A Sequential Choice Model of Recreation Behavior

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The travel cost model is the standard model used in the recreation demand literature. This model assumes that the decision on the number of trips to a particular site in a given period (a season, for example) is determined at the beginning of the period. For certain types of recreation activity, this decision may be more appropriately modeled as a sequential process, in which the decision of whether or not to take each additional trip is made after all previous trips have occurred. This decision is dependent on the realization of random variables on previous trips as well as travel costs. A model is developed in which the choice of a discrete number of sequentially chosen trips to a given site is specified as a function of site-specific variables and variables realized on previous trips. This model's advantage over the traditional travel cost model is that it specifies discrete, nonnegative integer values for the number of trips and allows intraseasonal effects to determine the probability of taking each additional trip.

Key words: benefit estimation, demand theory, discrete choice, recreation demand, travel cost models.

In estimating the demand for outdoor recreation, the travel cost demand model, or some variant of it, has been the most popular empirical model. In its most basic form this model estimates the quantity of visits to a particular site as a function of travel and time costs. The model can be derived from a utility maximization problem in which the optimal number of trips in a period, given travel costs, time costs, and available income, is chosen. The single-site model has been modified to include multiple sites, a number of time constraints, and a variety of other factors (e.g., McConnell), but the basic form of the model remains. The travel cost model requires modification in order to restrict the predicted number of trips to be positive (e.g., tobit models) and requires estimation of a Poisson regression (or some similar technique) to limit it to count data (Smith).

We examine an alternative model of recreation choice which analyzes several aspects of the problem ignored or obscured in the traditional approach. In this model the number of trips is not chosen at the beginning of the season or year as is assumed in the travel cost model; rather, trips are chosen sequentially, the choice of trip $t + 1$ being conditional on the individual already taking t trips. This allows intraseasonal effects to influence the number of trips chosen, and the number of trips chosen is an integer beginning at zero. We proceed by presenting the traditional travel cost model followed by the theoretical basis for the sequential choice model and its estimation. Next, we offer an example of sequential choice estimation of the demand for recreational hunting to a single site and compute the welfare estimates resulting from this model.

The Travel Cost Model

The basic travel cost model can be written as the maximization of utility of consuming trips and other goods subject to available income. This problem can be solved to yield a demand

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function for visits to a particular site which takes the form

$$Z = f(P, Y, w^*), \tag{1}$$

where Z is the number of visits by an individual to a particular site, P is a vector of relevant prices including travel costs to that site, Y is income, and w^* is the value of time. Depending on the time constraints, the value of time is generally some function of the wage rate (e.g., McConnell; Bockstael, Strand, and Hanemann). The demand function for a single-site model is easily estimated from data on the number of visits and travel cost to the site (assuming no other variable costs are pertinent).

Estimation by ordinary least squares results in the problem of predicting negative numbers of trips. Furthermore, estimation using only those individuals who actually visited the site corresponds to a censoring problem as information on those choosing not to visit the site is ignored. In these cases ordinary least squares results in biased estimates of the demand parameters. As a result, a truncated or censored regression approach is commonly used to estimate these demand functions (Smith). One approach is to use a tobit model which requires data on the independent variables for those who visit the site and those who do not. Alternately, the Heckman two-step procedure uses probit estimates of the probability of visiting the site to treat the bias introduced by censoring. When no information is available on those individuals who do not visit the site, the model is truncated (Amemiya), and a third approach to estimation is required.

Several other controversial issues surround estimation of the travel cost demand model. The choice of functional form is critical in determining welfare estimates (Kling; Adamowicz, Fletcher, and Graham-Tomasi) and parameter estimates. Inclusion of substitute prices and other independent variables in the demand function has been debated in this literature (Rosenthal; McConnell). While a variety of issues hampers formulation and estimation of the travel cost model, there appears to be consensus on the estimation of such models. A model which formulates the number of visits per season as a function of travel costs and is estimated using some form of censoring or truncation correction appears to satisfy most of the basic concerns addressed in the literature.

