INTEGRATING GIS DATA INTO A CHOICE EXPERIMENT OF PREFERENCES OVER RESOURCE USE ALTERNATIVE: A BRITISH COLUMBIA EXAMPLE

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ABSTRACT.—A valley in the Selkirk mountains of British Columbia was used as the setting for a choice experiment to determine resource values and individual preferences over management alternatives. GIS and management models of wildlife, recreation and timber already existed from previous research and lent themselves readily to application within a choice modeling framework for valuation and utility analysis. Choice models are a subset of stated preference modeling which have historically been applied to consumer problems. They are now emerging as an alternative to the more conventional valuation approaches such as contingent valuation. This study applies these techniques directly to a specific resource setting and using the spatially referenced detail available through GIS, communicates a great deal of resource information to survey respondents for their evaluation in a choice experiment format. The results of the survey allow inferences on preferences, valuation, trade offs and opportunity costs to be drawn. These are all extremely useful results for resource managers and policymakers alike. This study can serve as an example for larger scale research of this type.

INTRODUCTION

The measurement and valuation of benefits which are nonmarket in nature has perplexed economists and policymakers alike. Because these goods and services are provided and consumed without a transaction occurring in the marketplace, there is no observable market event from which value may be directly assessed. The traditional approach to the nonmarket benefit problem has been to estimate consumer surplus using compensating and equivalent variation concepts on Hicksian demand curves. The most widely used method in this regard has been the contingent valuation method or CVM.

Another approach is to explore the choice process employed by individuals in decision making. Consumers regularly evaluate the benefits attained from various goods and make their choices based on these evaluations. Although this behavior is most observable for choices of consumer goods made in the marketplace, the decision process itself and its connection to preferences and utility are applicable to nonmarket choices and public goods as well.

A significant distinction between the two aforementioned approaches has to do with the manner in which individual preferences are obtained. The contingent valuation methods are direct in the manner in which they determine preferences. Consumers are asked to reveal their preferences in the form of responses to hypothetical situations (willingness to pay for a day of fishing for example). Consumer choice theory uses indirect methods to determine preferences (the travel cost model is an example of an indirect method). The distinction between the direct and indirect methodologies is also described as the difference between revealed and stated preferences in the literature.

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Revealed and Stated Preference Methods of Valuation

Revealed preference (RP) methods, elicit valuation responses though indirect means. Observations of actual consumer behavior can provide revealed preference results. The method is indirect in that it relies upon the choices a consumer is faced with to define its decision space and simply observes the choices made. These methods do not depend on the direct information about prices and quantities that economists would rather use where available to value goods and services (Bishop and Heberlein, 1979). RP methods are applied to extra-market goods and services, (normally associated with natural resource problems) because of their ability to determine value without price and quantity information

Stated preference (SP) valuation methods are related to revealed preference methods through their use of random utility modeling (RUM). By asking consumers questions about their preferences, inferences about individual utility can be drawn. Similarly, by observing consumer behavior using indirect methods such as the travel cost method, utility may be assessed in terms of the choices made. Indirect utility functions are at the core of Random Utility Model.

Choice Experiments

A group of SP approaches, called conjoint analysis have been in widespread use in consumer product research but have only recently been applied to resource valuation problems (Coyne and Adamowicz, 1992; Adamowicz et al., 1994. Conjoint analysis refers to an ensemble of methods used to estimate characteristic utilities based on subjects' responses to combinations of multiple attributes or characteristics. The facility to arrange these multiple decision attributes into a wide range of combinations distinguish this methodology from other SP techniques. Common to all conjoint methods are algebraic models representing human judgment processes and an ability to test these models to determine which methods correctly represent preferences. Experimental choice analysis is a methodology among the approaches used in conjoint analysis. Probabilistic choice models are based on random or constant utility theory and are derived from assumptions about individuals' evaluations of choice objects. Choice experiments (CE)are used to survey individuals and aggregate their preferences into a relatively few (or single) models describing individual choices. This method shares some features with the RP and SP techniques used in resource valuation. As in the case of hedonic pricing methods there is use of individual resource characteristics (attributes) in valuation and as with contingent valuation, hypothetical situations are presented to respondents allowing a wide variety of possible resource combinations to be considered.

