during the summer of 2000. Volunteers from local trail riding organizations were used to collect the data. Respondents were asked to enumerate the total number of trips they made to each of the OHV sites during each of the previous three years. Although this procedure may induce some degree of recall bias, the number of trips taken to sites is relatively small, which would mitigate possible recall bias. Data for the three years were pooled for analysis.

Respondents provided information regarding the origin of their current trip, which allowed us to compute travel costs (estimated as $0.34 per mile). In addition, questions were asked to respondents regarding their riding experience, skill, type of vehicle used, OHV related expenses, age, education, and income. Respondents were also asked two questions that would help us evaluate possible means for protecting and restoring environmental quality at OHV sites. First, respondents were asked "Have you ever volunteered to maintain OHV trails?" Second, respondents were asked "Do you think that user fees can be a good tool to manage public recreation areas?"

3. Empirical Methods

During the past decade, there has been an explosion of interest in the use of count data models to estimate the demand for outdoor recreation (e.g., see Englin et al. 2003). In contrast to earlier Hotelling-Clawson-Knetsch travel cost models that used ordinary least squares regression methods, count data models emphasize the non-negative, integer nature of the data on the number of trips taken and are most useful when the per person counts are small. This condition is met with count data for OHV recreation.

A second development during the past decade has been the development of simulation-based econometric methods that allow the estimation of respondent preference heterogeneity via random parameters. This is accomplished by replacing integrals of large dimensions in the probability density function with simulated counterparts (Gouriéroux and Monfort 1996). The use of simulation for investigating preference heterogeneity has been applied most frequently in discrete choice analysis (Train 2003). However, similar methods can be applied to other econometric models. In this paper, we use simulation-based methods to investigate preference heterogeneity in count data models of recreation demand.

Random parameters are estimated using what is known as a 'mixed function', which is the weighted average of several functions and a mixing distribution provides the weights (Train 2003). Perhaps the best known mixed function count data model is the negative binomial (NegBin) model. In the NegBin model, the mean λ of the Poisson distribution is considered a random variable and the mixing distribution is the gamma density (Cameron and Trivedi 1986). The fit obtained with the NegBin model is often superior to the Poisson fit because the NegBin accounts for overdispersion of the data (i.e. it allows the variance to exceed the mean). As pointed out by Mullahy (1997), unobserved heterogeneity, or population mixing, implies overdispersion of the data, but overdispersion does not necessarily imply heterogeneity. For example, the zero-inflated Poisson model accounts for overdispersion in the data (Haab and McConnell 1996), but does not imply unobserved heterogeneity in the conditional mean.

One limitation of the NegBin model is that it assumes that heterogeneity arises solely in the mean event rate of the Poisson parameter λ. More recent models have been developed to account for heterogeneity in the mean event rate *and* the regression parameters β. If the mixing function g(β) is discrete, where β takes only a limited number of classes, it is referred to as a latent class (or finite mixture) model. Wedel and others (1993) developed a latent class Poisson model to account for heterogeneity in count data parameters β across market segments. If the mixing distribution is continuous, rather than discrete, heterogeneity in the parameters of count data regressions can be modeled as randomly distributed parameters (Greene 2002).

The random parameters count data model allows some parameters to be random (β_i) while others are not (β). The random parameters include an unobservable latent random term ν_i for each individual i:

$$\beta_i = \beta + \Gamma \upsilon_i \tag{1}$$

where ν_i has zero mean and variance one and Γ is a diagonal matrix which produces the variance matrix of the random parameters. Given this structure, the log-likelihood for the random parameters count data model is:

$$\log L = \sum_{i=1}^{n} \log \int_{\nu_i} g(\upsilon_i) P(y_i | x_i, \upsilon_i) d\upsilon_i \tag{2}$$

where $P(y_i|x_i,\nu_i)$ is the Poisson or NegBin probability conditioned on covariates x_i and ν_i, and y_i is the number of trips. Simulation of the log likelihood function

$$\log L = \sum_{i=1}^{n} \log \frac{1}{R} \sum_{r=1}^{R} P(y_i | x_i, \upsilon_{ir}) \tag{3}$$

over a large number R of simulated draws from the distribution of ν_i is used to estimate the parameters of the model.

