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TESTING NONMARKET VALUES IN A

NONPARAMETRIC FRAMEWORK

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TESTING NONMARKET VALUES IN A NONPARAMETRIC FRAMEWORK

I. Introduction

A large and growing literature has addressed the problem of valuing nonmarket goods such as recreational experiences, scenic amenities, and environmental quality [see, e.g. Freeman; Smith et al., 1986]. The estimation of these values involves either an indirect approach based on observed behavior, or direct elicitation of values via sample survey methods. Existing tests of the validity of the techniques are of three kinds: tests in experimental markets, comparisons of alternative approaches to valuing the same good, and, for the indirect methods, the ability of the technique to "explain" variations in observed behavior in some statistical sense. In this paper we take a different approach to testing the validity of the techniques based on their consistency with the axioms of choice.

The valuation approaches and/or their interpretation are based on an assumption of the economic "rationality" of consumers. In this paper rationality means that the observed quantities of the goods demanded at various prices correspond to those that could be generated by a consumer who is maximizing her preference ordering on a budget set. Using the quantities of goods and services purchased in the market and the quantities of nonmarket goods and their pseudo-prices generated by some valuation technique, one can determine if the quantities demanded at various "prices" could have been purchased by a utility-maximizing (rational) consumer. Following the nonparametric demand approach set forth by Varian (1982), we examine the prices and quantities for evidence of violations of the axioms of choice as embodied in revealed preference theory.

This study uses individual time series observation of recreational hunting behavior over a season and the travel cost and contingent valuation approaches to conduct revealed preference tests. Also, for those individuals who violate revealed preference conditions, an efficiency index (Afriat; Varian, 1982) is computed to determine the severity of the violations.

Several such tests are undertaken. First, we test the travel choices which underlie the travel cost model of recreation demand (see McConnell for a description of this model). We treat each trip taken by an individual over a recreation season as a separate choice occasion. The "price" (marginal value to the individual) of the recreation good is not observable, but the prices and quantities consumed of travel, lodging, and other market goods associated with recreation trips are known. Varian (1987) shows that if one set of prices and/or quantities is missing from the data, then revealed preference theory cannot be used to derive restrictions on the observable data which imply consistency with rationality. However, in our case the price of the recreation good is a marginal value per trip and the quantity is fixed at one unit per trip. In this instance the absence of this one value from the data does not alter conclusions regarding the consistency of the observed bundle with the axioms of choice. This allows us to test the rationality of choices of market goods associated with recreational travel.[1]

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[1]Note that this is somewhat different than the typical travel cost model in which the quantity is the number of trips over a season. Here, the trips define independent consumption bundles.

The statistical test we employ here involves a small-sample comparison of the number of revealed preference violations in the data versus the number in random choice data. As well, violations of the axioms are studied using a Probit analysis in order to test two hypotheses: that as the importance of making incorrect choices grows, the probability of making them falls; and that more complex decisions involve more violations of the postulates of rationality.

One of the more controversial issues in the use of travel cost models is the treatment of the value of time (Smith et al. 1983; Wilman; Bockstael et al.). Standard practice in this regard is to employ some fraction of the wage rate times travel time as a component of the travel cost variable (Cesario and Knetsch; Walsh). We test the efficacy of including time values in this manner by comparing the number and extent of violations of revealed preference theory across models with on-site and travel time valued from zero to the full wage rate.

Our second set of analyses incorporate non-market values into the consumption bundle via simple contingent valuation questions (for a full discussion of contingent valuation see Mitchell and Carson, 1989). The questions ask the amount that a respondent would be willing to pay per day for the recreational activities they were observed to choose. As well, willingness to accept compensation for foregoing recreation was elicited. The contingent value then was used as the price of recreation activities in the bundle of demanded goods, where the quantity variable is the number of days of recreation on each trip.

Our analyses can be given two interpretations. First, if the validity of the valuation methods is taken as given, then we are testing for the rationality of the consumers in our sample. If such choices are not rational, then the use of the simple travel cost model might be questioned. Or, more appropriately since we are not really testing the travel cost model (which has as the quantity variable the number of trips in a season), we might question the rationality of choices regarding recreational travel. Alternatively, we can operate under a maintained hypothesis of rationality and test the ability of the valuation method to capture the true values generating the observed behavior. Of course, if we find that few violations of the theory occur, it does not imply that the computed values are true ones; it just means that the computed values are not so at odds with the true values that they generate contradictions with the assumed rationality of consumers. On the other hand, if large numbers of violations are found, then either the techniques are flawed in some general way, or the very simple versions we employ are not adequate to the task and more complex approaches should be tested.