Choice experiment methods employ an attribute based approach to determine utility and ultimately value. As with CVM, choice experiments gather utility information directly from consumers, however, the methods differ in the number of resource descriptions they are able to represent. Typical problems associated with CVM are avoided with CE. Embedding effects are addressed directly in CE by having respondents implicitly value components (attributes) (Adamowicz, 1994). Yea-saying is avoided in CE because respondents are presented with a wide variety of variously configured alternatives rather than a base case - improved case pairing and would have greater difficulty isolating the "good cause" which generally triggers this form of strategic behavior.

Although CV analyses dominate much of the literature and compensatory judgments, further justification for the use of a choice experiment approach comes from the debate surrounding natural resource damage assessment. Jones et al. (1995) have argued for the notion of compensating goods to mitigate resource damages. This method has been touted for its avoidance of thorny funding and monetary disbursement issues, however, it is dependent on an attribute based approach in order to measure the amounts of other goods to be used as compensation. Consequently, choice experiment based approaches hold great promise in assessment of compensating goods cases.

Welfare analysis is also possible within the context of choice experiments. Modeling varying levels of resource attributes is the primary purpose of the choice set respondents (consumers) face. Connecting the different attribute levels to monetary changes provides the opportunity to extract welfare measures from the choice experiment

results. The methodology has evolved from the compensating variation welfare values extracted from travel cost data, first demonstrated by Hanemann (1984), and later applied to choice experiment data (Coyne and Adamowicz, 1992).

Choice experiments are also readily combined with other attribute descriptive technologies such as GIS (geographic information systems). The body of literature integrating GIS with multi-attribute choice experiments is just beginning to emerge, however, the use of visual representations have been suggested and applied in marketing research and in natural resource cases. Thus, the use of a visual medium, such as GIS, is a logical step in the representation of resource attributes. The emergence of accessible GIS technology has only recently become widespread enough that it can readily be considered for integration with choice experiment methods. GIS provides the opportunity to manipulate the attributes which describe the resource effortlessly within the digital environment. This allows simulation of a wide variety of attribute combinations in a visual, spatially referenced format. These simulations would be impossible to implement in reality but can be presented within a choice experiment survey. The ever increasing levels of resource conflict, driven by resource scarcity, also justify the use of spatial modeling tools such as GIS. The ability to represent multiple attributes and multiple uses as GIS overlays allows conflicts and potential conflicts over resources to be directly observed. Improved understanding of how various resource attributes interact and fall into discord improves the ability to understand more exactly that from which value is derived and further provides the means to reduce conflicts over resources and their use.

The advantages of an attribute based method such as choice experiments have been stated above (as have the positive effects of visual representations in valuation surveys). It is a logical conclusion then that a choice experiment of forest resource values supported by GIS information should provide meaningful utility and value results. Upon this foundation it is then possible to begin to identify a suitable forest resource for analysis, one for which there exits some GIS model support, and a suitable survey sample from which utility and value may be assessed.

THE STUDY AREA

The Department of Resource Management and Environmental Studies and the FEPA Research Unit at the University of British Columbia (UBC) have developed a digital resource database for the Tangier Watershed located in the Selkirk mountains of eastern British Columbia. The aforementioned groups, have produced a number of reports on the research covering this valley and the development of the GIS models describing it. Various other agencies such as Parks Canada, BC Hydro, BC Ministry of Forests and BC Ministry of Environment have had involvement in the study of this area. The research effort to produce a GIS model of activities and resources of the Tangier valley is most completely reported in the hypertext document titled “A GIS Approach to Multi-Resource Conflict” by Brown et al. in 1995. This is the final report of a series funded by BC Hydro and the Canadian Forest Service which summarizes the GIS modeling results and the multiple resource accounting and trade off analysis as applied to the Tangier valley. This report provided much of the physical resource information used to develop the choice experiment and many of the attributes and levels used. This report was also made available to survey respondents as part of the background provided in the choice experiment.

The Tangier watershed covers almost 29,000 hectares of alpine and subalpine forest and is surrounded by 2 National Parks. The area has significant recreational, wildlife and timber values (some of which are in conflict) and is well suited to be a case study for this type of analysis.

