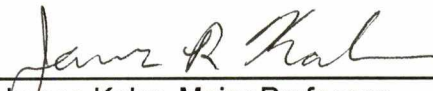


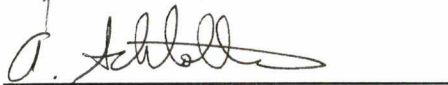
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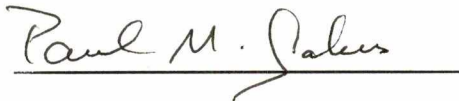
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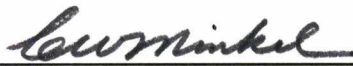
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Associate Vice Chancellor and
Dean of The Graduate School

THE ROLE OF RIGHT-HAND SIDE ENDOGENOUS VARIABLES
IN TRAVEL COST MODELS

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

Scott Rickard
August 1997

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ABSTRACT

In this study, two new travel cost models are presented which show methods for utilizing endogenous right-hand side variables. The first is a theoretical model describing the potential role of site congestion as an equilibrating mechanism in hedonic travel cost models. The second model explicitly considers the recreationist's provisioning of durable recreational equipment in his trips decision via an optimal control methodology. An empirical test of this model, utilizing a simultaneous equations, is then conducted using 1986-7 data on Long Island sport-fishing, and those testable elements of the theoretical models produced the expected results.

TABLE OF CONTENTS

CHAPTER		PAGE
1.	INTRODUCTION.....	1
	Travel Cost Models.....	6
	Revealed Preference Models	6
	Issues in Travel Cost Modeling.....	8
	Endogenous Sample Stratification and Participation	8
	Travel Time	10
	Substitute Sites and Multi-Site Models	15
	Multinomial Logit/Count Data Models	17
	Multiple Destination and Multi- Activity Trips	19
	Endogenous Travel and On-Site Costs	20
	The Choice of Dependent Variable: Number of Trips	23
	Entry and User Fees	25
	Site Congestion	26
	The Need for a Consensus.....	30
2	SITE CONGESTION AS THE EQUILIBRATING MECHANISM IN HEDONIC TRAVEL COST MODELS.....	32
	Hedonic Travel Cost Models.....	32
	The Two Stages of the HCM	33
	Specification and Identification Issues	35
	Site Congestion as an Equilibrating Mechanism	38
	Modeling Congestion Costs in the Hedonic Travel Cost Model Framework.....	40
	A Standard Hedonic Travel Cost Model	40
	A Hedonic Travel Cost Model With Endogenous Congestion Costs	43
	The Continuity of the Recreational Choice Set	48
3.	A TRAVEL COST MODEL WITH ENDOGENOUS DURABLE EQUIPMENT.....	53
	Introduction.....	53
	Modeling Durable Equipment	59
	Optimal Control Theory	63
	A Theoretical Travel Cost Model with Endogenous Durable Equipment.....	65
	The Model	67

	A Description of the Durable Equipment Bias	78
	Weak Complementarity, The Household Production Function, and How This Model is Different	80
	Using Expenditure Differences in Empirical Studies	85
	Empirical Testability	87
	Data Requirements	87
4.	AN EMPIRICAL ANALYSIS USING THE ENDOGENOUS DURABLE EQUIPMENT TRAVEL COST MODEL	90
	The Data Set	90
	Data Transformation and Creation of Variables	91
	Recreational Characteristics from this Sample	97
	Functional Form	100
	A Single-Equation Travel Cost Comparison Model	101
	The Endogenous Durable Equipment Simultaneous Equations Travel Cost Model	103
	Conclusion	108
5.	DISCUSSION AND SUGGESTIONS FOR FUTURE RESEARCH	110
	Travel Cost Models with Endogenous Durable Equipment	110
	Combining CV Data and Travel Cost Models	110
	The Time Path of Equipment Accumulation and Utilization	111
	Empirical Results	113
	Policy Implication	114
	Future Research	115
	The Hedonic Travel Cost Model with Congestion as the Equilibrating Mechanism	117
	Empirical Results	117
	Policy Implications	118
	Future Research	119
	Conclusion	120
	BIBLIOGRAPHY	122
	APPENDIX	136
	VITA	143

LIST OF TABLES

Table	PAGE
1. Signs of Partial Derivatives	46
2. A Comparison of First-Order Conditions	85
3. Description of Variables: Endogenous Durable Equipment Model	98
4. Descriptive Statistics: Endogenous Durable Equipment Model	99
5. Expected Relationships	104
6. Confidence Limits Comparison for Selected Parameter Estimates	106
7. A Comparison of Standard and Durable Equipment Model Estimates	109

LIST OF FIGURES

Figure	PAGE
1. Equilibrium Condition for WTP and Site Opportunity	49
2. Congestion's Affect Upon the Site Opportunity Function	50
3. Sparse Sets of Available Site Choices	52
4. Demand Relationship at Utility Maximization	79
5. Increased/Decreased Trips with Lagged Stock Adjustment	114

CHAPTER 1

INTRODUCTION

The travel cost model (TCM) is a frequently used technique for estimating the monetized benefits of recreational activities conducted in natural resource settings. The number of trips that individuals take to a given site are modeled as being influenced by travel costs, site amenity quality, and a set of socioeconomic variables which capture the effect of individual preference. Variations of the basic model may be used to evaluate single and multi-site systems in both static and comparative statics scenarios. The flexibility of the TCM and the simplicity of the data needed for an empirical study make it a ubiquitous methodology for evaluating environmental aspects of site quality, and within the environmental/natural resource valuation literature the TCM is, to some extent, a benchmark methodology against which other techniques are compared.

Using the travel cost model (TCM) to model recreational demand, it would seem reasonable to include those explanatory variables which are quantifiable and which add predictive power to the regression equations. But the

decision to take the trip is just one of many decisions the individual makes as he decides to engage in the recreational activity. To the extent that these other decisions affect the trip decision, they may be important explanatory variables, but their interconnectedness may lead to problems which hamper both theoretical and empirical examination and produce biased estimates of market value.

Endogenous right-hand side (RHS) variables complicate regression analysis, but there has been considerable research into econometric methods for handling endogenous explanatory variables. By imposing linear restrictions upon the coefficients and transforming the RHS variables, the covariance between the endogenous RHS variables and the error terms can be estimated. (Attfield 1991). Regressions containing endogenous RHS variables may produce asymptotically efficient parameter estimates if information contained in the residuals can be fed back into the system of equations (Newey 1987).

This work is not perfect. Krasker and Pratt (1987) show that the endogenous RHS variable, when used as a proxy for an unobservable explanatory variable, may in some instances

produce the incorrect sign and magnitude in a simultaneous equation.

The role of endogenous RHS variables has been considered a tangential issue in travel cost studies. Parsons (1991) examined the possibility that residential location was partially determined by recreational access, thus endogenizing travel costs and biasing consumer surplus estimates. Other issues such as endogenous on-site time are neatly handled by repackaging (Wilman 1987), where observations of multiday trips are converted into an equivalent number of single-day outings. In general, however, discussions of endogenous explanatory variables have consisted of reasons why specific variables are omitted from the analysis.

This dissertation presents two theoretical models for analyzing travel cost models involving two types of endogenous variable; site congestion and durable recreational equipment. An empirical study using the durable equipment model provides evidence of the potential benefits of this formulation. These models offer new ways to incorporate the information contained in endogenous variables in ways that improve travel cost demand estimates.

The importance of correctly incorporating endogenous RHS variables can be seen in the increased reliance upon benefit cost analysis in environmental damage and restoration case law. Compensation for natural resource damage due to releases or spills into the aquifer are spelled out in both the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the 1990 Oil Pollution Act (Mazzotta *et. al* 1994). In the former, the value of compensation was set to be the lesser of the costs of remediation or the reduction in use value. Analyzing the monetized benefits of reducing types of air pollution is also called for in the Clean Air Act (Hahn 1994).

These consumer surplus estimates based upon travel cost studies can be quite large. Beal (1995) used a travel cost methodology to estimate the consumer surplus from camping and day use activities at Carnarvon Gorge National Park, Australia, and estimated the value for 1993-94 trips to be \$40 million (Australian). For another example, consider the 1986 Amazon Venture oil spill off Savannah National Wildlife Refuge. The interim loss of hunting and fishing use value for this one affected wetlands was found using a travel cost model to be over \$689,000 (Mazzotta *et. al* 1994), and this value was found to be the lowest of three

estimates using different estimation techniques. In such cases where a travel cost model produces the chosen estimate, it is important that these results are based upon the best available information, regardless of whether the inputs are exogenous.

This dissertation continues with a discussion of the history of travel cost models, followed by the development of two theoretical models. The first model considers a noted incongruity of the hedonic travel cost model, the absence of an equilibrating mechanism that will adjust in response to a site amenity quality change. Without this adjustment mechanism, comparative statics scenarios cannot be estimated. In this model site congestion, which is endogenous, becomes the equilibrating mechanism. The second model describes how recreational durable equipment may be endogenous to the recreational trip decision and still incorporated into a travel cost framework. Following this theoretical model incorporating endogenous durable equipment, an empirical example is presented and discussed. This dissertation then ends with a summary of the conclusions from these two research topics and suggestions for future work in the area of endogenous RHS variables.

Travel Cost Models

The rest of this chapter outlines previous research on the travel cost model (TCM), with particular attention paid to those areas where right-hand side (RHS) endogenous variables are used and the theoretical and empirical problems that face the researcher.

Revealed Preference Models

The TCM is based upon the theory that individuals reveal their preferences by their consumption choices, and thus by analyzing actual consumer choices, the characteristics of demand can be estimated. In evaluating the recreational demand for a particular natural resource site, the TCM involves collecting data concerning the actual travel-related expenses facing each visitor, then estimating a demand function for all visitors by fitting the number of trips taken in a given time period to the estimated travel costs (Freeman 1993). This process differs from stated preference models, in which it is assumed that hypothetical questions posed to individuals will elicit preference choices that represent the choices that each person would make if actually confronted with the choice opportunity.

While much research has been conducted utilizing stated preference techniques, there is disagreement concerning it's ability to improve upon the estimates generated by revealed preference models. Balkan and Kahn (1988) state that "...one should be able to measure consumers' surplus by looking at actual decisions rather than hypothetical ones" (p. 533).

But neither revealed preference models in general nor the TCM in particular are perfect. Randall (1994) describes travel cost modeling as a compromise. While the researcher is interested in the true travel price, such prices are unobservable, or at least prohibitively expensive to observe. And as noted in Brown *et. al.* (1983), this true price is based upon the visitor's perceptions of costs facing them. If the individual underestimates, for example, vehicular wear-and-tear, his perceived travel price will be less than actual travel costs. Thus the TCM uses proxies for actual perceived travel prices, using such things as standard Internal Revenue Service mileage-based depreciation allowances. Englin and Shonkwiler (1995) develop a model which treat the full travel cost as an unobservable latent variable estimated via observable demand characteristics. This approach allows the authors

to directly estimate the dollar value of the various observable components of travel cost such as travel time.

Issues in Travel Cost Modeling

Once chosen as the appropriate empirical technique, several decisions remain. How should sample information be extrapolated to estimates for the general population? How does one model time spent traveling to and from the site? How important to the study are substitute sites and multiple-activity trips?

Endogenous Sample Stratification and Participation

A recreationist interviewed on the boat dock is an observation of actual behavior (at least for that particular trip). But it is unlikely that in any study every visitor will be observed and surveyed. The observations collected must be treated as a sample of the true visiting population. The act of conducting intercept site surveys bias a travel cost model (Shaw 1988), since recreationists who take a higher than average number of trips are likely to be disproportionately included in the sample. Endogenous sample stratification will produce biased and inconsistent OLS estimators, and necessitates such techniques as weighting observations in inverse

proportion to the number of trips taken. Smith (1988) suggests that such selection bias does not, in itself, have a large affect on estimation results, but depending upon the method used to correct for this bias, consumer surplus estimates may vary.