This study provides weak favorable evidence for the consistency between preference maximization behavior and nonmarket goods valuation methods. Few violations of the axioms of choice are noted and when they are found, the efficiency indices indicate that observed choices are not far from rational ones. The number of violations does decline significantly with the inclusion of time values, and very weak evidence is found for the valuation of travel time and on-site time at the wage rate. The analysis of violations using the Probit model confirms the hypotheses set forth above: there is a decreased probability of violations of the axioms of choice as the proportion of the budget spent on recreation increases and an increased chance of violations as the number of choices increases. When the contingent valuation responses are used to include the nonmarket good in the consumption bundle tested, there are even fewer violations of the axioms than when only market goods are tested.

This paper also represents one of the few attempts (see also Koo; and Koo and Hasenkamp) to test the rationality of observed behavior at the individual level, at least in humans (see Battalio et al., 1981, 1986 for tests of behavior in rats and pigeons) who are not mentally ill (Battalio et al., 1973 tested an economy constructed in a mental institution). Most empirical research in this area has employed aggregate data (e.g. Gross; Chalfant and Alston), which one would not necessarily expect to satisfy axioms of individual choice. In further work (Adamowicz and Graham-Tomasi), we explore the way in which alternative approaches to aggregation alter the number and extent of violations.

II. Nonmarket Valuation Methods

Even a partial review of the various approaches to the valuation of nonmarket goods is beyond the scope of this paper. Here, we merely sketch the issues involved.

Let the consumers preferences for all goods be representable by a utility function $U^*(N,R)$, where N is a vector of nonrecreation goods and R is a vector of leisure goods associated with recreation. The recreation goods are assumed to be separable from the nonrecreation goods. Hence, we let $U^*(N,R)=U(N,U(R))$, where $U(R)$ is the subutility function for the recreation goods. If U^* is increasing in its second argument for all values of N, we can treat $U(R)$ as a traditional utility function and all of the properties of classical demand theory carry over to it (Deaton and

Muellbauer). As well, the demands of a consumer maximizing a subutility function U(R) subject to a budget constraint should satisfy the axioms of revealed preference theory applied solely to the recreation branch.

The subutility function for recreation can be written in more detail as $U(R_1,\ldots,R_n,Z)$, where R_i is a market good associated with recreation, such as travel, and Z is a public or quasi-public good, i.e. the recreation site and its services. Let P be the vector of prices that correspond to the market goods R and let q be the marginal value of the public good to the individual. The individual's conditional (on N) indirect utility function for this branch can be written as V(P,Z,M), where M is the money income allocated to consumption of recreational goods. Marginal willingness to pay for the public good Z is given by

$$q = \frac{\partial V(.)/\partial Z}{\partial V(.)/\partial M} .$$

Total willingness to pay for a change in Z would be the integral of q over the range of variation of Z.

The problem of valuing nonmarket goods is to derive mechanisms for estimating marginal or total willingness to pay functions. Several approaches to this problem have been developed in the literature. There are two major classes of such approaches: indirect and direct. The indirect methods seek to infer the values by observation of behavior. In this study, travel behavior is used as it can be employed to deduce the values of unpriced recreational goods, as described by the literature on the travel cost model of recreation demand. The direct methods, known generally as contingent valuation, involve asking individuals via sample surveys their valuations of changes in the quantity of the nonmarket good.

Travel Cost

The travel cost model had its origins in a letter from Harold Hotelling to the U.S. National Park Service in 1947. Hotelling proposed that the value of a recreation site could be determined by using travel cost to the site as a proxy for a price and the number of trips to the site as a quantity variable. The modern approach is to derive a statistical relationship between the number of visits and the travel costs for each individual and perhaps some other variables, with the site value being given by consumer surplus, or perhaps a Hicksian welfare measure derived from the demand function.

Thus, let R_j be the round-trip miles chosen on a choice occasion (trip) to a site and let P_j be the price of travel per mile. The variation in travel costs to any site across a sample of individuals can be used to estimate a demand function for numbers of visits to a site over a season by an individual as a function of travel costs, e.g.

$$v_s = f(R_j P_j, m),$$

where v_s is the number of visits to site s in a season and m is income allocated to the recreation branch. The consumer surplus calculated from estimates of this demand function give the value of the recreation site, i.e. Z in the model above.

The basic assumptions of the simple travel cost model are that: (i) individuals treat changes in the unobserved entrance fee for the site and the cost of travel identically, (ii) the only purpose of the trip is recreation at the site, (iii) individuals spend and equal and fixed amount of time at the site, and (iv) no substitutes for the site exist. Each of these assumptions has been relaxed to some extent in the literature (see, e.g. Smith).

Among the more important and controversial issues in the estimation of the travel cost model is the selection of values for travel and on-site time. Time spent recreating has an opportunity cost and thus we expect its value to influence recreation choices. If such values are nonzero and are not included in the analysis, biased estimates of site value may result (Cesario).