The GIS database includes topography, hydrology and forest cover. In addition to the forest cover and harvesting models, there are detailed models of wildlife habitat and recreational use. Habitats have been mapped and modeled for Mountain Caribou and Pine Marten. Heli-skiing use in the watershed has been mapped and referenced with skier survey data. These research efforts provide a unique opportunity to apply a broad spectrum of forest resource uses in a spatial format and communicate multiple use issues in a very effective manner. Six attributes have been identified for analysis in the choice experiment. Of these attributes, five are resource attributes: timber, caribou,

pine marten, heli-skiing and backcountry skiing. The sixth attribute is a tax/compensation variable which enables monetary valuation and welfare analysis.

The survey methodology used in this analysis employs a choice experiment format. Since the harvest values are already known, and the wildlife models already integrated into the GIS maps these features can be explicitly (graphically) offered as part of the survey. It is possible to survey individual responses to combinations of attributes and determine their utility and thereby infer value from the results. Applying the GIS technology to ascertain nontimber benefit and preference information allows explicit evaluation of the trade-offs between uses and the measurement, in more tangible economic terms, of these trade-offs. Thus, it is possible to assess the opportunity cost of maintaining or enhancing a particular nontimber resource attribute and weigh this (opportunity cost) against the demand for the nontimber value in question.

EXPERIMENTAL METHOD

The random utility model is applied to develop probabilistic choice results among alternatives and their attributes. The utility, *V*, of alternative *i* for individual *n* is expressed as:

[1] $V_{i\,n} = V(Q_{i\,n}, ,S_n)$

Where *Q* is a vector of attributes and *S* is a vector of individual characteristics. Utility, *V*, is modeled as a random variable and is the sum of the observable and unobservable components of total utility. A random utility model gives the probability with which alternatives are chosen. Thus, the probability that the individual chooses alternative *i* is equivalent to the probability that the utility of alternative *i* is greater than the utilities of the other alternatives in the choice set.

[2] $P\,(i \mid C) = P\,(v_{i\,n}, + ?_{i\,n}, > v_{j\,n}, + ?_{j\,n}, \text{ for all } j \neq i\,,\, j \in C_n\,)$

The probability function, $P\,(i \mid C)$, is a complicated function of the attributes which has no closed analytic form and may be difficult to compute. It is therefore necessary to make assumptions regarding the form of the probability function in order to facilitate estimation. The most widely applied of these estimators is the multinomial logit form (Maddala, 1983):

[3] $P\,(i \mid C) = \exp v_{in} \,/\, \sum_{j \in Cn} \exp v_{jn}$

where $P\,(i \mid C)$ is the probability that alternative a will be selected from the choice set C. The *v*'s denote scale values or strict utilities which summarize the desirability of alternatives.

Estimation of MNL choice models is accomplished through several methods. The most commonly applied is the log likelihood estimation technique which was used in this experiment.

Once the utilities of the attributes have been estimated it is possible to estimate the welfare effects associated with a change in resource quality. The usual compensating variation expression is presented in Equation 4. However, this is ordinarily applied to recreational site choice, where there are a number of competing sites or states from which to choose and which continue to exist regardless of the choice made. Consequently, Equation 4 contains summations of the utilities of the various sites.

[4] $CV = 1/\alpha\,(\ln \sum_{i \in Cn} \exp {}^{v}n0 - \ln \sum_{i \in Cn} \exp {}^{v}n1\,)$

However, when the objective is to compare only two states of the resource, as it is in this case, this expression reduces to :

[5] $CV = (1/\alpha)\,(vn0 - vn1\,)$

Thus, the compensating variation expression reduces to a utility difference divided by the marginal utility of income (α). The inclusion of a monetary variable in the choice set makes this coefficient readily available and permits calculation of a welfare sum associated with a resource quality change. These values can then be compared with those obtained using other methods such as CVM and assist policy decisions.

In addition to the choice experiment a 10 question contingent valuation survey was included in the experiment to provide comparative results.