For an empirical study based upon data which represents only a sample of the underlying population, there must be some means of scaling the study's estimates up to a level representative of the entire population. If participation data is not included in a travel cost study, the estimated results may contain truncation biases due to underrepresentation of non participants (Wilman and Pauls 1987), but this bias may not greatly affect consumer surplus estimates and may be corrected by using a maximum-likelihood estimation with truncated error terms.

A separate model of participation may be used to augment the survey data (Kahn 1994). Several authors have attempted to build the participation decision into the TCM. Hansen and Hallam (1988) model the probability of participation, and number of trips given participation, as nested decisions. Whitehead (1992) folds the two-stage participation/use intensity model into a single-stage model where recreational value can be estimated solely from

participation decision, while Anderson (1993) used a dynamic optimization model to simultaneously determine the participation decision and use intensity.

Intercept surveys at the recreation site should be viewed as coming from a truncated distribution, since non users are never sampled (Heckman 1976, Smith 1988). Underrepresentation of the low-frequency site user is a recognized problem and the use of the Heckman correction has become a standard part of many empirical studies (Shaw 1988). If, via some ancillary process, relevant information about non users may be included, then a Tobit model may be used which incorporates both participation and site selection elements (Smith 1988).

Travel Time

In addition to the direct costs of traveling to and from the recreational site, the time spent in transit represents an additional opportunity cost. Cesario and Knetsch first suggested modeling travel and time costs by creating a composite multiplicative variable (1970), and later (1976) modified this to an additive composite variable. Citing transportation literature estimates of work commuting time, Cesario and Knetsch (1976) suggested that recreational travel time should be valued at a lower rate than the

transportation-related estimates of one-fourth to one-half of the wage rate. They hypothesized that workers would more likely value work commuting time at something closer to the wage rate, while individuals would not make the same valuation for leisure-related transportation times.

Cesario (1976) understood that failing to include the value of travel time could lead to underestimating the imputed demand curve, but noted that travel time and travel distance were highly correlated and thus hard to separate, and chose to value travel time at "... the amount one is willing to pay to save time spent traveling" (p. 34). Sorg and Loomis (1986) showed how the failure to include travel time costs negatively bias net benefit estimates, and stated the need for "... a time-corrected demand curve." (page 496). Wilman and Pauls (1987) suggest that the opportunity cost of time may greatly influence the estimated consumer surplus measurement.

Bockstael and Strand (1981) argued that the opportunity cost of time spent in recreation, measured as some fraction of the recreationist's market wage rate, was calculable from sample data. In their sport fishing example, this value was estimated at 61% of the hourly wage rate. McConnell and Strand (1981) estimated the value of travel

time as being a proportion of the individuals' wage rate, acknowledging that this process made their estimate, 60% of the hourly wage rate, sample dependent. However, in both of these articles, the authors admit that their approach cannot explain the opportunity cost relationship for individuals who have a fixed work schedule.

A related element is the possibility that, in addition to fixed work schedules, recreationists may have self- or externally-imposed recreational schedules. Smith *et. al.* (1983) discuss the possibility that recreationists must coordinate time-sensitive leisure activities with available leisure time. Hunting and fishing may have regulated seasons which must be coordinated with the free time of individuals working in jobs with inflexible schedules. Shaw (1992) shows that when an individual is constrained in scheduling available recreational time (a corner solution in the labor market), even a low wage earner (with an assumed low opportunity cost of time) can still have a high "value" for this time.

In a recent study, McKean, Johnson, and Walsh (1995) show that valuing time as a function of the opportunity cost of forgone wages depends upon the individual's ability to substitute work time for leisure on the margin. The

authors find that for trips of less than four hours, the opportunity cost of travel time is relatively constant. And Casey *et. al.* (1995) suggest that the opportunity cost of leisure time should be measured in the context of the individual's own valuation of the recreational activity rather than the wage rate.

Bockstael *et. al.* (1987) point out the difficulties in modeling travel time in the travel cost framework, stating that "... while time is formally an input into the production of the commodity, it may also serve as the unit of measure of the output." (page 293). Using travel distance as the data from which to create both the travel cost and travel time variables creates multicollinearity when time is included as a separate variable. The authors also assert that, due to the availability of part-time work, most individuals do not have a truly fixed work schedule, and that an individual's employment choice may be made in part to allow flexibility in work scheduling.

Other researchers question whether a trade-off exists between work and leisure. Bell and Leeworthy (1988) found that 98% of the Florida tourists sampled did not lose wages due to their vacation. But one can question whether their results, based upon Florida tourism, is applicable to the

recreational decision for a day trip to a local fishing spot.

A concurrent thread of discussion concerns whether on-site time should come under the same opportunity cost scrutiny as travel time (see Bockstael and Strand 1981, and McConnell 1992). Smith *et. al.* (1983) modeled on-site time as an endogenously-determined additional constraint in the model (see Endogenous Costs, later in this chapter). McConnell (1992) reinterprets the work of Smith *et. al.*, modeling wage income as the wage rate multiplied by work hours, where work hours may be increased or decreased due to changing time spent in recreation. McConnell does, however, state that in many instances explicitly modeling on-site time may do little to improve a model's statistical powers. Many researchers choose to sidestep this problem by limiting their model to explaining the behavior for recreational trips of a given length, and (Wilman 1987) shows that it is possible to repackaging recreational trips into a uniform trip-length metric.

The complexity of these findings befit the potential importance of choosing the correct hypothesis. Consider that Bockstael (1987) found that the demand elasticity with

respect to time was greater than similar measures for income and own prices.

Substitute Sites and Multi-Site Models

It is reasonable to assume that, for most types of recreation, the potential recreationist has a choice between various sites of differing suitability, whether this difference is due to distance or site amenity values. Failing to include the prices of substitute sites may lead to biased estimates of the included variables if the prices of substitute sites are correlated with any of the included variables (Caulkins, Bishop, and Bouwes 1985, Wilman and Pauls 1987). The direction of this bias will depend upon the effect of the omitted variables upon any of the included ones or upon the dependent variable.

Rosenthal (1987) presented research suggesting that the failure to model the prices of substitute sites will inflate per-capita consumer surplus estimates. Kling (1989) showed that the only instance when excluding substitute prices will not bias benefit estimates is the case where the omitted substitute prices are not correlated with included explanatory variables and price and quality changes only effect a single site. In this event the influence that omitted variables have on the dependent

variable is captured in the equation's constant. Smith (1993) shows Kling's analysis to be correct for the case of high correlation between site and substitute site prices.

Wilman and Perras (1989) show that omitting the prices of substitute or complementary recreational sites will also bias the estimated intercept of the demand function. Non zero cross prices between an omitted substitute site price and the included site price will create a negative bias upon the estimated intercept, and if the sites are complements, the intercept bias will be positive.

More recently, McKean and Revier (1990), replying to Caulkins, Bishop, and Bouwes, state that it is impossible to categorically declare that consumer surplus will be biased upward or downward based upon the failure to include data concerning a relevant alternative site. Biases likely occur, but their direction will depend upon the specifics of the study. Conversely, using the estimates from a multi-site model to analyze one of the individual sites may produce erroneous results (Loomis and Cooper 1990).

Others suggest that substitute sites need not be explicitly modeled in order to evaluate their impact. Smith (1993) suggests that the effects of substitute sites can be

included in a demand study for a single site by including one variable representing the total number of trips taken to all sites. Agnello and Han (1993) treat substitution effects in a varying parameters travel cost model by including a variable representing the number of alternative sites and another variable representing the average quality these sites. This representation produced lower consumer surplus estimates.

Multinomial Logit/Count Data Models

An interesting method for incorporating recreational participation, site selection (including substitutes), or both, into the travel cost framework is through the use of discrete choice models. Morey *et. al.* (1991) develop a repeated discrete choice random utility model which simultaneously estimates total trips and site selection and corrects for sample selection bias. In Feather *et. al.* (1995), the researchers model recreational participation and the decision of which site to visit -- given a set of possible destinations -- as a Random Utility Model (RUM) where the probability of an individual recreationist choosing to visit a site is modeled with a multinomial logit equation using the standard set of travel cost independent variables. It is assumed that, given the decision to participate, the decision of which site to

visit is independent for every site visit. A site amenity improvement increases the probability of visitation, which in turn increases the predicted probability of participation for all individuals.

Improvements in one site's amenities alters the matrix of destination probabilities which in turn changes expected prices and qualities. Interestingly, this model can predict an increase in total utility with decreased total visitation when a distant site's improvements leads users to substitute several short trips to local sites for fewer trips to the distant, higher quality site (page 219).

Hausman et. al (1995) use a combined discrete choice and count data model to estimate the number of recreational trips the individual takes and the allocation of trips across possible sites. These two processes are linked by a price index estimated in the trip allocation model which help predict the number of trips taken. The site selection process is modeled as a nested multinomial logit, where sites from a given region are grouped together and the individual first selects a group (region) then a specific site. This model, used to estimate recreation benefit losses from the Exxon Valdez oil spill, required panel data to correctly estimate participation.

In discrete choice random utility models, assumptions concerning the underlying distribution of the sample of sites determines the appropriate model (Morey, Rowe, and Watson 1993). Samples from a normal population suggest a Probit model; from an extreme value distribution, a logit model, and from a generalized extreme value distribution suggest a nested-logit model. The authors find evidence that the repeated nested-logit performs best in modeling Atlantic salmon fishing.

It would appear that all of these types of discrete choice models may exhibit the same endogeneity problems that appear in standard TCMs. For example, increases in recreational capital may change the effective amenity value of all sites. However, their ability to capture the difference in site amenity preferences for such cases as boat vs. shore fishing may reduce the magnitude of potential biases.

Multiple Destination and Multi-Activity Trips

A single recreational trip may include visits to several sites or engaging in multiple types of recreation at a single site. Haspel and Reed (1982) discussed the problems associated with joint costs in multiple destination trips, and suggested that for multiple-stop trips where the

visitation sites were sufficiently geographically dispersed, the average willingness to travel to each site may be approximated by dividing total trip distances and costs by the number of destinations. Mendelsohn et al. (1992) show that consumer surplus estimates assuming a single destination will underestimate the benefits when the trips are in fact multiple destination events, and suggest that the same problem exists for single destination trips where the individuals engage in multiple activities.

Endogenous Travel and On-Site Costs

Based upon the performance of some travel cost studies, one could question the importance of the travel cost variable at all. Phillips and Silberman (1985) find that visitation was price insensitive to travel costs, although these results could be statistical outliers. But poor performance of the central variable in a travel cost model may be do to a poor representation of actual costs.

While travel is a necessary input for a site visit, it frequently isn't the only cost. Recreationists may choose to incur out-of-pocket costs based upon personal preferences not captured in the TCM (Randall 1994). This becomes important since, as shown by Bell and Leeworthy (1988), recreationists may respond differently to travel

costs than to on-site expenses. Thus a TCM assuming equal on-site expenses will produce biased benefit estimates if recreationists respond differently to an increase in on-site costs than they do to an equivalent increase in travel costs.

Some on-site costs may be considered partially predetermined. For example, Smith *et. al.* (1983) extended the household production function (HHPF) to model on-site recreational time as an endogenous function. The authors modeled recreational on-site time as that which remains when work time is subtracted from total available time.