The Sequential Choice Model

The sequential choice model is a type of discrete choice model. The basic premise is that individuals choose whether or not to make a single trip based on which decision yields higher utility. As in the travel cost model, the choice of taking five trips suggests that the utility of taking five trips is greater than the utility of taking four trips or the utility of taking six trips. However, rather than deciding at the beginning of the season to choose five trips, the sequential choice model suggests that the consumer decides to take trips 1, 2, 3, and 4 before deciding on trip 5. Although trip decisions are made one at a time, under certain independence assumptions the total number of trips in the season can be modeled as the product of binary choices associated with taking (or not taking) individual trips.

Consider first the decision to make a single trip to a site. This can be modeled as the discrete choice between taking or not taking a trip. Following Hanemann, the discrete choice model can be specified as follows. Let X_1 and X_0 represent market purchased goods associated with going and not going on the trip, respectively. Let Q_1 and Q_0 represent the level of "quality" attributes of these two alternatives, and let Z be a numeraire good. The direct utility function of the consumer can be specified as

$$U(X_0, X_1, Q_0, Q_1, Z). \tag{2}$$

The optimization problem is to maximize utility subject to an income constraint, a constraint that indicates that one cannot both consume a trip and stay at home (i.e., only one alternative can be chosen), and a constraint that the level of X_i consumed for $i = 0, 1$ is fixed at a given level, X_i^*, if alternative i is chosen. The three constraints can be specified as:

$$\begin{aligned} &P_0X_0 + P_1X_1 + Z = Y, \\ &X_0 \cdot X_1 = 0, \text{ and} \\ &X_i = X_i^* \text{ or } 0 \text{ for } i = 0, 1. \end{aligned} \tag{3}$$

Given that only one alternative can be chosen, it is useful to work with the conditional utility function. Under the assumption that the quality of an alternative is not important if the alternative is not chosen (i.e., $X_i = 0 \rightarrow \partial U/\partial Q_i = 0$ for $i = 0, 1$), we can write the utility function conditional on having chosen to take a trip and the corresponding indirect utility function as

$$U = U_1(0, X_1, 0, Q_1, Y - P_1X_1^*) \\ = V_1^*(Q_1, Y - P_1X_1^*). \tag{4}$$

Similarly, the conditional indirect utility function for not taking a trip (V_0^*) can be obtained. If $V_1^*(\cdot) \geq V_0^*(\cdot)$, then the trip is taken.

Note that this formulation of the problem considers only one "site" as the destination. The individual chooses whether or not to make a trip to this site and does not choose between alternative sites. The correct role of substitute sites in such a model is not clear.[1] As a proxy for including a substitute site directly in an individual's choice set, we consider the following. If the assumption $X_i = 0 \rightarrow \partial U/\partial Q_i = 0$ for $i = 0, 1$ is relaxed, attributes of the alternative not chosen appear in the conditional indirect utility function. One of the advantages of choosing not to take a trip to the "target site" (i.e., $X_0 = X_0^*$) is the opportunity of visiting an alternative site. Hence the distance to this alternative site may be regarded as a quality attribute of the alternative of not taking the trip. We formulate a model in which the distance to the substitute site (regarded as an attribute of the decision of not taking a trip to the target site) is used as a proxy for the inclusion of an explicit site selection decision. We expect that the distance to the substitute site is positively related to the probability of choosing to take an additional trip to the target site.

The model described above analyzes the decision to take the first trip or not. Under the hypothesis of sequential choice, several similar choices are made throughout the season. The choice of higher numbers of trips can simply be considered as single trip choices conditional on already having taken the preceding trip.

The problem described above is formulated in a random utility framework. That is, the consumer's utility function has an observable or systematic component and a random component. The analyst or econometrician sees only the observable portion of the utility function and the outcome or choice. As such, the analyst uses the observable portion to assign probabilities to the choices. A random component is added to the indirect utility function in equation (5).