The appropriate valuation of time depends critically on the constraints that individuals are supposed to face on their choice occasions (Bockstael, et al.). If all time can be substituted across activities freely, then the opportunity cost of all time is the wage rate. But leisure time may be allocated to number of activities which may or may not (especially in the short run) directly conflict with time allocated to generating income. The relationship between time spent recreating and time spent working generally will vary across trips as well as individuals, e.g. some are taken during vacations and others involve time off from work paid at an hourly rate. As well, the disutility associated with travel may vary across trips to different sites (Wilman). And how time spent at the site should be valued relative to time spent traveling remains unclear. In general, one can say that time values will differ across individuals in the sample, across trips and sites for the same individual, and will be given by some non-linear function of the wage rate (Smith, et al., 1983). As may be expected, the empirical studies are far removed from the theoretical models. It is standard practice to treat all individuals and trips the same, to ignore on-site time, and to multiply travel time by a fraction of the wage (usually 1/4 to 1/2 based on time values revealed by commuting behavior, see McConnell and Strand for an estimate for recreation data), and add this to the travel cost variable. In this analysis we investigate several choices for the value of time using the standard approach and the effect of such values on the correspondence between observed choices and postulates of utility maximizing behavior.

Contingent Valuation

In order to develop a demand curve for public goods Ciriacy-Wantrup suggested in 1952 that individuals be asked survey questions to elicit values for successive additional quantities of such goods. This suggestion was first acted upon by Davis and has since seen considerable refinement under the rubric of contingent valuation.

In its most basic form contingent valuation involves a single open-ended question regarding willingness to pay for hypothetical changes in provision of a public good, with payments made via some vehicle such as "higher prices or taxes." Other approaches entail closed ended "take it or leave it" questions, with the offered value varied across the sample; these can be assessed in a referendum format as well. Or, bidding games can be employed in which closed-ended questions are asked, but the postulated payment level is changed within each interview to establish the value at which the response changes from payment to nonpayment (or vice versa).

The contingent valuation technique is extremely flexible, but potentially suffers from a number of theoretical and practical difficulties. Notable here are the opportunities for strategic behavior identified by Samuelson; the inability to define the good sufficiently well to allow all respondents to value the good the good the analyst wishes to value; the carefulness with which the respondent gives values when the exercise is hypothetical; and the ability to alter valuations by modifications of the survey instrument. Notable in the latter category are modifications to the payment vehicle, the starting points of bidding games, or the types of information provided about the target good and/or related goods. As well, the large differences between willingness to pay and willingness to accept compensation responses discovered in the empirical literature remain controversial. For full treatments of these and other issues concerning the use of contingent valuation methods see Mitchell and Carson, and Cummings et al.

III. Revealed Preference

The theory of revealed preference has its roots in Samuelson's (1948) attempt to find minimal conditions under which price and quantity bundles could be used to construct a preference ordering which would "rationalize" these data. The question is, can a preference ordering be constructed from the data such that a consumer acting under this preference order would choose the same consumption bundles as the original data?

Houthakker proved that, under conditions of continuity of the derivatives of the demand function with respect to prices and income and single-valuedness of demands, the strong axiom of revealed preference (SARP) implies the "utility rationality" of consumers. That is, that there exists a numerical function of goods such that, for all other bundles in a given budget set, the demanded bundle yields at least as high a value of the function, and that this relationship holds for all budgets. Houthakker's assumptions have been weakened. Given a nonsatiated consumer who satisfies SARP, convexity of the set of all bundles chosen for some budget, and a closed demand set for each budget, Richter showed that a real-valued function can be found which acts as a utility function for this consumer. Varian (1982) provided a further modification of the axioms of choice, called the generalized axiom of revealed preference (GARP). This allows multi-valued demands generated by indifference curves with "flat spots." The SARP does not admit utility functions that are not strictly quasi-concave.

More formally, let p be an nx1 price vector and let B be a family of budgets defined as $b=\{x: x \in X \ \& \ px \leq m\}$, where X is the consumption set and $m \geq 0$ is income. A consumer is said to be rational if there exists a binary relation R such that the bundle chosen from the budget "maximizes" this preference relation as

$h(b) = \{x: x \in b \ \& \text{ for all } y \in b, xRy\}$

for all b in B. The bundle x is called the demand for the consumer. If there exists a real-valued function u(x) such that xRy holds if and only if $u(x) \geq u(y)$ the consumer is said to be representable by the function u(x).

Let Q be a binary relation such that xQy if and only if there exists a budget b such that $x \in h(b)$ and $py \leq px$ with $x \neq y$. This relation states that x is chosen when y is available. The weak axiom of revealed preference states that if $x \neq y$, then xQy implies not yQx. This is stated as "x is directly revealed preferred to y." A cycle of binary relations of the form $xQx_1Qx_2...Qy$ for some finite sequence of intermediate bundles x_i indicates that "x is revealed preferred to y," with he word directly dropped. This can be rewritten as xHy; H is called the transitive closure of Q. Varian (1982) provides algorithms for computing the transitive closure of such relations. The SARP states that, if $x \neq y$, then xHy implies not yHx. The GARP states that, if xHy then it is not the case that $py > px$. Thus, the GARP states that if x is revealed preferred to y then there cannot exist a situation in which y is "strictly" revealed preferred to x. The strict inequality in the last part of the definition indicates that multivalued demands functions may satisfy the GARP.