The choice experiment utilized a partial factorial, main effects design which evaluated a 6 attribute, 3 level choice experiment. The result was a series of 18 response cards listing different combinations of the levels of the 6 attributes. Each choice response card offers 2 combinations of the 6 attributes as well as the status quo. Thus, respondents have the choice of 2 alternatives or leaving things as they are (status quo).

ESTIMATION AND RESULTS

The choice experiment and CVM survey were administered to a sample of 54 resource professionals living and working in the greater Vancouver area in 1995. The stated preference data obtained from the choice experiment were analyzed using multinomial logit modeling techniques applied through the LIMDEP (Greene, 1995) software package. Several variations of the logit model were constructed and analyzed. Effects coding was also applied to the data; however, models with all attributes specified in effects coded format violated the rank condition and were not solvable in LIMDEP. When the effects coding scheme was applied to the data, collinearity between some of the dependent variables became apparent. The resulting models were not solvable due to the creation of a singular determinant matrix which prevents estimation of the least squares estimator (which must be non singular), thereby violating the rank condition. When the attributes are left in the format used in the survey (where the data are continuous), the model achieves solution. A linear form of the model was specified and solved using continuous data. A model specified with effects coded variables for caribou and heli-skiing was successfully run, however; the addition of any of the remaining attributes in effects coded form resulted in the violation of the rank condition. A quadratic form of the model was also specified and solved in LIMDEP. Quadratic forms have been used to model utility in choice experiments (Pekelman and Sen, 1979) and have shown superior results to linear specifications.

Generally, the coefficients in all of the models are significant and behave as expected. In all cases the coefficients on the tax attribute have the expected negative sign. The intercept term is insignificant in all but the case of the effects coded model.

Utility for the individual attributes can be inferred directly from their coefficients. The coefficient for the attribute is the marginal utility of that attribute. Determining the utility at various attribute levels is accomplished by multiplying the various levels by their marginal utilities (this applies in the case of the linear and quadratic models). The utility curves for the various attributes are displayed in figures 1-5.

DISCUSSION AND CONCLUSIONS

The sample surveyed for this analysis was small and the results certainly reflect the similarity of respondents occupations. However, this does not diminish the usefulness of the results presented here. These methods may be easily applied to a larger, more representative sample. The experimental design would remain unchanged as would the estimation procedures. What would differ would be the implications of the estimates of utility, preferences, and value drawn from the results. These results represent the preferences of a small, relatively homogeneous group of resource professionals. Policy decision making requires a much larger (population level) consensus of opinion and as such would find a greater degree of usefulness in these results if they represented a larger segment of the population.

The result of the analysis of the sample of 54 resource professionals from the Vancouver area suggest that the best model of individual utility is the quadratic model. However, the linear model bears some consideration, if only for its simplicity and ease of estimation. While its performance vis à vis the quadratic model was poorer it was not so much so that the model could not serve as a useful alternative model or as a tool for confirming results of other model forms. The greater flexibility inherent in the quadratic functional form is extremely appealing, yet it is noteworthy that many of the quadratic utilities exhibited a linear structure. Finally the quadratic model appears to provide better estimates of the welfare effects associated with an increase in the levels of the 6 attributes. Although the welfare sum was higher than in the linear case it was not unreasonably so and may in fact be more appropriate for the multi-attribute improvements assessed in the welfare calculations (4 attributes were increased in the welfare calculation).

On an individual attribute basis, the models estimated showed an economically rational response to taxation in the form of a negative coefficient to the tax attribute. The utility functions traced out by the different models varied little between the linear and quadratic models for the caribou and pine marten attributes, suggesting that the linear form was appropriate. For the backcountry and heli-skiing attributes, however, the quadratic model differed noticeably from the linear case, suggesting that the utilities of these attributes may peak or plateau over the range examined in this study (and further suggesting that the linear model may be inadequate).

This analysis of consumer choice over forest resource alternatives demonstrates the flexibility of an attribute based approach to valuation and further illustrates a means by which market and nonmarket resource values may be included among the attributes to be valued. Preference based approaches allow comparisons between seemingly incompatible features to take place. Use of stated preference techniques make this possible because of their capacity to model any combination of alternatives and attributes, even those unlikely to occur in the real world. Linking these methods to the diverse and similarly flexible information available from geographic information systems exploits a natural complementarity and enhances the quality of the information gathered.