Ward (1984) proposed that out-of-pocket travel costs include two components representing exogenously- and endogenously-determined costs. Endogenous costs would include that component of travel and on-site spending that was above the minimum necessary level needed to engage in that form of recreation. These discretionary costs could be positively related to on-site time per trip and negatively related to the number of trips. He concludes that consumer surplus estimates will be biased if discretionary costs are significantly dependent upon the distances traveled by the recreationist. In Green's (1986) comment to the Ward article, he suggests that while

endogenous costs exist, they do not affect the slope of the estimated demand function. He states that, for all travel cost models, "...only exogenously imposed travel cost, not subject to 'choice' by the recreationist, are considered relevant to proxy the market value of an entry fee to access a recreational experience. As such, endogenous costs 'above the minimum necessary to recreate' ... are not appropriately assigned values for decision making, relative to a price taking recreationist" (p. 416).

Ward's (1986) reply was that Green made an error in a partial derivative that, if calculated correctly, would support Ward's conclusion. Ward also suggests that empirical tests be conducted to test if endogenous and exogenous travel costs are correlated: If discretionary costs increase with travel distances, then the estimated demand slope created excluding these items will be biased.

Later work suggests that this problem was larger than simply the failure to capture discretionary expenses. Parsons (1991) notes that prices associated with travel distances may be endogenous if recreationists consider the proximity of recreational sites in their housing location decision, and thus estimated prices will be correlated with the error terms (voting with their feet). Parsons suggests

that finding instruments which are correlated with recreational trip demand but independent of the housing location decision, such as using the distance from the individuals workplace to the recreational site instead of the distance from home to recreational site. McConnell (1992) suggests that the assumption of constant on-site trip costs endogenizes site quality attributes. Using charter boats as an example, if the price of these trips are based upon their quality, the assumption of constant on-site costs endogenizes the recreationist's charter boat quality choice.

The Choice of Dependent Variable: Number of Trips

In the TCM, observations are transformed into price-quantity pairs. But do the surveyed individuals decide upon each trip independently, or do they plan out their schedule of trips prior to the season? The difference has analytical implications. Assuming each trip is an independent decision eases modeling and data collection requirements, as detailed information about each trip isn't necessary. But Caulkins, Bishop and Bouwes (1986) find this assumption of independence implausible. In Bockstael and McConnell's 1983 household production function approach the authors model recreationists as planning the total quantity of recreation to undertake for the entire season

in a preseason recreational budgeting session. The number of trips to each site and the length of each trip is thus predetermined. As an alternative, Adamowicz, Jennings, and Coyne (1990) and Morey *et. al* (1991) use a discrete choice framework to model the recreational trip decision (number of trips) as the product of repeated binary choices of taking/not taking each trip.

Whether the number of trips decision is a result of a master plan or iterative decisions, if recreationists trade off between the number of visits to a site and the length of each visit, then the travel-cost derived demand function estimates can only be considered marginal value functions if the empirical data is transformed into visits of a uniform length (Wilman 1987).

Implicit in this line of discussion is that people do have a precise plan for the number of trips they intend to take. In fact, some imprecision may well be the norm. Consider that Dobbs (1993) finds evidence that survey respondents round their answers to the question of trip plans, and suggests that this rounding may introduce study-specific biases into the results.

The dependent variable "trips" can be considered continuous or discrete. Dobbs used simulation data to suggest that, while treating the discrete variable "number of trips" as a continuous variable does introduce biases, the direction of the bias may depend upon the study.

Entry and User Fees

Cesario and Knetsch (1976) explain the assumptions underlying an imputed demand schedule as "... the likely visitor response to the hypothetical imposition of incremental fees at the park gates." They further add that "... the corresponding changes in visit quantities are calculated as if the increase in park price is viewed no differently by the consumers than an increase in travel cost." (p. 99). Bowes and Loomis (1980) show that this first assumption holds if all potential visitors have information concerning this hypothetical entry fee prior to the visitation decision (i.e. visitors don't arrive at the gate, see the entry fee, then balk at entering the site).

Of course, entry and user fees to many natural resource areas do exist, in the form of park or boat ramp fees, and hunting or fishing licenses. Entry fees may be treated like other elements of travel cost for those recreationists that choose to pay the fee, but to the extent that this fee

reduces the participation of some who might otherwise have chosen to engage in the activity, the fee can influence demand (Bowes and Loomis 1980).

In a study which combined travel cost data and contingent valuation, Cameron (1992) posed a dichotomous choice question in the form of a hypothetical user fee, and used this information to supplement travel cost data.

Site Congestion

Congestion has often been used as an example in optimal resource taxes (Baumol and Oates 1975). In a number of articles starting with Wetzel (1977), various authors debated the biases inherent in ignoring the role of congestion in travel cost models. The standard TCM model produces a correct demand function at current visitation levels if one assumes that congestion is constant over the range of visits taken by the surveyed individuals, but even with this assumption the standard model may overestimate the estimated coefficient of the travel cost variable if the change in travel cost alters this static congestion level (Anderson 1980, Stevens and Allen 1980). Yet attempting to produce a congestion-corrected demand curve (Wetzel 1977) can lead to unreasonably high consumer surplus estimates (McConnell 1980), and the actual

direction of the bias in an aggregate demand estimation is a priori indeterminate (Smith 1981). Smith and McConnell were in agreement that congestion must be viewed in the context of its affect upon individual behavior, a concept which Smith and Karou (1987) extended into the hypothesis that if individuals chose a recreational site in part based upon site congestion, then each recreationist's decision is partially based upon his expectations of other recreationists decisions.

Congestion may impact the site visitation decision in several ways. First, sites may approach their physical carrying capacity (parking spaces, etc.) for visitors on a given day, making congestion a feature limiting site access (Cuddington, Johnson, and Knetsch 1981). However this physical limitation represents a physical upper-bound. A second way in which congestion affects visitation is the possibility that solitude may be an amenity sought by the recreationist. In their study of back country hiking and backpacking, Menz and Mullen (1981) found that recreationists were dissuaded from taking trips if they expected to meet even a few other hikers on the trails.

Congestion may also increase the time necessary to conduct the utility-producing activity. Cesario (1980) explains

congestion in terms of a 'units-per-time-period measure' of output. As the number of individuals competing for use of a finite area increases, per-user output decreases and each user would be willing to spend some amount of money in order to experience the same site with fewer other visitors present. Walsh, Miller, and Gilliam (1983) measured congestion as skiers per skiable acreage, and Greig (1983) in terms of long lift lines at a ski slope, both measures fitting into the Cesario concept of congestion.

Thus congestion may be treated as an implicit price if it is viewed in terms of the degree to which congestion increases (endogenizes) the time necessary to engage in a given recreational utility-producing activity (Deyak and Smith 1978) or as a separate demand equation detailing the relationship between trips and congestion (Shaw 1992).

"If a (congestion) measure is used that is endogenous to the visitor, the endogeneity should be a formal part of the attempt to estimate demand." (Shaw 1992 page 14).

Empirical results of attempting to measure the effects of congestion have been mixed. Shelby (1980) failed to find "consistent negative effects of higher densities." (p. 53). Brown and Mendelsohn (1983) found inconclusive evidence that congestion avoidance was important to the fishermen surveyed, with the congestion coefficient being positive

less than two-thirds of the time: However there was evidence that for higher income respondents, congestion avoidance was a normal good, finding that "(a) unit of scenery or lack of congestion ... are about equal to the difference between an average site and an excellent site." (page 430). Other researchers had better results. Walsh, Miller, and Gilliam (1983) found willingness-to-pay for increased skiing capacity positively correlated with household income, distance to the next closest ski area, and several other factors, and negatively correlated with skiing days and site quality.

Thus the researcher is faced with a decision. Either entertain the prospect that congestion influences the site visit decision in ways which may be endogenous to the model and affect static or comparative static estimates, or assume that "... either that congestion is not operating in this system to the extent that visitor flows are distorted or that congestion is operating and visitor flow patterns are affected in a manner which is somehow proportional to the undistorted flows." (Cesario and Knetsch 1976, page 101).

The problems associated with including congestion as a explanatory variable in the TCM include both site-specific

and system-wide components. Increased access to one amenity may directly reduce access to another amenity (McConnell 1990), which is interesting in the case where the one "amenity" is congestion. But congestion as a site phenomenon can be viewed in terms of the system of substitute sites. Increasing capacity at one site may lead to adjustments and new equilibriums at both that site and one or all substitute sites (Walsh, Miller, and Gilliam 1983).

The Need for a Consensus

In the last twenty years, there have been many articles published concerning the travel cost model. In 1975 researchers suggested that the search for new natural resource benefit estimation methodologies should be replaced with a focus upon empirical works using the current (travel cost) method (Gum and Martin, 1975). But the field of benefit estimation continued to expand and change, and with this change the TCM had become one of several possible methods. In their 1983 comparison of the travel cost, direct, and the hedonic price method for recreational benefit estimation, Adamowicz and Phillips (1983) state that, with the body of research covering various benefit estimation methodologies, a consensus was

needed on which methodology is most appropriate, and future research should focus upon refining the "best" technique. It has recently been argued that the travel cost method contains so many conceptual problems (e.g., endogenous costs, allocation of costs to specific trips, functional form influencing welfare estimates) that its main use should be as one of multiple methodologies brought to bear upon a single problem (Randall, 1994).

In 1997, the travel cost model is a benchmark by which the performance of other benefit estimation methodologies can be compared. Thanks to continued research, the strengths and limitations of travel cost models have been more fully documented than for any competing benefit estimation methodology. And one must only scan such bibliographies as the National Technology Information System to see that travel cost models continue to be used to evaluate natural resource and environmental policy issues conducted on behalf of various government agencies. This continuing research and use is strong evidence of the viability of the travel cost method as a valuable thread in contemporary natural resource benefit estimation research.

CHAPTER 2

SITE CONGESTION AS THE EQUILIBRATING MECHANISM IN HEDONIC TRAVEL COST MODELS

One area in which a right-hand side endogenous variable may improve travel cost modeling is the use of site congestion as an equilibrating mechanism in hedonic travel cost models. In this chapter a theoretical model is developed which describes how the disamenity of site congestion may be used to overcome one of the noted shortcomings of hedonic travel cost models.

Hedonic Travel Cost Models

Rosen (1974) first developed the hedonic model, modeling market equilibrium as a system of resolved supply and demand conditions for all utility-producing characteristics. Since all goods may have various quantities of multiple characteristics and must be purchased in whole units of the good, Rosen shows that marginal costs are endogenous. Characteristics are purchased in inseparable bundles and market equilibrium does not imply constant marginal costs across characteristics.

The hedonic travel cost model (HTCM) was developed by Brown and Mendelsohn (1983). In this model the choice of which site to visit signifies a purchase (at the imputed price of travel) of a bundle of site amenity characteristics. Examining the behavior of a number of individuals traveling to a number of sites offering different levels of these characteristics, Brown and Mendelsohn show that these travel costs and visitation rates can be used to estimate marginal costs for each characteristic.

Englin and Mendelsohn (1991) developed a theoretical hedonic travel cost model based upon the premise "that each individual has a conditional utility function given that she has decided to take a trip" (p. 276). The authors note that this produces biased welfare measurements, but assert that these biases will be small if "... the change in site quality is a small fraction of the value of a trip or that the number of trips taken is insensitive to quality changes" (p. 278).

The Two Stages Of The HTCM

The HTCM can be viewed as a two-stage process. In the first stage, the travel cost for the representative individual from each origin is modeled as the cost of acquiring the bundle of site characteristics at the site

visited (Freeman 1993). In Freeman's terminology (1993, page 473), the individual's goal is to maximize utility by taking (x) trips to the various (j) sites from origin (i), given a standard budget constraint. Each site offers quality level c_j .

$$\text{Max } u(x_i, c_j, y)$$

$$\text{Subject to } W = y + \sum_{j=1}^m x_j \cdot TC(c_j)$$

Where (y) is the quantity of the numeraire good. A first-order condition of this maximization gives us the marginal implicit price of each of the (k) characteristics:

$$\frac{\partial u}{\partial x_k} = x_j \cdot \frac{\partial TC}{\partial c_k}$$

From these marginal implicit prices, marginal implicit willingness-to-pay (WTP) estimates for each characteristic can be calculated via a second stage regression. These marginal implicit prices are regressed against the characteristics available at each site and other demand shifters.