The multitrip aspect of this situation is incorporated by expressing the indirect utility function and associated random component as

$$V_{ti}^* = V_{ti} + \epsilon_{ti}, \tag{5}$$

where t specifies the trip choice alternative (1, 2, etc.) and $i = 1, 0$ specifies the alternatives of taking trip t or not, respectively. V_{ti} is the systematic portion of the indirect utility function, and ϵ_{ti} is the random component. Note that if alternative $i = 0$ is chosen for trip t, it is not possible for the individual to take more than t trips. Also, if $i = 1$ is chosen for some trip t, the next step in the sequential choice is to compare the utility of taking $t + 1$ trips with the utility of taking t trips only. Therefore, the subscript t is of primary importance, as all trips can be modeled as comparisons between taking an additional trip ($t + 1$) or not taking an additional trip. The subscript i is suppressed from here on as it is implicit in the choice process.

We now model the total number of trips chosen. Let P_t denote the probability that t trips are chosen. This probability is written as

$$P_t = \Pr\,(V_t^* \geq V_s^*; \text{ for all } s \in I); \text{ for all } t \in I, \tag{6}$$

where I indexes the possible number of trips. Two assumptions are made in order to estimate this model. First, no higher alternative can be chosen without having already chosen all lower-ranked alternatives. Second, the marginal utilities of the alternatives in the choice set are independent random variables (Sheffi). The first assumption implies that trip t cannot be chosen without trips $t - 1, t - 2, \ldots, 1$ having been chosen also. This is more a description of the process being modeled than an assumption. Nevertheless, it requires that decisions be made sequentially and not at a single point in time and implies that each P_t incorporates the probabilities of having already selected alternatives $t - 1, \ldots, 1$.

The second assumption implies that all trip choices (made as binary comparisons with the adjacent higher- and lower-ranked alternatives) are independent. Hence, the marginal utility of alternatives (e.g., $V_t^* - V_{t-1}^*$) or the

[1] In order to incorporate substitute sites, one could hypothesize that a utility tree exists in which individuals choose to go on a trip then they choose a certain site. In this case, the sequential choice model is modified by the inclusion of a multinomial choice model to describe the choice among alternative sites. Since choices are made at several points in the season and are conditional on the realization of previous trips, the most general formulation of such a model would involve site choice evaluation at each trip. Such a model is quite complex as it leads to a large number of possible combinations, especially since the order of site choices and trip choices is important. This approach is beyond the scope of the present article, but it is an important avenue for further research.

"utility differences" are regarded as independent random variables. The result of this assumption is that the probability of choosing (trip) t is the product of the binary choice probabilities of the form "the probability of one trip versus zero trips, the probability of two trips versus one trip, . . . the probability of t trips versus $t - 1$ trips and one minus the probability of $t + 1$ trips versus t trips." This description of the model is developed more formally below.[2]

Define elements of the choice index I which are below choice t (i.e., trips $t - 1, \ldots, 0$) as I_1 and the elements of this index above choice t (i.e., trips $t + 1, t + 2, \ldots$) as I_2. The probability of choosing alternative t can be written

$$(7) \qquad P_t = \Pr(V_t^* \geq V_s^*; \text{ for all } s \in I_1) \cdot \Pr(V_t^* \geq V_r^*; \text{ for all } r \in I_2),$$

where each successive trip choice is conditional on all lower-ranked alternatives having already been chosen. Since alternatives are considered and chosen sequentially (and thus all trips previous to t must have already been taken) and the marginal utilities are independent (the probability of $V_k \geq V_{k-1}$ is independent of $V_s \geq V_{s-1}$ for all $s \neq k$), the first term in equation (7) can be expressed as the product of all individual binary choice probabilities for alternatives up to t;

$$(8) \qquad \Pr(V_t^* \geq V_s^*; \text{ for all } s \in I_1) = \prod_{k=1}^{t} \Pr(V_k^* \geq V_{k-1}^*).$$

Only one alternative ranked higher than alternative t needs to be considered in estimating the probability of choosing t, since the probability of choosing the remaining higher-ranked alternative is zero as their predecessors have not been chosen (also a result of the first assumption; see Sheffi). The second half of equation (7) can be specified as the probability that alternative t is chosen over the higher ranked alternative;

$$(9) \qquad \Pr(V_t^* \geq V_r^*; \text{ for all } r \in I_2) = \Pr(V_t^* \geq V_{t+1}^*).$$