Economic theory does not provide guidance on which parameters of the model should be specified as random and which ones should not. Consequently, to simplify the presentation, we only specify our two policy variables as having random parameters. Randomness in the parameters of a count data model of recreational trips reveals information on the relationship between the variable and the number of trips taken by the respondent. We interpret the randomness, then, as an indication of how the 'avidity' of recreational users changes with respect to the policy variables. This is consequential for policy analysis because, *ceteris paribus*, people who are more avid participants in a sport are more likely to be concerned about potential changes to the recreational resource. In our analysis, potential changes include expanded scope for utilizing user fees to pay for environmental protection at recreation sites and the use of volunteer effort to maintain the recreational environment.

4. Results

Surveys were completed for 357 respondents. A profile of the characteristics of OHV riders in western North Carolina shows that, on average, riders are generally young (32 years), predominantly male (88%), and middle-class ($50,100 annual income) (Table 1). ATVs (52%) and four wheel drive vehicles (55%) are much more commonly used than are trail bikes (19%). A very small proportion of riders are handicapped (2%) and a significant proportion of riders have received injuries that required medical attention (13%). A moderate number of riders reported that drinking alcoholic beverages at OHV sites is a typical part of their OHV trip (21%). Respondents have, on average, nearly a decade of riding experience (9.8 years) and self-reported their skill level as mid-way between Intermediate and Advanced. Average annual expenses incurred in pursuit of OHV riding were about $1,811 and riders spent about $7,053 on their most recent OHV purchase.

Count data models were estimated for each of the study sites (Tables 2, 3 and 4). The statistical fit, as measured by one minus the likelihood ratio, was better for the random parameter models than for the nonrandom parameter models. In particular, the random parameter Poisson model was found to have the best fit at all three sites. The dispersion parameter in the NegBin model was found to be significantly different than zero at Brown Mountain and Badin Lake. The value of the dispersion parameter was much smaller in the random parameter NegBin model than in the nonrandom parameter model. The random parameter NegBin model did not converge for the Upper Tellico site.

Parameter estimates on the travel cost variable were negative and statistically significant at the 0.05 level or greater in each of the model specifications. In addition, a number of socio-economic and behavioral variables were found to have a statistically significant impact on the demand for OHV trips. Parameter estimates from the random parameter Poisson models for each site (the best-fit models) provide insight into the factors that influence OHV demand. Different factors have varying impact on recreation demand depending on the site considered. For example, consider the factors that influence the demand for trips to Upper Tellico, which is considered to be a premier regional OHV destination. Estimates from the random parameter Poisson model demonstrate that riders participate more frequently at this site if they are older, more experienced, better educated and with higher income levels. In contrast, at the other two sites, younger riders with lower incomes participate more frequently. Apparently, the OHV market can be segmented based on rider characteristics. Presumably, rider characteristics influence the type of riding experience that is being sought at each of the OHV sites.

Statistically significant random parameters were estimated for the mean and standard deviation of the two policy variables. Four of the five random parameter estimates for the mean value of the USER FEE variable were negative, indicating that people who thought that user fees can be a good tool to manage public recreation areas were less avid riders, on average. Conversely, more avid riders did not think that user fees can be a good management tool. In the one instance that a positive random parameter estimate was found for the USER FEE variable, the estimate was not statistically significant at the 0.10 level and the magnitude of the parameter estimate was close to zero, indicating that feelings about user fees did not have any impact on avidity in that model.