One case that is not investigated by any of these axioms is one in which the prices change but the consumption bundle does not. This may be due to kinks in indifference curves, or nonconvexities in the choice set. This may also be a sign of uncertainty or a lack of information about the goods purchased, or operation of a habit effect.

The tests of consistency with revealed preference axioms are all or none tests since a consumer either satisfies the axioms or not. Varian (1985) introduced the notion that measurement errors in the data could be used to test whether the unobserved true structure violates the axioms when they are violated in the observed system. Statistical tests have been proposed by Varian (1985), by Epstein and Yatchew, and by Tsur. Koo (1963) has proposed some non-statistical tests such as the maximal subset of observations that satisfy the axioms. As well, one might make comparisons of observed data to the number of violations expected in random choices; this latter test is employed below.

In order to measure the severity of violations of the axioms we use an approach proposed by Varian (1987). Let the binary relation Q_e be written as xQ_ey if and only if $epx \geq py$ and $x \neq y$ with e in the interval [0,1]. The transitive closure of the relation Q_e is defined by the relation H_e. Now, analogues to SARP and GARP can be defined using the relation H_e. If $e=1$

then we are returned to the original definition of SARP and GARP. However, if e is less than 1 we are reducing the size of the budget set on the left hand side of the directly revealed preferred relation. The number e is calculated as the value that minimizes (1-e) subject to satisfying $SARP_e$ or $GARP_e$. Thus, e can be used as a scalar efficiency index of the severity of the original violation of the SARP or GARP, with large values of e indicating that only small reductions in the budget will lead to consistency of the data with the axioms of choice.

An example of the efficiency index is provided in Figure 1. The solid lines indicate the actual budgets for the consumer and the squares on the graph are the bundles consumed. This combination of budgets and bundles violates the axioms of choice because in both cases one bundle was chosen while the other was available. The dotted lines indicate the reduced budgets that lead to satisfaction of the axioms, the amount of the reduction being measured by the index e described above.

IV. Procedures and Results

The data used in this analysis are from a mail, recall survey of Bighorn sheep hunters in Alberta, Canada, collected in 1982. A more complete description of the data, details of all of the empirical routines used here, as well as some additional analyses, are available in Adamowicz (1988). A total of 621 respondents were sampled, but missing data results in a reduction in the useful sample to 343 individuals.

The data include the hunting activity on each trip (destination, miles traveled, activity duration in days, size of party, game sought, game bagged) and expenditures on travel, lodging, food, and other hunting-