Substituting equations (8) and (9) into (7), we derive the probability of choosing t trips as

$$(10) \qquad P_t = \Pr(V_t^* \geq V_{t+1}^*) \cdot \prod_{k=1}^{t} \Pr(V_k^* \geq V_{k-1}^*).$$

In order to make the notation simpler, we define

$$(11) \qquad P_{t+1|t} \equiv \Pr(V_{t+1}^* \geq V_t^*).$$

Equation (10) can now be expressed as

$$(12) \qquad P_t = (1 - P_{t+1|t}) \prod_{k=1}^{t} P_{k|k-1}.$$

The relationship implied by this equation was described in the text above. The probability of choosing t trips is the product of the probabilities of choosing all lower-ranked alternatives and one minus the probability of choosing the higher-ranked alternative. In other words, the unconditional probability of choosing trip t depends on the conditional (on the choice of each previous trip) probability of choosing trip 1 over 0, 2 over 1, up to t over $t - 1$ and one minus the probability of choosing $t + 1$ over t.

The sequential choice model is composed of a set of binary choices. Therefore, estimation of a simple logit or probit model of the choice to take trip t versus $t + 1$ or $t - 1$ would constitute an unrestricted estimator of this model (see Vickerman and Barmby) and would produce a separate parameter vector for each trip. The unrestricted approach, however, fails to use information contained in the previous trips. Simultaneous estimation of the binary choice models minimizes the number of parameters to be estimated and facilitates interpretation of the parameters.

The likelihood function for the restricted model, being the joint probability given a particular parameter vector, can be written as the product of the individual probabilities over all individuals of the sample. For the model in equation (12) this can be written as

$$(13) \qquad L = \prod_{s=1}^{S} \left[(1 - P_{t+1|t}) \prod_{k=1}^{t} P_{k|k-1} \right],$$

where S is the sample size and s indexes individuals. Since we only observe a single-response alternative for each individual (i.e., each person in the sample has chosen a certain number of trips), the likelihood function is estimated as

$$(14) \qquad L = \prod_{s=1}^{S} \left\{ \left[(1 - P_{t+1|t}) \prod_{k=1}^{t} P_{k|k-1} \right] \right\}^{Y_{st}},$$

[2] The "Independence of Irrelevant Alternatives" assumption which characterizes much of the discrete choice literature is not present in this model as all choices are binary choices. As long as the two assumptions discussed above hold, the model is free from such difficulties.

where $Y_{st} = 1$ if individual s chooses t trips and zero otherwise. Given a specification of the utility function, this likelihood function can be estimated with any nonlinear optimization routine.[3]

Specification of the utility function is critical in this analysis. There are two forms of observations that enter the utility function, those experienced at the same level on every trip (generic variables) and those that only are experienced on some trips and/or at different levels for different trips (nongeneric variables).[4] Generic variables include such factors as travel cost. In a linear form of utility function, the generic variable G_t would be modeled as $V_t = t \cdot \beta \cdot G_t$, since it would be experienced on every trip, 1 through t. Nongeneric variables enter only on the trip they apply to and at the level experienced on that trip. An example of a nongeneric variable for a recreational hunting trip is harvest. In addition to the specification of generic and nongeneric variables, the form of the utility function also must be determined. In this article, as in much of the literature in the discrete choice area, we use a linear form of utility.

Data, Models, and Estimation Procedures

The data used for the estimation of the sequential choice model were collected in a mail survey of recreational hunters in Alberta in 1982. The portion of the survey results used here relates to Big Horn sheep license holders. Of the 1,000 questionnaires sent out to sheep license holders, 63.9% were returned. After processing, questionnaires with missing or incomplete data and those for individuals who did not hunt were removed. The remaining sample was made up of 455 hunters. Two hunting "sites" were investigated, one being the target site and the other a substitute. The target site was made up of two Wildlife Management Units (WMU) in the southern portion of Alberta. All trips to the site, whether they were sheep hunting trips or not, were modeled. The substitute site was an adjacent hunting region in the province. There were no regulations on the sites available to these hunters (even for sheep hunting), thus these sites were chosen by individuals and do not reflect regulations or administrative decisions.