All five random parameter estimates for the mean value of VOLUNTEER were positive and statistically significant at the 1 percent level. This result suggests that people who volunteer to help maintain OHV areas and trails are, in general, more avid riders. It seems that the volunteer labor and effort supplied by this group of riders could be encouraged and applied to help protect and restore environmental quality at OHV sites.

Estimates of the standard deviation of the random parameters can be used to understand respondent heterogeneity regarding the relationship between the policy variables and

OHV trip frequency (Table 5). At two of the three study sites, the vast majority (85%-88%) of riders who think that user fees are a good management tool are less avid riders. Conversely, only a small percentage (12-15%) of respondents who think that user fees are a good management tool are avid riders. At the third site, what people think about user fees does not seem to be strongly related to trip frequency. These results suggest that increased reliance on user fees to protect and restore OHV areas will not likely gain the support of the more avid users. However, at all of the study sites, the majority of people (53-78%) who volunteer to help maintain and restore OHV areas are more avid riders. This result provides further support for the idea that volunteers could be an important resource for managing OHV areas on public land.

Estimates of consumer surplus show that the value of OHV riding varies dramatically across the western North Carolina sites included in the analysis (Table 6). This variation is likely due to differences in site characteristics. For example, Upper Tellico is considered to be a premier regional site with many scenic attributes and extremely challenging trails. The value of this site for OHV use is reflected in the consumer surplus estimate ($333.33/ trip). At the other end of the spectrum, the Brown Mountain site is considered to be more favorable to beginning riders, for which more substitutes would be available, and the consumer surplus estimate is considerably smaller ($27.03/ trip). The characteristics of the Badin Lake site would fall in between the two other sites in terms of difficulty, which is captured by a moderate consumer surplus estimate ($55.00/ trip).

5. Conclusions

OHV recreation on public land is growing rapidly, largely due to the advent of ATVs (Havlick 2002). As OHVs can cause negative impacts to the environment, as well as to other riders, it is essential that public land management agencies take appropriate steps to assure the protection of the environment, restore the environment where it has been damaged, and provide safe riding conditions. Proposed revisions of OHV regulations by the USDA Forest Service demonstrate that this agency has recognized the need to improve the management of OHV recreation sites.

In this paper, we have provided estimates of the demand for, and value of, OHV recreation at three sites in western North Carolina using standard and simulation-based count data models. In addition to travel cost, a number of socio-economic and behavioral characteristics were shown to influence the demand for OHV recreation. Income, age, and education influence the demand for OHV recreation, but have different impacts at different sites. The segmentation of demand across sites is likely due to the characteristics of the sites. A better understanding of what types of riders choose to ride more frequently at various sites could help managers protect and improve important site characteristics. Alternatively, data could be pooled across sites to estimate a single visitation demand function. Heterogeneity in parameter values across sites could then be identified using the simulation-based random parameter models.

The random parameter count data models we estimated fit the data better than the nonrandom parameter models and, consequently, represent a promising new tool for modeling recreation trip count data. Random parameters were estimated for two policy variables related to the protection and restoration of OHV recreation areas. It was discovered that increased implementation of new user fees in western North Carolina may meet resistance from more avid riders. That is, the riders who think that user fees are a good management tool are the less avid riders. In contrast, riders who volunteer to maintain trails and OHV areas are, in general, more avid riders. It seems that the encouragement of volunteer labor and effort could be a viable and productive means to improve trail maintenance and environmental protection at OHV sites. We suggest that strategies utilizing this approach, such as providing user fee vouchers for volunteers, should be evaluated through future research endeavors.