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Figure 1: Heli-Skiing Utility Curves

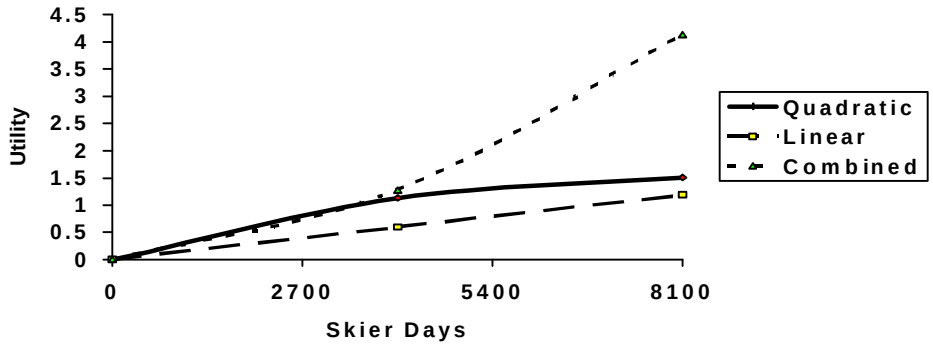

Figure 2: Pine Marten Utility Curves

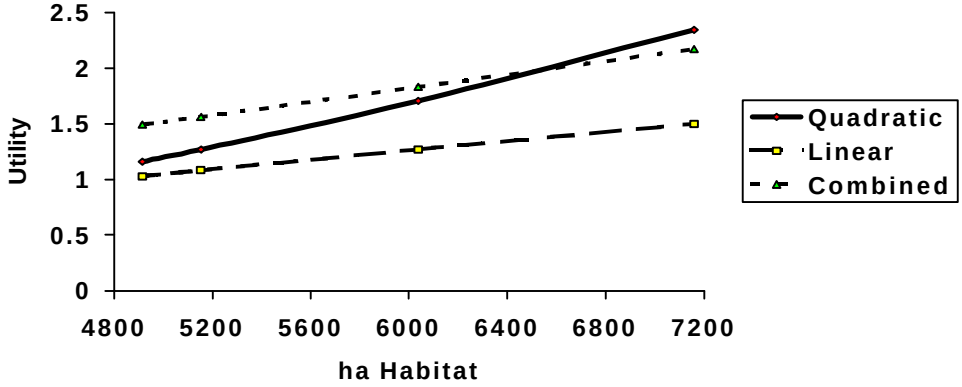

Figure 3: Timber Utility Curves

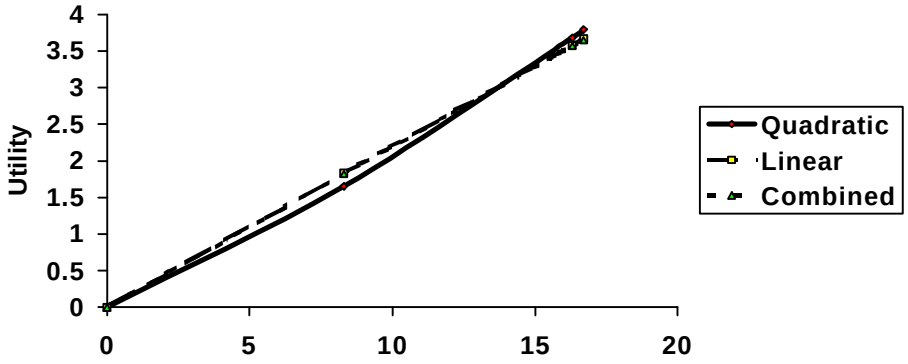