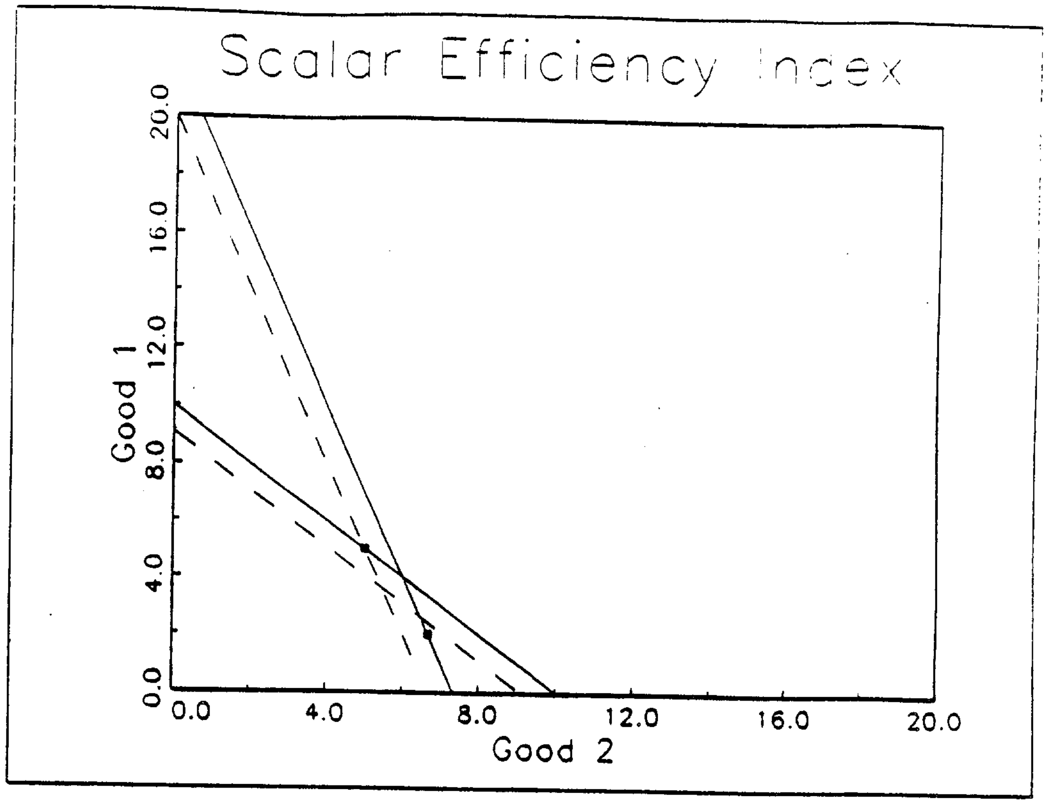

Figure 1: Scalar Efficiency Index Example

related items. In order to derive a price measure for each trip, the expenditure and party size data were used to determine an effective price to an individual. The procedures rely on averaging costs over the party, which may or may not be appropriate, but the available data did not allow more refined individual price estimates to be determined.[2]

Nonparametric Analyses of Market Data

In this section of the paper we study the rationality of the purchases of markets goods associated with travel for hunting. As mentioned above, the value of the site is missing from the data, but since the quantity is fixed at one unit per trip, violations of the axioms of choice would not be changed by the inclusion of the price of this single fixed quantity.

Nine nonparametric tests of the market data were performed, the nine differing regarding the value of time. In order to incorporate the value of time, both the wage rate and 1/2 the wage rate were used, as well as no time values. The wage rate was calculated as income divided by 280 days of work per year for 8 hours per day. Income was elicited by categories with the midpoint of each category used here. This is a simplified approach for determining hourly wages (though a common one in such studies) which more complete data may reveal to be inappropriate. We began with only the market goods data with no values of travel or on-site time. Next, the additional cost per mile was calculated by dividing the hourly wage (or 1/2 of it) by

[2]The revealed preference tests require observations of choices under at least two budgets. Computation of expenditures per person per trip reveals considerable variation over the different trips over a season. While most of the variation in prices over a season is due to differences in party size, we cannot guarantee that identical goods are purchased on different trips. As well, recall data may exhibit errors of measurement that generate specious differences in budgets.

an average traveling speed of 50 miles per hour. The implicit price of on-site time was included by using the wage rate (or 1/2 of it) times the number of work hours per day, assumed to be 8. The quantity of site time was days on site.

The number of violations of the axioms of choice for the nine different approaches to generating the implicit prices of travel are presented in Table 1. In general, agreement with the theory of revealed preference appears to be quite close, with nearly 95% of the individuals satisfying the axioms of choice for all models. In all of the tests there were no cases in which the GARP was satisfied but the SARP was not, indicating that there were no flat spots in the indifference curves.

As a standard of comparison, we use the number of violations of the axioms that would appear in random choice data. Note that the number of hunting trips reported is fairly small, ranging from one to seven per individual. Clearly, with only one trip no violations of the axioms are possible. In order to examine the small sample aspects of the test a series of simulations were performed with randomly generated numbers for the prices and quantities used in revealed preference tests. These are presented in Table 2, where the rows are the number of choice occasions and the columns are the number of commodities in the bundle being examined. The elements of the table are the percentage of cases violating the GARP or the SARP (in the generation of the budgets no cases arose in which GARP was satisfied but SARP was not). It is clear that in small samples, randomly generated budgets can satisfy the axioms in a significant proportion of cases.

The percentage of cases which violate the axioms is far larger than

Table 1. Results of Nonparametric Tests: Value of Travel and On Site Time Models

Value of Travel Time		Value of On Site Time		
		zero	.5 × wage	1.0 × wage
zero	Violations	14	2	1
	Percent Violating	4.08	0.58	0.29
	% violating (multiple trips)[1]	5.30	0.76	0.38
	Equal con. spot cases[2]	113	113	113
	No. of trips evaluated	1125	1125	1125
.5 × wage	Violations	7	5	1
	Percent Violating	2.04	1.46	0.29
	% violating (multiple trips)[1]	2.65	1.89	0.38
	Equal con. spot cases[2]	113	113	113
	No. of trips evaluated	1125	1125	1125
1.0 × wage	Violations	7	5	2
	Percent Violating	2.04	1.46	0.58
	% violating (multiple trips)[1]	2.65	1.89	0.76
	Equal con. spot cases[2]	113	113	113
	No. of trips evaluated	1125	1125	1125

[1] Single trip cases automatically satisfy the axioms, this figure indicates the percentage of multi-trip responses which violate the axioms.

[2] Cases with equal consumption spots are those which the prices change but the consumption bundle remains constant.