Specification and Identification Issues

In order to successfully estimate the marginal implicit WTP, several model specification and identification issues must be understood. First, these estimates are based upon first stage results, thus they may be very close to the coefficients of the first-stage hedonic function. Also, unlike a standard market model, individuals choose both a price and quantity. This makes it difficult to identify which independent variables are important to the choice of the price/quantity point on the demand curve and which are more generic demand shifters (Freeman 1993, p. 389). This problem may be compounded if these demand shifters include personal preferences correlated with the visitor's home location (which determines travel distance), since in this case the demand equation for site characteristics will be biased (Englin and Mendelsohn 1991).

Epple (1987) discusses the restrictions which must be imposed upon hedonic models in order to assume that an equilibrium condition exists. There is the potential for estimation biases if unmeasured characteristics are correlated to measured characteristics, and one must assume orthogonality and that unobserved characteristics are truly unimportant in order to have a properly defined error term.

Bartik (1987) states that there isn't an identification problem with the standard model. Rather, the problem is that unobservable preferences are captured in the disturbance term of the marginal bid estimate, which leads to biased bid estimates. This cannot be corrected by Freeman's (1979) assumptions of fixed availability of characteristics or unlimited availability of a static characteristic price. Thus ordinary least squares and two-stage least squares estimates remain biased. Alternately, assuming a perfectly elastic supply of amenities will make such amenities exogenous in the hedonic model, but this assumption can lead to an overestimation of the marginal willingness-to-pay estimates (Adamowicz and Phillips 1983).

In Bartik's view, households face both endogenous hedonic prices and endogenous quantities, a combination which produces nonlinear budget constraints. Bartik proposes the use of instrumental variables which are correlated with characteristics but not personal preferences.

Given the degree to which hedonic price models may be prone to specification biases, Epple (1987) states that care must be given to developing "a relatively exhaustive set of product, demander, and supplier characteristics" (p. 78).

Functional form is also important. The implicit price of characteristics must be based upon a nonlinear expenditure function, since a linear function implies linear characteristic prices and such constant prices make it impossible to derive a demand curve for characteristics (Adamowicz and Phillips 1983).

One empirical problem with the HTCM is that studies frequently find that certain site characteristics exhibit negative marginal prices. Mendelsohn (1987) gives four reasons for these findings. First, the characteristic may indeed have a negative marginal price, thus individuals would be willing to travel further to avoid this characteristic. Englin and Mendelsohn (1991) suggest that a negative marginal willingness-to-pay may represent over-satiation of a particular amenity for which the visitor still holds a positive total willingness-to-pay. Second, users may be satisfied with the levels of the amenity that they are currently consuming and are willing to pay the (travel) price for variety (Mendelsohn 1987). A third possibility is measurement error which produces negative estimates of an amenity for which individuals have little or no value. And fourth, negative prices may be a symptom that the hedonic model is misspecified. Kahn (1994) shows that negative marginal prices may be found when subjects

choose to travel further (pay more) to visit a site with inferior characteristics due to a failure to track an important site characteristic. And Smith *et. al* (1991) model the recreationist's site decision process using a frontier equation. Higher travel prices bring greater utility through higher levels of some site characteristic, and irrational site choices (traveling further for less) are excluded.

Site Congestion as an Equilibrating Mechanism

One problem with the HTCM is the inability of hedonic prices to adjust given changes in site characteristics. Travel distance does not change given an improvement in one aspect of site quality. This fact would appear to limit the applicability of HTCM studies to static analysis.

However, the behavioral underpinnings of the HTCM offer another possibility for implicit price equilibration. Since a site's quality is modeled as the sum of its characteristics, a site characteristic with negative marginal utility, positively correlated with visitation rates, may serve as the equilibrating mechanism. With increased trips, larger quantities of the negative amenity will reduce marginal utility. One such amenity with these properties is site congestion.

It is possible that congestion, not price, is the equilibrating mechanism which explains why inferior or equal sites are visited despite higher travel costs. Given equal travel costs, sites with greater levels of the amenity characteristics will be the chosen destination, with congestion increasing with visitation. The increasing cost of increasing congestion levels will lead some potential visitors to choose travel further to visit inferior but less congested sites¹. Thus the marginal trade-off between exogenous site quality and costs -- both travel and site congestion -- may be the preferable model to use within the HTCM.

The theoretical model presented below incorporates congestion into the marginal implicit price equations generated in an HTCM, showing that the very endogeneity issues that have made congestion a difficult concept to model in the standard travel cost framework are useful and possibly necessary in order to expand the use of hedonic travel cost models.

¹Individuals choosing to travel to a closer, inferior site will not produce a negative marginal implicit price estimate.

Modeling Congestion Costs in the Hedonic Travel Cost Model Framework

In this section, the first stage of a standard hedonic travel cost model is developed, then expanded to explicitly include a site congestion function. By contrasting this expanded model with the standard, the potential role of congestion as an equilibrating mechanism is shown.

A Standard Hedonic Travel Cost Model

Consider the following model of a representative recreationist choosing among various recreational sites for his next recreational trip. In equation (1), utility (u) is a function of a vector of other goods and services (Y), site characteristics of a given recreational site (c_1 through c_n), and income (M). The recreationist attempts to maximize utility given his income, trip prices (P_X), and a normalized price vector for the other goods and services (P_Y), as shown in equation (2).

$$u = u(Y, c_1, c_2, \dots, c_n, M) \quad (1.)$$

$$M = Y \cdot P_Y + P_X \quad (2.)$$

From the direct utility function we can formulate an indirect utility function $V(\bullet)$ which is determined by input

prices and site characteristics. Assuming that the choice set of recreational sites offers a variety of levels of each amenity (a strong assumption which is covered in detail later), indirect utility may be assumed to be constant at V^* .

$$V^* = V(P_Y, c_1, \dots, c_n, P_X, M) \quad (3.)$$

By totally differentiating $V^*(\bullet)$ and holding the other variables fixed, we can examine the effect of a marginal improvement in site characteristic c_1 .

$$\text{If } dV^* = dP_Y = dc_i = 0 \text{ for all } i \neq 1, \text{ then} \quad (4.)$$

$$0 = \frac{\partial V}{\partial c_1} dc_1 + \frac{\partial V}{\partial P_X} \frac{dP_X}{dc_1} dc_1 \quad (5.)$$

Dividing this equation through by dc_1 :

$$0 = \frac{\partial V}{\partial c_1} + \frac{\partial V}{\partial P_X} \frac{dP_X}{dc_1} \quad (6.)$$

This equation can be rearranged to show that, at equilibrium, the marginal implicit willingness-to-pay for

an increase in a characteristic $\left(\frac{\partial V}{\partial \hat{a}_1} \right)$, which consists of the ratio of the marginal change in indirect utility $\left(\frac{\partial V}{\partial \hat{a}_1} \right)$ to the marginal change in indirect utility due to the increase in travel price $\left(\frac{\partial V}{\partial p_x} \right)$, is equal to the marginal change in travel costs due to this amenity improvement $\left(\frac{dp_x}{dc_1} \right)$. Since $\frac{\partial V}{\partial p_x} = \frac{\partial V}{\partial M}$ (if $dp_y = 0$), then $\left(\frac{\partial V}{\partial \hat{a}_1} \right)$ can be interpreted as the marginal willingness to pay for the characteristic. This equation would then imply that the marginal price of the characteristic $\left(\frac{\partial p_x}{\partial \hat{a}_1} \right)$ is equal to the marginal willingness to pay for the characteristic:

$$\frac{dp_x}{dc_1} = \left(\frac{\frac{\partial V}{\partial \hat{a}_1}}{-\frac{\partial V}{\partial p_x}} \right) \quad (7.)$$

This price is in money terms, since from equation (2.) it can be shown that in order to stay on a particular indifference curve, the change in indirect utility from a marginal change in travel price must equal the negative of

the marginal change in indirect utility from an equivalent change in income $\left(\frac{\partial V}{\partial P_x} = -\frac{\partial V}{\partial Y}\right)$.

A Hedonic Travel Cost Model With Endogenous Congestion Costs

Now consider the following model, which expands upon the previous model by explicitly modeling site congestion ($N(\bullet)$). Site congestion is exogenous to the individual but determined by the same site characteristics as those which are important to the individual.

$$u = u(Y, c_1, c_2, \dots, c_n, N(c_1, c_2, \dots, c_n), M) \quad (8.)$$

The recreationist attempts to maximize utility given an identical budget constraint as in equation (2).

$$M = Y * P_Y + P_x \quad (9.)$$

The indirect utility formulation of the problem now becomes:

$$V^* = V(P_Y, c_1, \dots, c_n, N(c_1, \dots, c_n), P_x, M) \quad (10.)$$

Totally differentiating $V^*(\bullet)$ and holding the other variables fixed (equations (11.) and (12.)), the effect of a marginal improvement in c_1 can be calculated.

$$\text{If } dV^* = dP_Y = dc_i = 0 \text{ for all } i \neq 1, \text{ then} \quad (11.)$$

$$0 = \frac{\partial V}{\partial c_1} dc_1 + \frac{\partial V}{\partial N} \frac{\partial N}{\partial c_1} dc_1 + \frac{\partial V}{\partial P_x} \frac{dP_x}{dc_1} dc_1 \quad (12.)$$

In equation (12.), a change in characteristic c_1 directly affects indirect utility through $\left(\frac{\partial V}{\partial c_1} dc_1 \right)$ and indirectly affects indirect utility through congestion $\left(\frac{\partial V}{\partial N} \frac{\partial N}{\partial c_1} dc_1 \right)$ as well as through prices $\left(\frac{\partial V}{\partial P_x} \frac{dP_x}{dc_1} dc_1 \right)$.

Dividing equation (12.) by dc_1 and rearranging the terms, the relative influences of price and congestion changes can be seen (equation (14.)).

$$0 = \frac{\partial V}{\partial c_1} + \frac{\partial V}{\partial N} \frac{\partial N}{\partial c_1} + \frac{\partial V}{\partial P_x} \frac{dP_x}{dc_1} \quad (13.)$$

$$\frac{\partial V}{\partial c_1} = - \left(\frac{\partial V}{\partial N} \frac{\partial N}{\partial c_1} + \frac{\partial V}{\partial P_x} \frac{dP_x}{dc_1} \right) \quad (14.)$$

A marginal change in indirect utility is the sum of two influences; the change due to marginally-increased site congestion $\left(\frac{\partial V}{\partial N} \frac{\partial N}{\partial c_1} \right)$, and the change due to the increase in

marginal characteristic price $\left(\frac{\partial V}{\partial P_x} \frac{dP_x}{dc_1} \right)$. The marginal

willingness-to-pay for an increase in characteristic c_1 can be found by dividing equation (14.) by $\frac{\partial V}{\partial P_x}$.

$$\frac{\frac{\partial V}{\partial c_1}}{\frac{\partial V}{\partial P_x}} = \left(\frac{\frac{\partial V}{\partial N} \frac{\partial N}{\partial c_1}}{-\frac{\partial V}{\partial P_x}} + \frac{dP_x}{dc_1} \right) \quad (15.)$$

The term $\frac{\frac{\partial V}{\partial N} \frac{\partial N}{\partial c_1}}{-\frac{\partial V}{\partial P_x}}$ is the marginal willingness to pay for congestion.