Figure 4: Backcountry Skiing Utility

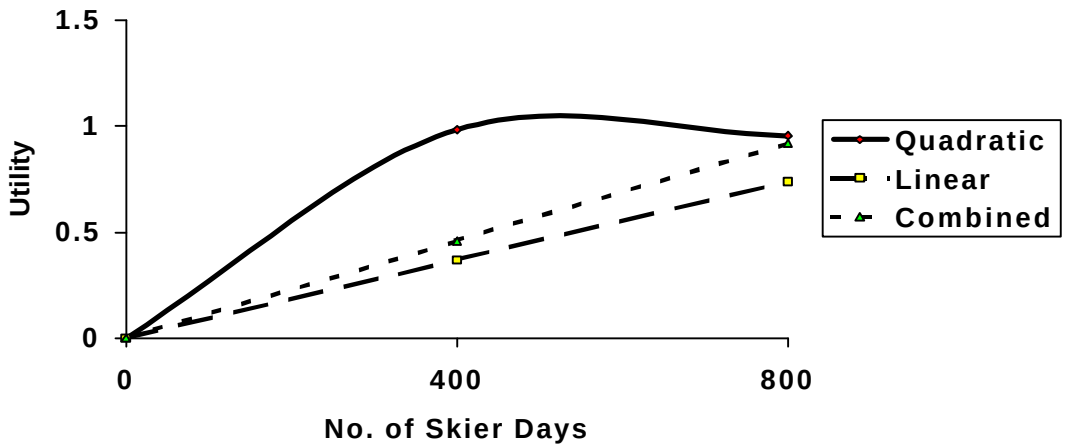

Figure 5: Caribou Utility Curves

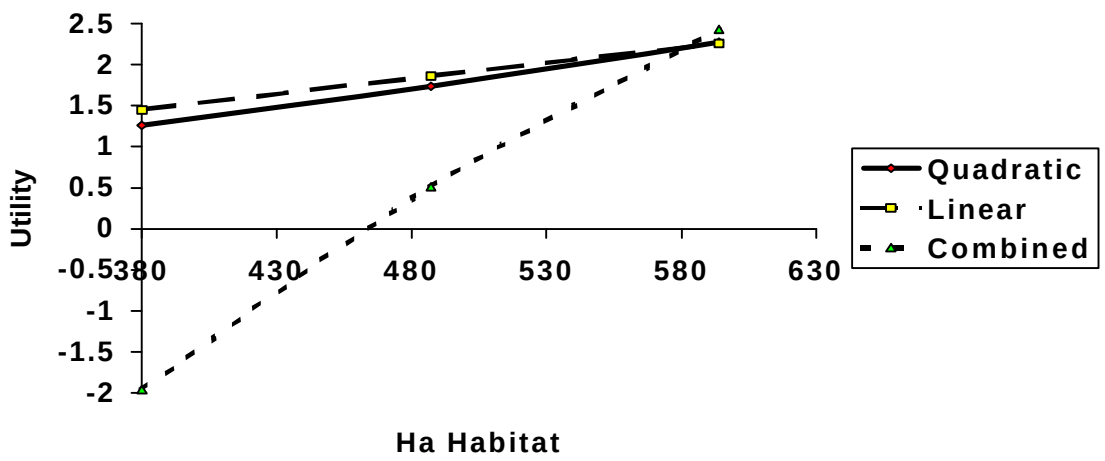
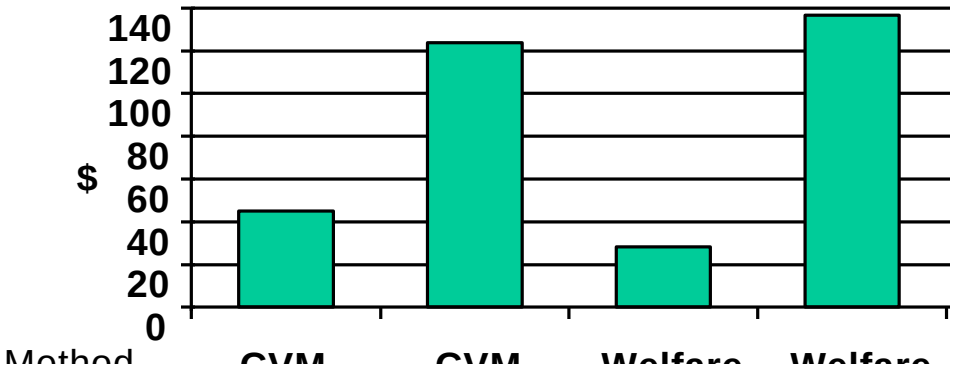
Figure 6: Comparing Choice Experiement and CV Results: the Value of Attribute Enhancement