Table 2. Percentages of Cases Violating the Axioms[a] of Choice from Randomly Generated Budgets[1]

Number of Bundles	Number in the Commodity Bundle 1	2	3	4	5
1	0	0	0	0	0
2	0	9	10	15	12
3	0	21	32	29	26
4	0	31	41	39	44
5	0	53	58	65	59
6	0	65	71	75	81
7	0	73	79	82	77
8	0	76	88	94	89
9	0	82	95	93	95
10	0	88	95	97	98

[1] There were no differences between the results for the GARP and the SARP thus these results represent violations of both axioms.

the corresponding numbers in the observed travel data for all nine models. Statistical tests of the significance of the difference in the numbers of violations (see Adamowicz, 1988, for details) lead to rejection of the null hypothesis of no difference in the number of violations at very high levels of significance. Thus, under a maintained hypothesis that the prices used are true prices, we conclude that consumers do behave in a manner consistent with utility theory in their choices regarding recreational travel.

An interesting finding is that nearly one-third of the individuals displayed some evidence of not reacting to price changes due to kinks in indifference curves or nonconvexities in the choice set. The latter interpretation is especially compelling in the current context since hunting can take place only at a finite set of sites.

There is no clear pattern in the way that the violations change over the values of time, except that the model without any time values does not perform as well as the models with time values included. A simple two-way classification table can be constructed which allows for a statistical comparison of the number of violations under alternative time value assumptions. A contingency table with time value alternatives on one axis and violations or non-violations on the other axis serves as the basis for a Chi-square test of the difference between groups. Let n be the total number of individuals in both groups, 1 refers to violations of axioms, 2 to their satisfaction, a refers to the first implicit price approach and b to the second. For example, n_1 is the number of individuals in total who violate the axioms, n_a the number of individuals tested using the first implicit price approach and a_1 the number of observed violations using the first approach, etc. The appropriate test statistic is

$$k = \frac{n(a_1b_2 - a_2b_1)^2}{n_1n_2n_an_b} \quad .$$

The statistic k is distributed as a Chi-square variate with 1 degree of freedom (Spiegel). Table 3 contains the results of selected tests between the various models.

The results of these tests of proportions indicate that models with positively-valued on-site time tend to have significantly different numbers of violations than models with no value of on-site time. However, the models with on-site time valued at 1/2 the wage is not significantly different (at the 95% level) than the one with travel time valued at 1/2 the wage. It is important to note that different individuals violated the axioms for different values of time, indicating that approaches which assume the same fraction of the wage across all individuals are incorrect.

Further evidence regarding the value of time is provided by the efficiency indices for the violators in the various models as presented in Table 4. These indices show that the efficiencies for the different models do not always agree with the numbers of violations. Combining the numbers of violations with the efficiencies seems to indicate that a conservative approach (one that gives a lower estimate of surplus), which yields few violations of the axioms of choice and high efficiencies for the violations that do occur, is to value travel time at zero and on-site time at the wage rate. However, valuing both types of time at the wage rate gives the same revealed preference results. In general, the performance of values of travel time seem to be more volatile across values of on-site time than is the performance of on-site time across values of travel time.

Table 3. Statistical Test[1] of the Comparison of the Number of Violations Between Models

Comparison	Chi Squared Value	P-Value
TT=0, ST=0[2] vs TT=.5, ST=0	2.407	.121
TT=0, ST=0 vs TT=1, ST=0	2.407	.121
TT=0, ST=0 vs TT=0, ST=.5	9.215	.002
TT=0, ST=0 vs TT=.5, ST=.5	4.385	.036
TT=.5, ST=0 vs TT=.5, ST=.5	0.339	.560
TT=.5, ST=0 vs TT=0, ST=.5	2.815	.093

[1] Chi Squared test statistic.

[2] TT=0 indicates travel time value of zero, TT=.5 indicates travel time value of .5 times the wage, TT=1 indicates travel time value of 1.0 times the wage. ST=0 indicates site time value of zero, ST=.5 indicates site time value of .5 times the wage and ST=1 indicates site time value of 1.0 times the wage.

Table 4. Results of the Efficiency Tests

	Value of Site Time = 0			Value of Site Time = .5			Value of Site Time = 1.0		
Value of Travel Time	0	.5	1.0	0	.5	1.0	0	.5	1.0
Mean efficiency index	.941	.956	.974	.978	.952	.947	.946	.961	.978
Std. dev. of efficiency index	.0471	.0337	.0233	.0180	.0389	.0280	.0000	.0000	.0080
Minimum efficiency index	.821	.913	.935	.960	.883	.904	.946	.961	.971

Violations of the axioms may be due to measurement errors in the data, misspecification of the separable structure of the utility function, or other reasons including, of course, "irrational" behavior by individuals. While rational choice is expected in a world of perfect information and zero computational costs, in more complex milieus a more careful definition of rationality is needed which allows the balancing of the marginal benefits and marginal costs of acquiring and processing information. One would expect that as the "cost" of making irrational choices increases their frequency would decline. Therefore, we hypothesize that as the expenditure on the recreation branch increases as a proportion of income, the number of violations for that branch would fall. As well, when decisions are more complex, we would expect that the number of violations of narrowly-defined rationality postulates would increase. Thus, we also hypothesize that the number of violations of the axioms would increase with the number of choice occasions or trips that the person takes.