The role of site congestion can be seen by comparing equation (15.) with the standard model (equation (7.)). Given the assumed signs of the partial derivatives (see Table 1.), the standard model will always overestimate the marginal willingness-to-pay for marginal increases in utility-producing amenities by the amount of the marginal

Table 1. Signs of Partial Derivatives.

Partial Derivative	Description
$\frac{\partial N}{\partial c_1} > 0$	Indirect utility is increasing in characteristics.
$\frac{\partial N}{\partial p_x} < 0$	Indirect utility is decreasing in prices.
$\frac{\partial N}{\partial N} < 0$	Indirect utility is decreasing in congestion.
$\frac{\partial N}{\partial c_1} > 0$	Congestion increases with greater quantities of the amenity.
$\frac{\partial N}{\partial p_x} < 0$	Congestion experienced decreases with higher trip prices.

willingness to pay for congestion due to the amenity improvement.

These theoretical results show that in empirical studies, the marginal cost of each characteristic $\left(\frac{dp_x}{dc_i}\right)$ should be adjusted to incorporate the marginal willingness to pay for site congestion. Failing to do so will produce lower second-stage estimates of site-specific characteristic values.

In terms of modeling congestion-corrected demand for a recreational site, to the recreationist the set of potential recreational site choices (the site opportunity function) is determined by their characteristics, resultant prices, and the prices of other goods and services. In equation (16.), each of the "i" possible sites are available at price P_{xi} , and offer amenities c_{i1} through c_{in} and congestion level N .

$$P_{xi} = P_{xi}(c_{i1}, c_{i2}, \dots, c_{in}, N(c_{i1}, c_{i2}, \dots, c_{in}, P_{xi})) \quad (16.)$$

One can find the marginal implicit price of each characteristic at each site using total differentiation.

$$dP_{xi}^* = dc_{in} = 0 \text{ for } n \neq 1$$

$$0 = \frac{dP_{xi}}{dc_{i1}} dc_{i1} + \frac{\partial P_{xi}}{\partial N} \frac{\partial N}{\partial c_{i1}} dc_{i1} + \frac{\partial P_{xi}}{\partial N} \frac{\partial N}{\partial P_{xi}} dP_{xi} \quad (17.)$$

Dividing equation (17.) through by dc_{i1} :

$$0 = \frac{dP_{xi}}{dc_{i1}} + \frac{\partial P_{xi}}{\partial N} \frac{\partial N}{\partial c_{i1}} + \frac{\partial P_{xi}}{\partial N} \frac{\partial N}{\partial P_{xi}} \frac{dP_{xi}}{dc_{i1}} \quad (18.)$$

Rearranging the terms of equation (18.), the marginal implicit price of characteristic 1 at site i becomes:

$$\frac{dP_{xi}}{dc_{i1}} = \frac{\frac{\partial P_{xi}}{\partial N} \frac{\partial N}{\partial \hat{c}_{i1}}}{\left(1 - \frac{\partial P_{xi}}{\partial N} \frac{\partial N}{\partial P_{xi}}\right)} \quad (19.)$$

As shown in Figure 1, by tracing the points of tangency of

congestion-corrected marginal WTP $\frac{dP_x^*}{dc_i} = \left(\frac{\frac{\partial N}{\partial \hat{c}_i} \frac{\partial N}{\partial \hat{c}_1}}{\frac{\partial N}{\partial P_x}} + \frac{dP_x}{dc_i} \right)$ to

marginal implicit characteristic prices $\frac{\partial P_{xi}}{\partial \hat{c}_i}$ for every

level of the characteristic, one can find the market demand function for each characteristic. Empirically, by assuming that each recreationist is rational and can choose from a rich set of recreational choices, marginal willingness-to-pay would be inferred by estimation based upon actual travel choices. $\frac{dP_x^*}{dc_i}$ would be determined by each

recreationist's travel cost and congestion experienced.

The Continuity of the Recreational Choice Set

Like the Clark and Kahn (1989) study, this theoretical model is based upon the assumption that the set of available sites offers a continuum of each characteristic. If the sites whose marginal implicit characteristic prices trace out this site opportunity function are independent of personal preferences (characteristics are rated or graded

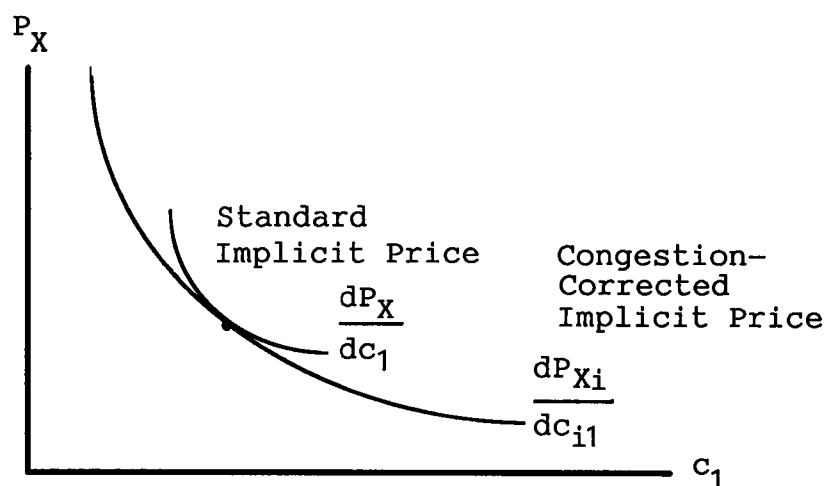


Figure 1
Equilibrium Condition for WTP and Site Opportunity

using a preference-neutral metric), recreationists' preferences are represented by visitations to different sites, while all visitors to a given site hold identical preferences.

The role of congestion can be seen by examining a hypothetical improvement in an amenity value at one of the sites which make up the site opportunity function. An example of this process is shown in Figure 2.

Given that amenity R at site i improves, this site will become the tangency point for the willingness-to-pay function. Many recreationists will deem this the site

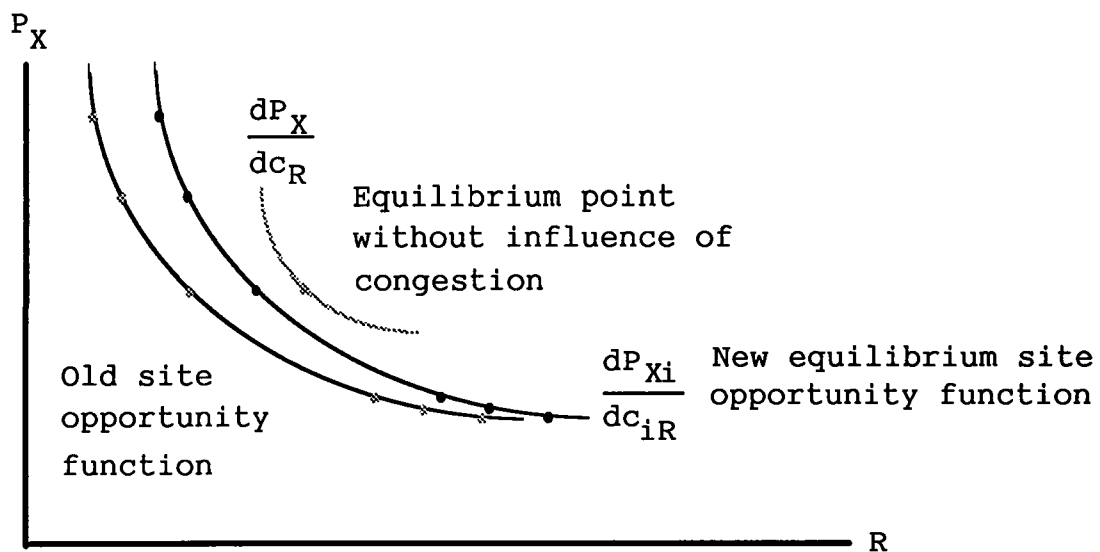


Figure 2

Congestion's Affect Upon the Site Opportunity Function

offering the highest utility. Shifting visits to this site will reduce congestion at other sites, offering higher relative amenity values at the same travel prices for those remaining visitors. This shifts the rest of the site opportunity function.

But this increase in visitors to site i will reduce the increased utility available from amenity R and shift this point to the left. A new equilibrium site opportunity function for amenity R would thus be strictly greater than the initial level for all sites, but lower than the point representing site i if congestion were not a hindering factor.

If the visitor makes his choice from a limited set of available sites, the site opportunity function traced out by these choices will not be continuous. In such cases all individuals will not be able to choose a site which is represented by an equilibrium point.

This complication has two implications. First, similarly to Clark and Kahn (1989), the site opportunity function will not accurately reflect marginal willingness-to-pay for the characteristics, since empirically one will see observations of visits to sites which are inferred to represent tangencies.

Second, given a sparse set of potential sites, an amenity improvement to one site could be evaluated as a negative willingness-to-pay for the characteristic if this improvement shifts individuals too far from their desired equilibrium levels. In Figure 3, the site opportunity function is characterized from three available sites (1,2,3). If a hypothetical site P^* existed, this would be the point of equilibrium between marginal implicit characteristic price and equilibrium willingness-to-pay. However, since this site does not exist, individuals pick site 2 as being closest to their ideal choice and arc A would be the inferred equilibrium willingness-to-pay.

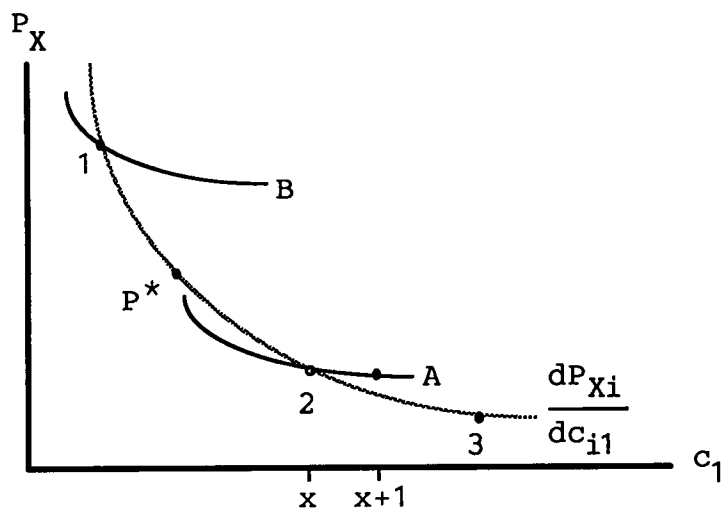


Figure 3

Sparse Sets of Available Site Choices

If the amenity level of site 2 were to increase sufficiently, individuals would find that site 1 now offered the closest to ideal level of the amenity, and arc B would become the inferred willingness-to-pay.

This scenario shows another problem associated with an incomplete set of potential sites; the often-seen empirical result of negative marginal prices for characteristics. Given these problems associated with empirical estimation from a system of a small number of potential sites, this model will work best in situations where the available sites offer both a wide range of the targeted amenities and that discontinuities are sufficiently narrow.

CHAPTER 3

A TRAVEL COST MODEL WITH ENDOGENOUS DURABLE RECREATIONAL EQUIPMENT

In this chapter, it will be shown that the failure to incorporate the provisioning of durable recreational equipment in a travel cost model may lead to underestimates of monetized benefit estimates. With quantity of equipment held endogenous to the trip decision, optimal control theory can be used to understand the influences of the equipment decision upon the equilibrium conditions.