The average age of respondents was 35.02 years and 98.6% of respondents were male. The median income was $31,123 (1981 Canadian dollars). The average respondent had 17.68 years of big-game hunting experience and held 6.61 different hunting licenses. Each respondent provided his/her place of residence, and these were used to compute the distance to the target site and the substitute site. Travel costs were computed by multiplying the return travel distance by 18¢ per mile, the cost of travel in 1981 as reported by the Alberta Government Department of Treasury. Harvest statistics were provided by the respondents for each trip. Harvest constituted the total number of big-game animals captured.

Sequential Choice Estimation

In modeling the discrete choice decision, we specify utility as a function of income, less travel cost to the target site, travel distance to the substitute site, cumulative harvest from all previous trips to the target site, and the expected harvest for the trip under consideration. Income is included (as in most discrete choice models) as the amount available from which travel costs are subtracted. Therefore, income is individual-specific (rather than alternative specific) and drops out of the parameter estimation. Such a formulation is necessary for the calculation of welfare.

Harvest is assumed to be an exogenous variable. When choosing whether to take the tth trip, the individual is aware of the travel costs to the site and the distance to the substitute site as well as the level of harvest obtained on the $t - 1$ trips already taken. However, the harvest on trip t is unknown. Expected harvest (which is assumed to be known by the individual) is included as a determinant of the utility of trip t. We expect that the effect of increasing harvest on previous trips will reduce the probability of taking an additional trip. Particularly in the case of big-game hunting, it is hypothesized that once a hunter harvests an animal, the frequency of hunting is reduced dramatically. Since the individuals in our sample hunt for several species, however, the prob-

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[3] The programs used to estimate this model were written in GAUSS and are available from the authors upon request.

[4] There is some disagreement in the literature on the use of the term "generic." Sheffi uses generic in the form above while Vickerman and Barmby and Barmby use generic for the opposite form.

ability of returning to the site after an animal has been harvested is not zero.[5]

The indirect utility function (for t trips) for the discrete choice analysis is formally specified as

$$(15)\quad V_t = \alpha_t + (Y - t\cdot TC)\cdot\beta_{tc} + t\cdot(DS)\cdot\beta_{ds} + \left(\sum_{j=1}^{t-1} H_j + E[H_t]\right)\cdot\gamma_h,$$

where Y is income, TC is the travel cost to the site, DS is the travel distance to the substitute site, H_j is the harvest on trip j, and $E[H_t]$ is the expected harvest on trip t. The coefficients α_t, β_{tc}, β_{ds}, and γ_h are parameters to be estimated. The α_t are intercept parameters that are alternative specific. They indicate the level of utility with all other variables held constant and are equivalent to alternative specific dummy variables in multinomial choice analysis. Therefore, if k is the total number of alternatives evaluated, only $k - 1$ constants can be estimated.

As specified above, the utility of t trips depends on harvests up to that point and the expected harvest on trip t. Recall that the model is sequential, and therefore all previous harvests are known to the individual deciding whether or not to take trip t. Let the expected harvest be constant across alternatives[6] or $E[H_t] = H^*$ for all t. Then, in expressing the utility difference between trip t and $t + 1$, we obtain

$$(16)\quad V_{t+1} - V_t = (\alpha_{t+1} - \alpha_t) + \beta_{tc}TC + \beta_{ds}DS + \left(\sum_{j=1}^{t} H_j + H^* - \sum_{j=1}^{t-1} H_j + H^*\right)\gamma_h.$$

This can be simplified to

$$(17)\quad V_{t+1} - V_t = \alpha_{tj} + \beta_{tc}TC + \beta_{ds}DS + \gamma_h H_t,$$

where H_t is the harvest on the previous trip and α_{tj} is an alternative-specific constant which is normalized to be zero on one of the alternatives.