In order to test these hypotheses a Probit model was estimated with a dependent variable equal to 1 if the individual violated the axioms and equal to 0 if they did not. The results of the model, estimated with zero value of on-site and travel time, are presented in Table 5. In the estimated model the independent variables are the number of choice occasions (trips) and proportion of income spent on recreation. The results confirm our conjectures regarding the influence of these variables on the probability of violating the axioms.

Contingent Valuation

In this section we add the value of the recreation experience to the

Table 5. **Probit Analysis of Axiom Violations**

Variable	Coeff.	Std. Error	t-Stat	P-Value
Constant	-2.252	0.083	-2.707	0.007
Trips	1.112	0.413	2.695	0.007
Expen/Inc	-0.281	0.152	-1.845	0.065

Observations: 343
Log-Likelihood: -52.587

travel consumption bundle evaluated in the previous section. We do this by valuing the public input (i.e. the recreation site) using contingent valuation questions regarding the willingness to pay (WTP) per day for the consumption bundle observed. We explore as well as the use of willingness to accept compensation (WTA) for foregoing this bundle. We then seek to determine if the individuals could have paid this amount for their hunting experience and maintained rationality as defined by satisfaction of revealed preference axioms. Three basic approaches are used: the answer to the WTP and WTA questions and the prediction of a bid function estimated from the WTA responses. Efficiency indices also are computed for those individuals who violate the axioms.

The WTP question was of the form "What was it worth to you in dollars per day, above what you spent on travel and other expenses, to participate in hunting." The WTA question was "How much would you have to be paid not to hunt for one year." Both of these appeared on the same questionnaire as that used to collect the data employed in the last section. The WTP response provides a "price" that can be used directly in the nonparametric analysis. The WTA response was converted to a price per day by dividing by the activity days of participation in the season for each individual. The quantities corresponding to these prices are the number of days spent on the trip.

Of the 343 respondents who provided complete trip activity and expenditure data, 223 provided WTP values and 148 provided WTA values. Although the appropriate treatment of nonresponses to contingent valuation questions is a controversial topic (Mitchell and Carson), those who did not respond to these questions were dropped from further consideration.

Tables 6 and 7 contain the WTP and WTA results respectively. In Tables 8 and 9 these results are presented by hunting zone (site). These results show that there is considerable variation in the contingent valuation responses, with standard deviations larger than the mean. The ratio of the WTA to WTP responses is 1.72. This is not as large a difference as has been reported in other studies (see Cummings, et al.) although the difference here is statistically significant.

An alternative approach to determining the price from the contingent valuation responses is to estimate a bid function for the good in question (see e.g. Sellar, Stoll, and Chavas; Cameron). Here, we estimate a bid function from the WTA responses for values for the season of hunting as a function of the number of days of activity. The estimated equation, using natural logarithms of the variables, is

$$\underset{}{\ln(WTA)} = \underset{(17.6)}{4.762} + \underset{(6.4)}{0.816\ln(DAYS)} \quad R^2=.219 \quad N=148$$

The numbers in parentheses are t-statistics.

The marginal value per day of activity can be derived from the bid function and used as an implicit price for the observed quantity of days in the nonparametric analysis. The results of the revealed preference tests are presented in Table 10. As with the market data analyses described above, there were no cases in which the GARP was satisfied but the SARP was not, while there is considerable evidence of kinks in the indifference curves or nonconvexities in the choice set. As well, very few violations of the axioms of choice are noted, with the fewest over all our tests yielded by the WTA-bid function approach. The efficiency indices for those violating are presented in Table 11.

A test statistic similar to that presented above regarding the

Table 6. Willingness to Pay (WTP)
Descriptive Statistics for Individuals Reporting WTP

	Mean	Std. Dev.
No. of cases	223	
No. of Trips per season	4.336	1.790
No. of Days per trip	3.10	3.46
WTP per person per day	87.90	122.62

Table 7. Willingness to Accept Compensation (WTAC)
Descriptive Statistics for Individuals Reporting WTAC

	Mean	Std. Dev.
No. of cases	148	
No. of Trips per season	4.371	1.762
No. of Days per trip	3.00	3.61
WTAC per person per day	151.57	216.06

Table 8. Willingness to Pay (WTP)
Descriptive Statistics for Individuals Reporting WTP by Zone