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Table 1. Profile of OHV riders in western North Carolina

Variable	Description	Mean	Std. dev.	N
Income	Dollars	50,100	10.95	282
Age	Years	32	10.36	351
Male	Percent	88	0.33	345
Education	Years	13.6	2.47	354
Injury	Percent needing medical attention	13	0.33	354
Drinking	Percent responding drinking alcohol at OHV site is typical part of trip	21	0.41	354
Handicap	Percent having a Handicapped Parking Permit	2	0.13	357
History	Number of years have been riding	9.8	8.5	354
Skill	Self-reported 3-point scale (Beg.-Int.-Adv.)	2.5	0.6	342
ATV	Percent of respondents who ride this vehicle	52	0.50	354
4WD	Percent of respondents who ride this vehicle	55	0.49	354
Trail bike	Percent of respondents who ride this vehicle	19	0.39	354
Annual expense	Average spent per year on OHV equipment and gear, dollars	1,811	2,240	315
Most recent purchase	Expenditure on most recent OHV, dollars	7,053	6,816	327
User fee	Percent agreeing	77	0.43	342
Volunteer	Percent who have volunteered	45	0.50	351

Table 2. Count Data Models for Brown Mountain

Variable	Poisson parameters	NegBin parameters	RP Poisson parameters	RP NegBin parameters
		Nonrandom Parameters		
Constant	-1.23	1.64	4.35	11.08
	(-3.31)	(1.28)	(14.82)	(12.51)
TCOST	-0.006	-0.02	-0.04	-0.015
	(-6.08)	(-3.29)	(-20.75)	(-3.51)
YEARRIDE	-0.04	0.02	0.03	-0.08
	(-6.33)	(0.71)	(5.43)	(-4.68)
AGE	0.02	0.03	-0.02	0.09
	(5.90)	(1.52)	(-4.92)	(7.68)
SCHOOL	-0.18	-0.23	-0.16	-0.76
	(-8.98)	(-2.57)	(-7.77)	(-14.51)
SKILL	0.15	-0.58	-0.75	-2.21
	(1.80)	(1.68)	(-8.89)	(-8.60)
INCOME	0.01	0.01	-0.01	0.01
	(10.13)	(1.90)	(-11.16)	(2.54)
DRINKING	0.65	0.87	0.12	1.55
	(7.30)	(2.06)	(1.48)	(6.12)
TRAIL BIKE	1.36	0.85	0.90	1.52
	(13.51)	(1.95)	(9.44)	(5.02)
ATV	0.30	0.31	-1.72	-1.28
	(3.70)	(0.85)	(-21.24)	(-5.97)
USER FEE	0.18	-0.29	--	--
	(1.85)	(-0.67)		
VOLUNTEER	1.93	1.77	--	--
	(16.74)	(5.18)		
		Mean for Random Parameters		
USER FEE	--	--	-5.73	-2.06
			(-30.26)	(-6.66)
VOLUNTEER	--	--	0.87	2.26
			(9.52)	(11.36)
		Standard Deviation for Random Parameters		
USER FEE	--	--	5.47	6.08
			(42.31)	(15.08)
VOLUNTEER	--	--	2.80	0.53
			(39.53)	(3.86)
		Dispersion Parameter		
α	--	11.61	--	0.29
		8.01		16.18
$1-L_1/L_0$	0.33	0.61	0.75	0.64

Note: Parameters in parentheses are t-statistics.