Given the utility difference, $V_{t+1} - V_t$, the probability of taking trip $t + 1$ conditional on already having taken trip t can be specified by the simple logit model as

$$(18)\quad P_{t+1|t} = \frac{e^{V_{t+1}}}{e^{V_{t+1}} + e^{V_t}} = \frac{1}{1 + e^{-(V_{t+1} - V_t)}}.$$

Using these simple conditional probability statements, the joint probability can be specified as in equation (14). The probability of taking any trips to the site must also be estimated ($t + 1 = 1$, $t = 0$). For this purpose the model is estimated using data on hunters who did not visit this site but did visit other sites. The utility function for the 0,1 choice includes only travel cost, substitute distance, and a constant.

Results of the sequential choice model are presented in table 1. For comparison three versions of the model are examined. The first model includes substitute distance and harvest as explanatory variables. The second model does not include the substitute, and model 3 includes neither the substitute nor harvest variables. The most notable feature across all models is the strong significance level (at least 99%) of the travel cost parameter. As expected, the higher the cost of travel, the less likely is an additional trip. The substitute distance variable is also significant (at a 99% level) and has the expected sign. The probability of taking an additional trip to this particular site increases as the distance to the substitute site increases. The sign on the harvest variable is negative; the probability of taking an additional trip decreases if an animal is harvested on the previous trip.

The predicted and actual shares are presented in table 2. The "full data aggregation" approach (see Sheffi) which uses the actual values of the independent variables is used to calculate the predicted shares. The predicted shares of trips are very similar to the actual shares in all models. The model with substitute and harvest variables overpredicts the total number of trips by a small amount, and the largest error in the share of each trip is .008. The model without the substitute variable also overpredicts the number of trips, while the model without the harvest or substitute variables underpredicts the number of trips.

In summary, the sequential choice model seems to perform very well as a description of trip choice with travel cost to the site, a substitute site variable, and a harvest variable acting as significant explanatory variables.

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[5] If we were to explore a particular type of hunting, sheep hunting for example, it is possible that hunters would not participate after the harvest of an animal. Even in this case, however, hunters return to an area after a harvest to survey the region for the next season. This also can be considered a trip to the region for hunting purposes and should be included in the sample. Most hunters also carry several licenses, and thus they hunt for several species at a time. Modeling single-species hunting, except in the case of highly regulated hunts, may be difficult.

[6] This is only a reasonable assumption if learning does not take place during the season. However, for our purposes it simplifies the analysis significantly, and it may be reasonable for seasoned hunters.

Table 1. Results of Sequential Choice Model Estimation

Parameter Name[a]	Model 1[b]	Model 2[b]	Model 3[b]
α_1	0.7084** (2.81)	1.1014** (4.81)	1.0664** (4.70)
α_2	1.8734** (5.97)	2.3673** (8.23)	2.1928** (8.04)
α_3	1.2805** (3.90)	1.8015** (6.12)	1.6566** (5.83)
α_4	1.4188** (3.64)	1.9420** (5.40)	1.9047** (5.31)
α_5	1.0545* (2.42)	1.5822** (3.88)	1.4152** (3.52)
α_6	0.5237 (0.96)	1.0193 (1.94)	0.8173 (1.60)
α_7	0.2540 (0.35)	0.7407 (1.04)	0.6271 (0.87)
Travel Cost (β_{tc})	−44.9430** (−10.12)	−36.8574** (−9.72)	−36.1681** (−9.69)
Substitute (β_{ds})	11.5521** (3.36)		
Harvest (γ_h)	−0.8022* (−2.30)	−0.8034* (−2.29)	

[a] Parameters α_1 to α_7 are trip-specific constants or intercepts in the estimated utility functions. The parameter α_0 (for no trips) is normalized to be the value zero.
[b] Asymptotic t-statistics are in parentheses. Single asterisks and double asterisks indicate significance at 95% and 99% levels, respectively.