Introduction

Many types of recreation involve the use of durable recreational equipment. Recreational boating and fishing are examples frequently seen in the travel cost literature. However, the ways in which equipment is modeled vary widely. Bockstael and Strand (1981) interpreted boat length as a wealth proxy or a sign of commitment to sport fishing. McConnell and Strand (1981) utilized data on boat length in their participation estimation process, stating that it "represents a previous commitment to sport fishing or a wealth proxy" (p154). Bell and Leeworthy (1987) and Smith (1988) used binary (dummy) variables to

model boat ownership decisions. In the study by Bell and Leeworthy, the demand for marinas was modeled as partially determined by the characteristics of the boat (acknowledging that the socioeconomic characteristics that influence the type of boat purchased may not be the same as the characteristics that determine the demand for a slot at a marina). Boat lengths of less than or greater than 25 feet were used as binary variables in the analysis, perhaps because this cut-off represented different types of mooring requirements.

Including durable equipment as more than a dummy variable in a travel cost model may lead to several potential problems. First, such costs may be endogenous and highly discretionary (Randall, 1994). Trips and equipment may be inputs in a joint production function. A rowboat may get the user to exactly the same fishing hole as the expensive bass boat, but the decision of which boat to purchase may depend upon individual preferences. However, Larson (1993) states that while individuals may employ different quantities of recreational equipment in their activity, this decision can be considered exogenous when modeling a season's or year's worth of recreational trips, an assumption which allows equipment levels to influence trip

demand estimation without the problems associated with endogenous RHS variables. Second, this equipment may have more than a recreational use, and thus the quantity of equipment utilized in the recreational activity may be, in part, due to non recreational demand for the equipment. But even if recreational use is ancillary to the decision to possess a given amount of equipment, it may still influence the recreation decision. Caswell and McConnell (1980) found evidence that individuals more frequently engage in certain forms of recreation given that the individual participates in related forms of recreation. Thus one may own the boat in order to water ski, but by possessing the boat, the individual would be more likely to boat fish.

Third, allocating the costs of this equipment to recreational trips may be arbitrary (Randall, 1994). Cameron (1992) notes that it is problematic to assign capital equipment costs into a per-trip charge. Anderson (1993) shows that there could be negative net benefits with high fixed costs when few trips are taken. Hof *et. al.* (1985) shows that there can be no unique allocation of costs for the various outputs when these outputs are produced jointly. But others have applied economic reasoning to the problem. Kahn and Buerger (1994)

considered boat maintenance costs and an interest-rate-based opportunity cost of the market value of the boat as valid components of trip costs.

Fourth, equipment owners may not be aware of how much the equipment actually costs to own and operate. Ward and Loomis (1986) point out that recreationists base their behavior upon perceived costs, and may not fully recognize the costs of equipment wear and tear. But Milon (1988) found that, in a study of Florida boat owners, the costs of boats with more powerful engines is a deterrent to offshore recreational fishing, which suggests that the normal properties of demand analysis may still apply.

Fifth, recreational equipment may influence the quality of the recreational experience. McConnell (1979) used a HHPF to model recreational fishing with endogenous catch rates. Fishing equipment was included among the variables influencing catch rates. His approach assumed that catch rates could be improved by employing more equipment, although his interpretation of equipment was limited to the assumption that higher equipment levels necessitated higher per-trip costs. His empirical study found that the number of rods and reels owned (his proxy for equipment) was highly significant in predicting catch rates. McDonald

et. al (1992) modeled endogenous fishing effort. Karpoff (1985) views time and equipment as inputs which produce the intermediate output of fishing effort, and increased effort leads to higher catch rates. If Ward's (1984) implications of endogenous trip costs pertain to larger capital equipment holdings, greater travel distances could influence the individual to choose to take fewer trips but of longer length and/or use more recreational equipment with each trip in order to maximize total recreational utility.

Ward and Loomis (1986) argue that, in many cases, the quality enhancing attributes of recreational equipment may be ignored, since "... (h)aving a better kayak does not improve the river for rafting." (page 167)². But this cannot be a blanket statement. Equipment such as skis can improve the perception of the quality of the ski slope if one's perception is based upon how the slope feels when skiing upon it. Available equipment may also expand the number of available potential recreational sites. In other cases, recreationists can improve their chances of success in hunting or fishing by employing larger quantities of equipment (Karpoff 1985). This concept suggests two

²Which ignores the question of whether the quality of the kayak influences the decision of which passages to attempt.

mechanisms by which equipment quantity may enhance recreational utility: When a harvest variable is used in the utility construct, and when the physical size or quality of the equipment limits or expands the choice set of potential sites.

Most recently, Randall (1994) summarized many of the failures of the TCM to capture the realities of durable equipment usage. He states: "Recreationists vary considerably in their investment in durable equipment useful in travel and recreation. Such equipment may be more or less expensive, and more or less specialized. Allocation of the costs of owning and maintaining vehicles and other durable equipment to any particular trip proceeds, if at all, in arbitrary fashion." (page 90). However other studies suggest that the magnitude of moneys spent on recreational equipment may be significant. In their empirical example, Bockstael *et. al.* (1987) analyzed data collected from recreational fishermen who were also boat owners. While their analysis was focused upon modeling time, their research question pertained to the elimination of the fishing resource. Their estimation showed compensating variations of between \$2,700 and \$4,200 for per-user net benefits, figures which they felt were reasonable considering that the data subjects reported

spending on average \$4,800 for fixed boating costs. More recently, Offenbach and Goodwin (1994) found that the dollar value of the hunting equipment used by Kansas hunters was positively correlated with the demand for hunting trips.

Modeling Durable Equipment

Assuming that some travel cost studies can be improved by incorporating information concerning durable goods, a review of the durable good literature is useful. A durable good is a type of capital good that is used to produce something of economic value. The stock held partially determines productive service flows. Hall (1968) modeled the flow of services provided by a stock of capital as being the product of three separable factors representing the degree of physical deterioration, the quantity of embodied technology, and an index representing the overall technological level of the environment in which the capital will be used. For example, the flow of housing services provided by central air conditioning is quite limited if the surrounding area doesn't offer electricity. This decomposition allowed Hall to examine how time affected the flow of capital services.

Graham-Tomasi *et. al.* (1986) discussed the implications of Keynes's theory of precautionary demand as it pertained to natural resource assets. Though recreational equipment isn't a natural resource, the concept of insurance for an uncertain future is the same. Equipment ownership insures that it will be available for the desired trip.

The desire to acquire and maintain a given stock of durable equipment may involve a series of investments. Juster and Wachtel (1972) model the investment process as being guided by both the long-run goal of a desired stock holdings, based upon long-run expectations, and short-run adjustments to this goal based upon unanticipated events which do not change long-term plans but which may alter the trajectory to the desired end. Markusen (1979) showed that the demand for a stock of an asset is determined by current prices and expectations of the future (e.g. interest rates) and that the demand for asset flows are determined, in part, by the stock held and thus by past activities.

Ingram and Oron (1977) modeled housing capital as consisting of a combination of non depreciating and depreciating components. Structural housing elements were modeled as having an infinite life span while other elements (termed quality capital) had a finite life span,

but could be replaced. Thus with necessary capital augmentation, the capital stock of a given quality could be perpetuated indefinitely.

Margolis (1981) created a housing model to show that there are conditions under which a landlord who, via maintenance expenditures, is capable of maintaining a house in a "new" condition will nevertheless allow the structure to deteriorate. In his interpretation of Hall's (1968) work on capital services, Margolis lumped together the influences of physical deterioration and technological obsolescence, stating that "(t)he two are probably inseparable empirically" and "... it is of little economic importance whether, for example, the heater is inefficient because it is broken or because its fuel is relatively expensive." (page 92). Interpreting these conditions for the case of durable recreational equipment, it would appear that it is important to capture the current value of the capital equipment, since a rational owner may choose to allow some level of deterioration (and depreciation). Also, while technological advances and non use deterioration may reduce the value of a given piece of equipment, these influences may be combined into a single variable if the equipment quantity variable is modeled in monetary units.

While recreational durable equipment appears to be significantly different than housing capital, the economic questions relating to the vintaging (loss of productive capacity with age) of housing stock offers interesting insights into the sticky questions of technological obsolescence and the demand for product "newness". Margolis cites Ratcliff (1949) as the first to observe that the age of the structure negatively affects the value of housing capital. Lowry (1960) hypothesized that the quality of a house can be perpetuated given sufficient attention to maintenance, yet the market price of the house may nevertheless fall if market demand places a premium upon a house's age independent of quality. Margolis explored maintenance decisions in a dynamic optimization framework problem where marginal maintenance costs remained constant or increased. With increasing marginal maintenance costs one can expect the owner to allow more net deterioration of the durable over time. Similarly, in modeling recreational equipment, the degree to which an individual allows his equipment to deteriorate below its original value will be partially determined by the slope and rate-of-change of marginal maintenance costs.

Optimal Control Theory

One method of modeling durable equipment is optimal control theory. Dorfman (1969) states that "optimal control theory is formally identical with capital theory, and that its main insights can be attained by strictly economic reasoning" (page 817). Optimal control models can focus upon the optimal quantity of a variable over time where the value of this variable is determined or influenced by equations representing physical limitations to the process (see Chaing 1992, Ch. 7). For example, optimal control models permit the evaluation of both investment and consumption paths to determine the combination of investment and consumption that maximizes profit or utility streams and identify those paths which are not sustainable. Here profits would be considered the variable being maximized given the constraints of investment and consumption, which control realized profits. Combinations of consumption and investment which cannot be supported given the limits of costs and revenue streams, or which drive the company into bankruptcy, are not sustainable.

Optimal control problems may be modeled assuming discrete or continuous time. The applicability of each type may depend upon the behavior being modeled and the desired results (see Dixit 1991). In dynamic optimization

problems using discrete-time control equations, the Euler equation is the critical control (Judd 1991). At each optimal point along the time path, the marginal value of current period consumption must equal the present value of future consumption from funds invested for this purpose.

Full solutions to an optimal control problem may be difficult. However, a full solution is not always necessary in order to provide interesting insights into the underlying behavior. An understanding of the steady state conditions may suggest the direction in which the non stationary processes are heading (Burt and Cummings, 1977, and Knapp, 1983). Emmett *et. al.* (1971) examined two possible steady state equilibria associated with their optimal control model of pollution. By limiting their examination to equilibria conditions, they could reduce the complexity of the problem. Anderson (1993) used optimality conditions to compare the equilibrium use levels for an open access fishery given different assumptions of participation. In their modeling of the optimal pricing policies for landfills, Ready and Ready (1995) examine microeconomic theory-relevant optimality conditions of their optimal control model while acknowledging that they were unable to find a closed solution to the model. Their model revealed useful characteristics given that the

partial solutions must adhere to the properties of microeconomic market equilibrium.

A Theoretical Travel Cost Model with Endogenous Durable Equipment

As previously presented, durable recreational equipment such as private fishing boats may be an important part of the recreational fishing trip decision and thus a valid component in some travel cost models. Using optimal control theory, insights into the degree to which durable equipment provisioning decisions influence the behavior modeled in travel cost models may be explored and analyzed.

The model uses optimal control theory to show the importance of modeling durable recreational equipment in the TCM. It shows that failing to explicitly account for the provisioning of durable recreational equipment can lead the researcher to significantly underestimate the monetized value of recreational benefit. This model captures the salient features of economic behavior for equipment acquisition and recreational use within the travel cost framework, and provides guidance in determining what additional data will be needed for empirical travel cost studies.

Failing to incorporate recreational equipment in a travel cost study will lead to biased estimates if the equipment in question is a complement or substitute of recreational trips in the production of recreational utility and if the quantity of equipment that the individual provisions is largely based upon its ability to produce recreational utility. Given these conditions, in the travel cost model framework, the money spent on maintaining the stock of durable recreational equipment could vary with the desired number of site trips and is an additional measure of the benefits the recreationist derives from the site.

This model also offers the researcher more structure in analyzing certain types of site amenity improvements, specifically those amenities that chiefly affect equipment utilization and provisioning. It is reasonable to hypothesize that amenities such as camping facilities or boat ramps may impact recreational utility differently than water quality, and these differences can be better captured in this model.