	Mean	Std. Dev.
ZONE 11		
No. of cases	88	
No. of Trips per season	1.919	1.259
No. of Days per trip	2.55	1.89
WTP per person per day	90.01	143.52
ZONE 10		
No. of cases	73	
No. of Trips per season	2.726	1.726
No. of Days per trip	4.28	7.39
WTP per person per day	88.37	144.17
ZONE 9		
No. of cases	65	
No. of Trips per season	1.785	1.096
No. of Days per trip	3.25	2.53
WTP per person per day	101.46	151.15
ZONE 7		
No. of cases	73	
No. of Trips per season	1.643	0.962
No. of Days per trip	3.97	3.02
WTP per person per day	95.62	137.99
ZONE 6		
No. of cases	27	
No. of Trips per season	1.370	0.839
No. of Days per trip	6.89	4.03
WTP per person per day	116.48	184.99
ZONE 5		
No. of cases	51	
No. of Trips per season	1.804	1.265
No. of Days per trip	3.36	2.65
WTP per person per day	89.41	141.01

Table 9. Willingness to Accept Compensation (WTAC) Descriptive Statistics for Individuals Reporting WTAC by Zone

	Mean	Std. Dev.
ZONE 11		
No. of cases	56	
No. of Trips per season	1.821	1.162
No. of Days per trip	2.31	1.62
WTAC per person per day	149.16	250.19
ZONE 10		
No. of cases	47	
No. of Trips per season	2.659	1.723
No. of Days per trip	4.63	9.04
WTAC per person per day	131.34	143.74
ZONE 9		
No. of cases	49	
No. of Trips per season	2.020	1.314
No. of Days per trip	3.12	2.56
WTAC per person per day	217.07	350.92
ZONE 7		
No. of cases	56	
No. of Trips per season	1.553	0.971
No. of Days per trip	3.87	3.13
WTAC per person per day	104.57	137.54
ZONE 6		
No. of cases	20	
No. of Trips per season	1.100	0.308
No. of Days per trip	6.10	3.57
WTAC per person per day	132.29	159.73
ZONE 5		
No. of cases	41	
No. of Trips per season	1.707	1.167
No. of Days per trip	3.61	2.87
WTAC per person per day	100.77	103.13

Table 10. Results of Nonparametric Tests: Contingent Valuation

Form		
CV WTP	Cases Evaluated	223
	Violations	2
	Percent Violating	0.90
	% violating (multiple trips)[1]	1.19
	Equal con. spot cases[2]	72
	No. of trips evaluated	706
CV WTAC	Cases Evaluated	148
	Violations	1
	Percent Violating	0.67
	% violating (multiple trips)[1]	0.88
	Equal con. spot cases[2]	43
	No. of trips evaluated	456
BID FN[3]	Cases Evaluated	148
	Violations	0
	Percent Violating	0.00
	% violating (multiple trips)[1]	0.00
	Equal con. spot cases[2]	43
	No. of trips evaluated	456

[1] Single trip cases automatically satisfy the axioms; this figure indicates the percentage of multi-trip responses which violate the axioms.

[2] Cases with equal consumption spots are those which the prices change but the consumption bundle remains constant.

[3] Results from a bid function of the form ln(WTAC) = f(ln(days)).

Table 11. : Results of the Efficiency Tests: Contingent Valuation

	Contingent Valuation WTP	WTAC	BID FN
Mean efficiency index	.962	.957	N/A[1]
Std. dev. of efficiency index	.0125	0	N/A
Minimum efficiency index	.950	.957	N/A

[1] No violations were recorded.

statistical significance of differences between the travel cost models may be used here to test the difference between the violations in the contingent valuation models and the travel cost violations. Compared to a travel cost model with no value of time included, all three of the contingent valuation approaches result in significantly fewer violations. The contingent valuation approaches compared very favorably to the best-performing travel market data models in terms of consistency with the axioms of choice. Comparison of the WTP and WTA methods revealed no significant differences between them in this regard.

V. Conclusions

In this paper we have proposed an alternative approach to the validation of methods for valuing nonmarket goods. Our approach is based on the ability of the techniques to provide implicit prices for the nonmarket goods which, when combined with observed quantities of these and other goods, yield bundles that could have been purchased by a rational consumer. This is a very weak test of the methods, since there is no guarantee that even if the prices are consistent with rationality they are the correct prices. But it is a fundamental test, since if the prices so derived could not have been used by a rational consumer maximizing any utility function, the techniques are questionable indeed.

In general, the travel cost and contingent valuation methods used here performed admirably. Since the models are very simple ones relative to approaches exhibited in the literature, it may be that more sophisticated versions would do even better, though they may do worse if individuals are not sophisticated decision-makers. However, it also is the case that the goods we evaluated, travel for hunting and hunting sites, are fairly well-suited to the assumptions made in the techniques. The approach we employ might usefully be applied to more complex valuation problems.

One other alternative use of revealed preference theory may exist in this context. Suppose that individuals are rational and that the only missing data for the recreation (or other public good) branch is the price of the public good Z. Then one could compute the minimum and maximum prices consistent with satisfaction of the axioms of choice for each individual and these could serve directly as goods valuations. The primary problem with this approach is its maintained hypotheses: that the correct separability structure is known, that no measurement errors exist in the data, and that the consumers are rational in their other goods purchases. However, the approach may be of some value and warrants further research.

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