Welfare Calculation

One of the most common uses of the travel cost model in economics is to estimate the value of the site in terms of consumer surplus (see McConnell or Walsh). Welfare estimates from discrete choice models are the subject of much discussion in the literature at present. Small and Rosen's early efforts in this area have been modified by Hanemann; Bockstael, Hanemann, and Kling; and others. We follow the approach of Hanemann, who derives the compensating and equivalent variation functions for a multinomial choice model. Hanemann provides several formulae for the compensating variation of a price or quality change in a discrete choice framework. In an independent logit model with no income effects, the welfare impact of a price or quality change is

$$CV = \frac{1}{\mu}\left[\ln\left(\Sigma\, e^{V_j^0}\right) - \ln\left(\Sigma\, e^{V_j^1}\right)\right], \tag{19}$$

where μ is the marginal utility of income, V_j^1

Table 2. Actual Shares, Predicted Shares, and Summary Statistics

		Predicted Share		
Trip	Actual Share	Model 1	Model 2	Model 3
0	.758	.758	.758	.758
1	.079	.085	.082	.086
2	.061	.060	.062	.063
3	.033	.027	.029	.028
4	.028	.022	.023	.023
5	.020	.018	.018	.019
6	.011	.012	.011	.010
7	.009	.016	.015	.013
Number of Visits Predicted		298.17	296.84	288.67
Number of Actual Visits		292.00	292.00	292.00
Value of Likelihood (Maximum)		−355.49	−361.28	−363.95
Value of Likelihood at Zero		−683.75	−683.75	−683.75

is the indirect utility of alternative j at price (or quality) level 1, and V_j^0 is the indirect utility of alternative j at price (or quality) level 0. This formula is used in the subsequent welfare measures.[7]

In the sequential choice model, however, all choices are binary applications of the multinomial logit model. Therefore, for each paired comparison of alternatives (trips) we can evaluate the effect of a price change using (19) above. However, the model contains a number of binary comparisons and since trip choices are made sequentially, the price impact must be addressed at each choice occasion. Therefore, we aggregate individual binary choice welfare measures over all alternatives (trips) and then add individual welfare estimates to arrive at the value of the site for the sample. This value then is divided by the predicted number of trips to determine the compensating variation per trip.

In estimating the value of the site, the welfare impact must be evaluated up to the point where the price is so high that no trips to the site are taken. This corresponds to the notion of a choke price in conventional demand analysis.[8] For each binary choice, equation (19) is evaluated at the initial price (travel cost) and a large price. The CV in (19) is bounded so any arbitrarily large price can be chosen. Note that this price also reduces the probability of choosing to take that particular trip to zero. When evaluated over all possible choices of trips, this corresponds to an evaluation of the impact of not having the site available for any trips.

The resulting estimate of welfare for the model with the substitute and harvest variables is \$34.89 per trip. The estimate from the model without the substitute variable is \$50.73, while the welfare measure yields \$52.83 for the model with neither substitute nor harvest variables. As expected, removal of the substitute results in an increase in measured welfare as the possibility of substitution is removed. Therefore, the inclusion of a substitute site variable acts as one would expect in a multisite analysis. The welfare estimates from the sequential choice models fall into the range of the estimates from a number of traditional travel cost models which were also estimated using this data set (see Adamowicz, Jennings, and Coyne).[9] However, the travel cost and sequential choice welfare estimates are based upon decision models which are very different and are not meaningfully compared.

Conclusion

In this article we have presented and estimated a sequential choice model of recreation behavior. The sequential choice model assumes a form of behavior in which individuals choose to take an additional trip only after the previous one is complete. This differs from the traditional travel cost approach which assumes that the number of trips is determined at the beginning of the planning period. It also differs from the multinomial choice model which treats individual trips as independent and does not typically incorporate the number of trips chosen. The problems of negative prediction and noninteger predicted values common in the travel cost literature are not encountered using this model.

We found that the sequential choice model performed well as a predictor of trip choice. The version of the model estimated here included a harvest variable which is usually inappropriate in the traditional travel cost model as harvest is an intraseasonal effect. A substitute site was also modeled although the appropriate framework for inclusion of substitute sites is an important avenue for further research. We also measured the value of the site using the sequential choice model.