Table 3. Count Data Models for Badin Lake

Variable	Poisson parameters	NegBin parameters	RP Poisson parameters	RP NegBin parameters
Nonrandom Parameters				
Constant	-0.65	1.01	-0.65	-3.57
	(-2.39)	(1.04)	(-4.02)	(-6.93)
TCOST	-0.008	-0.02	-0.02	-0.02
	(-6.95)	(-3.94)	(-16.79)	(-7.37)
YEARRIDE	-0.01	-0.004	-0.01	-0.004
	(-3.06)	(-0.02)	(-3.60)	(-0.43)
AGE	-0.03	-0.04	-0.03	-0.03
	(-8.29)	(-2.48)	(-9.18)	(-3.58)
SCHOOL	0.06	-0.02	0.06	0.40
	(4.01)	(-0.31)	(5.17)	(11.62)
SKILL	0.34	0.15	0.34	0.06
	(5.79)	(0.60)	(8.23)	(0.58)
INCOME	0.005	0.007	-0.01	0.008
	(4.64)	(1.44)	(-15.43)	(3.58)
DRINKING	0.11	0.34	0.11	1.26
	(1.47)	(0.93)	(2.20)	(8.22)
TRAIL BIKE	-0.10	0.30	0.10	-0.13
	(-1.21)	(0.86)	(1.77)	(-0.90)
ATV	0.31	0.79	0.31	-0.64
	(4.84)	(2.56)	(6.91)	(-5.06)
USER FEE	0.09	-0.08	--	--
	(1.21)	(-0.27)		
VOLUNTEER	0.56	1.06	--	--
	(8.81)	(3.20)		
Mean for Random Parameters				
USER FEE	--	--	0.08	-1.27
			(1.63)	(-9.40)
VOLUNTEER	--	--	0.56	0.27
			(9.23)	(2.04)
Standard Deviation for Random Parameters				
USER FEE	--	--	4.29	2.06
			(57.43)	(19.85)
VOLUNTEER	--	--	6.68	1.75
			(54.37)	(14.54)
Dispersion Parameter				
α	--	8.58	--	0.45
		(10.69)		(17.76)
$1-L_1/L_0$	0.14	0.62	0.67	0.65

Note: Parameters in parentheses are t-statistics.

Table 4. Count Data Models for Upper Tellico

Variable	Poisson parameters	NegBin parameters	RP Poisson parameters
Constant	-3.60	-4.52	-9.75
	(-10.48)	(-6.00)	(-32.43)
TCOST	-0.006	-0.002	-0.003
	(-3.56)	(-1.96)	(-4.20)
YEARRIDE	0.01	-0.007	0.06
	(2.79)	(-0.58)	(15.82)
AGE	-0.003	0.004	0.01
	(-0.99)	(0.45)	(5.24)
SCHOOL	0.04	0.02	0.18
	(2.25)	(0.51)	(14.30)
SKILL	0.72	0.93	1.61
	(9.31)	(5.90)	(26.28)
INCOME	0.002	0.01	0.01
	(1.74)	(3.25)	(10.79)
DRINKING	0.02	0.12	1.12
	(0.20)	0.49)	(16.18)
TRAIL BIKE	-0.93	-1.18	-3.89
	(-8.89)	(-5.00)	(-31.47)
ATV	0.05	0.08	0.38
	(0.63)	(0.46)	(7.23)
USER FEE	-0.04	-0.05	--
	(-0.57)	(-0.23)	
VOLUNTEER	2.06	2.26	--
	(18.72)	(11.27)	
Mean for Random Parameters			
USER FEE	--	--	-2.68
			(-29.72)
VOLUNTEER	--	--	1.96
			(26.71)
Standard Deviation for Random Parameters			
USER FEE	--	--	2.32
			(41.09)
VOLUNTEER	--	--	2.54
			(39.81)
Dispersion Parameter			
α	--	3.19	--
		8.85	
$1\text{-}L_1/L_0$	0.35	0.33	0.54

Note: Parameters in parentheses are t-statistics.

Table 5. Preference Heterogeneity Regarding Policy Variables

	How Random Parameters Affect Trip Frequency	
	User Fee	Volunteer
Brown Mountain	85% negative	62% positive
Badin Lake	49% negative	53% positive
Upper Tellico	88% negative	78% positive
	→ People that support user fees are less avid	→ People that volunteer are more avid

Table 6. Consumer Surplus Estimates, Per Trip

	Poisson	Negative Binomial	Random Parameter Poisson	Random Parameter NegBin
Brown Mtn.	$166.00	$50.00	**$27.03**	$66.67
Badin Lake	$125.00	$45.45	**$50.00**	$50.00
Upper Tellico	$625.00	$416.66	**$333.33**	--

Note: Values in bold are for the best-fit model.