Also, this model can be used to evaluate indirect effects of changing relative prices in the recreational equipment sector. Given a relative increase in equipment prices, one could predict a change in recreational benefit.

It must also be noted that, in broad terms, travel cost studies are an attempt to use market prices and opportunity costs to infer prices upon non market activities. Given this, it makes sense to incorporate as much relevant market information as possible. Units of recreational equipment are tangible. In some cases their ownership is tracked by government entities for taxation and safety purposes. Corporations and trade organizations collect such information as helps their marketing efforts. Overall, there can be a wealth of additional market information available to the researcher.

The Model

This model utilizes the basic assumptions of individual and market behavior as outlined in Freeman (1993, page 447). Individuals respond to changes in travel prices as they would to changes in a site entrance fee, and travel time offers neither utility nor disutility. The sole purpose of the trip is recreation at the site, and all utility is gained from on-site activities. All visits are of equal length. Wage rates are the appropriate opportunity costs of time, and individuals have no available alternative recreational activities. Utility garnered in each time period is a function of the consumption of recreational trips x , recreational capital equipment k , and other goods

y. Each site offers amenities a. Individuals may gain utility from the ownership and use of k independent of recreational trips, but the quantity of k kept is partially determined by its role in trip utility production.

$$U(t) = U(x(t, a), k(t), y(t))$$

Equipment may be purchased out of current-period income and/or bank account funds B, which are augmented out of current-period income by the amount s(t). Initially (at time period 0) it is assumed that individuals hold a non-negative bank account balance ($B(0) \geq 0$). Individuals may also borrow up to b_1 in bank funds to buy equipment, and at any point each individual may have a bank account balance of up to b_2 . Bank account funds accrue interest at the continuous compounding rate of r percent per period.

$$B(T) = \int_0^T (B(0)e^{rt} + s(t)e^{rt}) dt$$

$$-b_1 < B(t) < b_2$$

$$B(0) \geq 0$$

Equipment is consumed through recreational use at the rate of ϕ percent per trip, making the total consumed in a

season $\phi x(t)$ ³. Equipment also deteriorates and is consumed in nonrecreational activities at the rate of δ percent per year. Through spending on replacement capital equipment, the quantity of replacement equipment is modeled as I percent (all units of equipment are assumed to be homogenous and infinitely divisible). Thus the change in equipment stock per year is:

$$\frac{dk(t)}{dt} = \dot{k} = k(t)(I(t) - \delta - \phi x(t))$$

The individual receives wage income w for each day's work. Assuming a maximum of h days of possible work, he implicitly chooses his income via his choice of the number of days to spend in recreation day trips (x) and the number of days to spend in other forms of leisure (l days) (similar to Shaw, 1992b). His yearly wage income is thus $w(h-x-l)$. Recreational trips, other goods, and recreational equipment are priced at p_x , p_y , and p_k respectively. In any time period individuals spend the

³Epstein and Denny (1980) used a production function where capital utilization and depreciation were endogenous and determined by profit maximization goals. In their model, the current size of capital was "chosen given the knowledge of prices up to and including the (current) period but subject to expectations about future prices." (page 193). A similar process is envisioned here.

wages earned (the left-hand side of the following equation) on trips, other goods, recreational equipment, or savings.

$$w(h - x(t) - l(t)) = (x(t)p_x + y(t)p_y + I(t)k(t)p_k + s(t))$$

The individual's goal is to maximize discounted lifetime utility from trips, equipment, and other goods

$$\text{Maximize } \int_0^T U(x(t), k(t), y(t)) e^{-\rho t} dt$$

where ρ is the individual's rate-of-time preference.

Utility is maximized subject to the following conditions:

$$\dot{k} = k(t)(I(t) - \delta - \phi k(t)) \quad [\text{Equipment stock changes over time}]$$

$$w(h - x(t) - l(t)) = (x(t)p_x + y(t)p_y + I(t)k(t)p_k + s(t)) \quad [\text{Income} = \text{expenses}]$$

$$\frac{dB}{dt} = s(t) \quad [\text{Bank balances change by the amount saved or borrowed from this balance per period}]$$

$$-b_1 < B(t) < b_2 \quad [\text{At a given time bank balances may be negative up to } b_1 \text{ or positive up to } b_2]$$

$$B(0) \geq 0 \quad [\text{Initial bank balances are non-negative}].$$

The full model uses a Hamiltonian for dynamic optimization.

$$H = U(x(t), a, k(t), y(t))e^{-\pi} + \lambda(k(t)(I(t) - \delta - \phi x(t)) + \mu(w(h - x(t) - l(t)) - x(t)p_x - y(t)p_y - I(t)k(t)p_k - s(t))e^{-\pi} \quad (1)$$

and subject to:

$$\frac{dB}{dt} = s(t)$$

$$-b_1 < B(t) < b_2$$

$$B(0) \geq 0$$

Suppressing the time variable, several of the first-order necessary conditions for a solution offer interesting economic interpretations.

$$\frac{\partial H}{\partial x} = \frac{\partial U}{\partial x} e^{-\pi} - \lambda \phi k - \mu(w + p_x) e^{\pi} = 0 \quad (2)$$

Assuming that the individual's rate-of-time preference is equal to the prevailing interest rates ($\rho=r$), equation (2) may be restated as:

$$\frac{\partial U}{\partial x} = \mu(w + p_x) + \lambda \phi k e^{\pi} \quad (3)$$

Equation (3) shows that, at equilibrium, the money budgeted for the final recreational trip of a season and the last equipment consumed in that last trip produces utility exactly equaling the marginal utility for that last trip:

$$\begin{aligned} MU_{trips} = & \text{Shadow } P_{income} * (\text{travel} + \text{opportunity costs of a trip}) \\ & + \text{Shadow } P_k * K \text{ consumed per trip} * e^r \end{aligned}$$

The compounding interest variable e^{rt} represents the concept that any equipment consumed in a trip is unavailable for utility production in future trips.

$$\begin{aligned} \frac{\partial H}{\partial A} &= \lambda k - \mu k p_k e^{-n} = 0 \\ \lambda k &= \mu k p_k e^{-n} \\ \frac{\lambda}{p_k} e^n &= \mu \end{aligned} \tag{4}$$

The first-order condition in equation (4) shows that the optimal equipment holdings is that level which maximizes the ratio of the shadow price of equipment to the actual price of an additional unit of equipment, and the interest-compounded value of this ratio is equal to the shadow price of income.

$$\dot{k} = \frac{\partial H}{\partial \lambda} = k(I - \delta - \phi x) \tag{5}$$

$$\dot{\lambda} = -\frac{\partial H}{\partial k} = -\frac{\partial U}{\partial k}e^{-\pi} - \lambda(I - \delta - \phi x) + \mu p_k e^{-\pi} \quad (6)$$

Equation (5) is a restatement of the time-path of the change in equipment quantity held. Equation (6) describes the time-path of changes in the shadow price of equipment. The future shadow price of equipment must be discounted based upon the individual's rate of time preference. Higher equipment stock holdings reduce the time path, and increases in the shadow price of income increases it.

$$\begin{aligned} \frac{\partial \text{Shadow } P_k}{\partial a} &= -MU_k e^{-\pi} - \text{Shadow } P_k * (\text{change in } k \text{ stock}) \\ &\quad + \text{Shadow } P_{\text{income}} * \text{pct. invested} * p_k e^{-\pi} \end{aligned}$$

$$\frac{\partial U}{\partial \mu} = (w(h - x - 1) - xp_x - yp_y - Ikp_k - s)e^{-\pi} = 0 \quad (7)$$

Equation (7) is a restatement of the budget constraint). Assuming that a recreational user who holds some quantity of equipment for recreational purposes ($k > 0$) is in equilibrium, neither x nor k would change over time ($\dot{\lambda} = 0$), thus investment will be exactly sufficient to replace consumed or deteriorated equipment⁴.

⁴ Equipment deteriorates independent of use and can be consumed via use in other forms of recreation.

$$k(I - \delta - \phi x) = 0 \quad (8)$$

$$\therefore I = \delta + \phi x$$

Inserting this result into (6), which may also be set to zero for examination of equilibrium conditions, we find the marginal utility of additional equipment (equation (9)).

$$-\frac{\partial U}{\partial k} e^{-n} - \lambda(I - \delta - \phi x) + \mu p_k e^{-n} = 0$$

$$-\frac{\partial U}{\partial k} e^{-n} - \lambda(0) + \mu p_k e^{-n} = 0$$

$$\frac{\partial U}{\partial k} e^{-n} = \mu p_k e^{-n}$$

$$\frac{\partial U}{\partial k} = \mu p_k (\delta + \phi x) \quad (9)$$

Equilibrium at a utility-maximizing combination of inputs also implies that the marginal utility per unit of cost for each input is maximized, and this ratio is the same for the marginal unit of both input $\left(\frac{\frac{\partial U}{\partial x}}{p_x} = \frac{\frac{\partial U}{\partial k}}{p_k} \right)$. At equilibrium, an

additional dollar spent on trips will produce the same added utility as spending that dollar on additional durable equipment.

$$\frac{\mu(w + p_x) + \lambda k \phi e^n}{p_x} = \frac{\mu(\delta + \phi x) p_k}{p_k} \quad (10)$$

Solving equation (10) for k (equation (11)):

$$\begin{aligned}\frac{\mu(w + p_x) + \lambda k \phi e^n}{p_x} &= \frac{\mu(\delta + \phi x) p_k}{p_k} \\ \mu(w + p_x) + \lambda k \phi e^n &= \mu(\delta + \phi x) p_x \\ \lambda k \phi e^n &= \mu(\delta + \phi x) p_x - \mu(w + p_x) \\ \lambda k \phi e^n &= \mu((\delta + \phi x) p_x - (w + p_x)) \\ k &= \frac{\mu p_x}{\lambda \phi e^n} \left(\delta + \phi x - \frac{w + p_x}{p_x} \right)\end{aligned}\tag{11}$$

Since the individual is assumed to hold some recreational equipment, equation (11) can be used to show that trips and equipment are gross complements (equation (12)).

$$\frac{dk}{dp_x} = \frac{\mu}{\lambda \phi e^n} (\delta + \phi x - 1) < 0 \text{ for } (\delta + \phi x) < 1\tag{12}$$

The sign of equation (12) depends upon the seasonal consumption and deterioration of the durable equipment $(\delta + \phi x)$. Using the standard definition of a durable having a lifespan of at least three years, $(\delta + \phi x) \leq \frac{1}{3}$, equipment is a normal gross consumption good $\left(\frac{dk}{dp_k} < 0 \right)$.

Equation (11) can also be used to examine the slope of the indifference curve.

$$\frac{dk}{dx} = \frac{\mu}{\lambda} p_x e^{-n} > 0 \quad (13)$$

The marginal rate of substitution between trips and equipment ($MRS_{x,k}$), at equilibrium, is the ratio of equation (3) : equation (9) :

$$\begin{aligned} \frac{\frac{\partial U}{\partial x}}{\frac{\partial U}{\partial k}} &= \frac{\mu(w + p_x) + \lambda k \phi e^{rt}}{\mu p_k (\delta + \phi x)} = \frac{w + p_x}{p_k (\delta + \phi x)} + \frac{\lambda}{\mu} \frac{\phi k e^{rt}}{p_k (\delta + \phi x)} \\ &= \frac{1}{p_k (\delta + \phi x)} \left((w + p_x) + \frac{\lambda}{\mu} \phi k e^{rt} \right) > 0 \end{aligned} \quad (14)$$

Equation (14) shows that the $MRS_{x,k}$ is strictly positive for positive levels of x and k , and at equilibrium, marginal increases in equipment raise the $MRS_{x,k}$ ($\frac{\partial MRS_{x,k}}{\partial k} > 0$) while marginal increases in trips reduce it ($\frac{\partial MRS_{x,k}}{\partial x} < 0$).