The sequential choice model offers an alternative to the traditional approach to estimating recreation demand. While the traditional

[7] The parameter μ is equal to the travel cost parameter except it has the opposite sign. This results from the formulation of the discrete choice model with income minus travel cost ($Y - t \cdot TC$).

[8] Note that the demand function derived from this model is not a conventional demand function but a discrete choice demand. Such a demand function and its properties are discussed in Hanemann for the multinomial logit model. The essential difference is that the compensated demand function is multiplied by a discrete choice index which takes the value 1 if the alternative is chosen and zero if not.

[9] Four different versions of a traditional single-site travel cost model using these same data were estimated. One of the models used a simple OLS procedure with a truncated sample. The other three versions estimated travel cost parameters including information on individuals who did not visit the site (i.e., a censored sample) using OLS, tobit maximum likelihood, and the Heckman two-step procedure. The statistical results were broadly consistent across models. Estimates of consumer surplus per visit to the site ranged from \$10 to \$218 depending on the model specification and the estimation approach. These estimates of welfare differ from those determined from the sequential choice model as the theoretical models are different and the sequential choice model provides Hicksian measures.

approach is best suited to some forms of recreation, there are many cases where the sequential choice model may offer a more appropriate depiction of actual trip choice behavior. Also, combining a sequential choice model of trip choice and a multinomial choice model of site selection may address some of the problems in the current discrete choice literature surrounding the number of trips chosen in a season. Such topics are avenues of further research.

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References

Adamowicz, W. L., S. Jennings, and A. Coyne. "A Sequential Choice Alternative to the Travel Cost Model." Dep. Rural Econ. Staff Pap. #89-06. University of Alberta, Edmonton, April 1989.

Adamowicz, W. L., J. J. Fletcher, and T. Graham-Tomasi. "Functional Form and the Statistical Properties of Welfare Measures." *Amer. J. Agr. Econ.* 71(1989): 414–21.

Amemiya, T. *Advanced Econometrics.* Cambridge: Harvard University Press, 1985.

Barmby, T. "Models for Analysing Trip Level Data." *Environ. and Plan. A.* 20(1988):119–23.

Bockstael, N. E., W. M. Hanemann, and C. L. Kling. "Estimating the Value of Water Quality Improvements in a Recreational Demand Framework." *Water Resour. Res.* 23(1987):951–60.

Bockstael, N. E., I. E. Strand, and W. M. Hanemann. "Time and the Recreational Demand Model." *Amer. J. Agr. Econ.* 69(1987):293–302.

Hanemann, W. M."Applied Welfare Analysis with Qualitative Response Models." University of California, Berkeley, Work. Pap. No. 241. October 1982.

Heckman, J. "Sample Selection Bias as a Specification Error." *Econometrica* 47(1979):153–61.

Kling, C. L. "Comparing Welfare Estimates of Environmental Quality Changes from Recreation Demand Models." *J. Environ. Econ. and Manage.* 15(1988): 331–40.

McConnell, K. E. "The Economics of Outdoor Recreation." *Handbook of Natural Resource and Energy Economics,* Vol. II, eds., A. V. Kneese and J. L. Sweeney, pp. 677–722. New York: Elsevier Science Publishers Ltd., 1985.

Rosenthal, D. H. "The Necessity for Substitute Prices in Recreation Demand Analyses." *Amer. J. Agr. Econ.* 69(1988):828–37.

Sheffi, Y. "Estimating Choice Probabilities Among Nested Alternatives." *Transport. Res. Bull.* 13B(1979):189–205.

Small, K. A., and H. S. Rosen. "Applied Welfare Economics with Discrete Choice Models." *Econometrica* 49(1981):105–30.

Smith, V. K. "Selection and Recreation Demand." *Amer. J. Agr. Econ.* 70(1988):29–36.

Vickerman, R. W., and T. A. Barmby. "Household Trip Generation Choice—Alternative Empirical Approaches." *Transport. Res. Bull.* 19B(1985):471–79.

Walsh, R. G. *Recreation Economic Decisions: Comparing Benefits and Costs.* State College, PA: Venture Publishing, Inc., 1986.