More specifically, equation (14) shows that equilibrium $MRS_{x,k}$ is influenced by both trip and equipment prices. Higher trip prices ($w + p_x$) increase the $MRS_{x,k}$, representing a shift to relatively more per-trip equipment utilization. Higher per-trip equipment consumption (ϕk) also increases

the $MRS_{x,k}$ via the marginal benefit of investment in equipment $\left(\frac{\lambda}{\mu}\right)$. This increase in per-trip consumption will increase future costs by a factor of e^{rt} since increased funds which must be dedicated to equipment replacement in order to maintain the equilibrium condition $\dot{\lambda}=0$. An increase in total seasonal equipment consumption $(\delta+\phi x)$ will decrease the $MRS_{x,k}$, and the magnitude of this change also depends upon the prevailing investment price of equipment, since the entire equation is multiplied by its reciprocal $\left(\frac{1}{p_k(\delta+\phi x)}\right)$.

The overall magnitude of a change in the $MRS_{x,k}$ will depend upon the relative quantities of trips taken and equipment held and the prices of trips and equipment, since, given $\dot{\lambda}=0$, increased per-trip equipment consumption creates higher seasonal equipment consumption which must be replaced to maintain equilibrium.

Since at equilibrium the $MRS_{x,k}$ equals the ratio of the shadow values $\left(\frac{\mu}{\lambda}\right)$, by combining equation (14) and equation (13), the slope of the indifference curve at the point of equilibrium can be evaluated:

$$\begin{aligned}\frac{dk}{dx} &= - \left(\frac{\mu(w+p_x) + \lambda k \phi e^{-rt}}{\mu p_k (\delta + \phi x)} p_k e^{rt} \right) \\ &= \left(\frac{\mu(w+p_x) e^{rt} + \lambda k \phi}{\mu (\delta + \phi x)} \right)\end{aligned}\tag{15}$$

where $\mu(w+p_x)e^{rt}$ is the utility cost of the marginal trip and $\lambda k \phi$ is the utility cost of this trip's capital consumption. Figure 4 depicts the overall utility-maximizing demand relationship for a given number of trips ($\bar{x}$).

A Description of The Durable Equipment Bias

At this point we can examine the effects of an individual's decision to increase the number of recreational trips taken in a given season and examine the degree to which a traditional travel cost model will underestimate both changes in costs and recreational utility.

Assuming this individual's actions represents a shift from an equilibrium offering $U^1 = U(x^1, k^1)$ to a new equilibrium offering $U^2 = U(x^2, k^2)$, where $x^2 = x^1 + 1$, the equipment bias is based upon $\Delta k = k^2 - k^1$. From (13), taking an additional trip will increase desired equipment holdings by $\frac{\mu}{\lambda} p_k e^{rt}$. This new (and larger) equilibrium level of equipment holdings k^2 ($k^2 = k^1 + \frac{\mu}{\lambda} p_k e^{rt}$) will increase yearly replacement

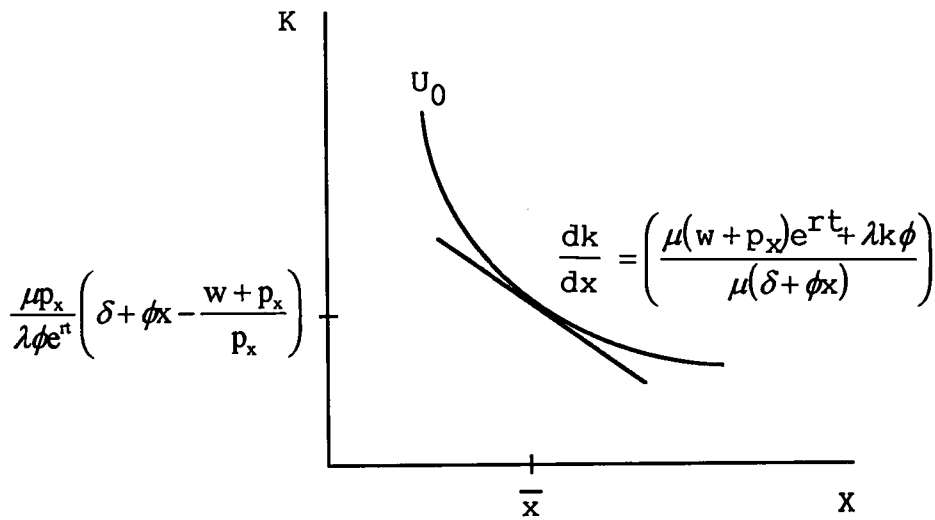


Figure 4

Demand Relationship at Utility Maximization

expenditures, since equipment deterioration and consumption are modeled as fixed percentages independent of the size of the equipment stock. Since yearly consumption at the initial equilibrium level was $k_1(\delta + \phi x_1)$, the new yearly equipment consumption level becomes $k_2(\delta + \phi x_2) = \left(k_1 + \frac{\mu}{\lambda} p_k e^n \right) (\delta + \phi(x_1 + 1))$, and thus yearly equipment replacement will increase by $\frac{\mu}{\lambda} p_k e^n (\delta + \phi(x_1 + 1))$ units of equipment.

The total increase in costs for the first year at the new equilibrium will be composed of the cost of the additional trip, the cost of purchasing the additional equipment at price p_k , and the additional yearly capital consumption due

to the additional trip: $(w+p_x) + \left(\frac{\mu}{\lambda} p_k e^{\pi}\right) p_k + \phi\left(k_1 + \frac{\mu}{\lambda} p_k e^{\pi}\right)$. A

traditional travel cost model would only capture the first term of this equation.

Similarly, the additional utility accrued from moving to U^2 includes both the additional utility that one additional trip will provide and the additional utility per trip which comes from having the additional equipment available to the user. Assuming a functional form having additive and separable utility streams, moving to the new equilibrium will increase total utility by:

$$U(x^2, k^2) - U(x^1, k^1) = \left(U(x^2, k^1) - U(x^1, k^1) \right) \text{ (Utility from more trips at original equipment levels.)} \\ + \left(U(x^2, k^2) - U(x^2, k^1) \right) \text{ (Utility from more equipment available on all trips.)}$$

where the second term represents the components of utility change that is not specifically captured in travel cost models which only model the change in trip frequency.

Weak Complementarity, the Household Production Function (HHPF), and How This Model is Different.

In attempting to model the utility derived from a public good, separability becomes an issue. If the utility derived from "consuming" quantities of the public good is

strongly separable from the utility gained from the consumption of market goods, then the marginal rates of substitution between any pair of market goods will be independent of the quantity of public good consumed, and thus the quantity of the public good will not be part of the demand functions for the market goods (Freeman 1979). Given these conditions, a model could not be used to derive the utility of public good consumption from consumption data on the market goods.

Freeman borrows Måler's (1974) concept of weak complementary to assert that one can develop a system of demand equations which both satisfy the Slutsky conditions of integrability and provides a linkage between demand for the public and market goods. Bockstael and McConnell (1983) use weak complementarity in a household production function (HHPF) framework. With the HHPF and assumption of weak complementarity, travel costs are the market goods which are combined with recreational site in the production of recreational utility.

Weak complementarity may also be extended to cases where individual market goods are not weak complements, but if taken as a set, the set is a weak complement of the public good. In their two-good example, Bockstael and Kling

(1988) show that compensating variation measures in such cases must be made by evaluating (integrating) the area between the demand curves for good 1 while holding the price of good 2 fixed at it's prevailing level, then adding to this the area between the demand curves of good 2 while holding the price of good 1 set at it's choke price (so that zero quantities of good 1 are consumed). This specific methodology requires that the demand for each good in the set be estimated as a function of the prices of all goods in the set, which may prove empirically difficult.

Weber (1992), building upon Bockstael and McConnell (1983), takes the theory of weak complements in a different direction, offering a method of estimating the demand for a public good by analyzing changes in aggregate private demand bundles. Such estimation depends upon the ability to apply a uniform metric to the private good. Empirically this may be difficult. For many private goods, the lumpiness and lags in purchase and consumption, quality differences between given models, and relative prices may be difficult to determine and quantify.

Bockstael and McConnell (1993) point out that the hypothesis of weak complementarity implies a participation function. Changes in site quality do not affect those who

don't choose to visit this site, but weak complementarity does not remove the possibility that a sufficient increase in site quality would lead a utility maximizing non user to choose to start visiting.

It should be understood that the concept of weak complementarity is not a testable hypothesis (Bockstael and McConnell 1993, p. 1254). Rather, it is an assertion that can be based upon whether these conditions appear logical for a particular scenario. If the area of research is limited to include such market goods as travel costs, it may be reasonable to use this assumption.

In order to see the difference in this formulation of the travel cost model compared to more traditional static models, it is useful to consider that the second stage of a HHPF-TCM may be treated as a discrete Lagrangian maximization problem.

$$L = U(x, y) + \mu(w(h - x - l) - xp_x - yp_y)$$

Typically, the HHPF-TCM assumes that equipment is a seasonally-fixed cost. Desired equipment holdings are determined prior to the decision on the number of trips to be taken, as opposed to this model, where both decisions

are made simultaneously. Depending upon the study, some of the durable equipment costs may be captured in the trip price variable p_x or in the composite other goods quantity-price pair $y p_y$.

In order to examine the implications of this assumption, it is interesting to compare the first-order conditions as shown in Table 2. At equilibrium, the standard model specifies a smaller marginal rate of substitution between trips and income than does the durable equipment formulation, by the amount determined by the additional term $\frac{\lambda}{\mu} k \phi e^{rt}$. The larger (or higher) the equipment holdings, equipment consumption per trip, interest rates, or value for λ , the larger will be this difference. The greater the income or the smaller the shadow value of income (μ) also leads to larger differences.

Intuitively, this difference represents the concept that when recreationists consider recreational trips and equipment as complements in utility production, their value of the marginal trip is equal to the sum of travel price for the marginal trip and additional equipment desired to

Table 2. A Comparison of First-Order Conditions

Standard HHPF-TCM ⁵	HHPF-TCM With Endogenous Durable Equipment
$\frac{\frac{\partial U}{\partial x}}{\mu} = (w + p_x)$	$\frac{\frac{\partial U}{\partial x}}{\mu} = (w + p_x) + \frac{\lambda}{\mu} k \phi e^r$

complement this higher frequency of site visits. Larger equipment holdings or greater equipment consumption per trip necessitate larger annual purchases to maintain the optimal equipment levels.

Using Expenditure Differences In Empirical Studies

In the standard HHPF-TCM, comparative statics estimates of net benefit changes due to a change in amenity "c" yield a measure of consumer surplus which can be used as an approximation of compensating variation or equivalent variation measurements. This consumer surplus measurement is determined by examining the change in expenditures of

$$^5 \frac{\partial \mathcal{L}}{\partial x} = \frac{\partial U}{\partial x} - \mu(w + p_x) = 0$$

$$\therefore \frac{\frac{\partial U}{\partial x}}{\mu} = (w + p_x)$$

the necessary input travel costs. In a reduced form, one evaluates the differences in expenditures between the initial equilibrium (e_1) and new equilibrium (e_2) when a change in amenity value (c_1 to c_2) induces a change in the number of trips (x_1 to x_2):

$$\Delta \text{benefit} \equiv f[e_2(x_2; c_2, p_x, p_y) - e_1(x_1; c_1, p_x, p_y)]$$

In examining the importance of durable equipment, one should explicitly examine both changes in trips and equipment holdings:

$$\Delta \text{benefit} \equiv f[e_2(x_2, k_2; c_2, p_x, p_y) - e_1(x_1, k_1; c_1, p_x, p_y)]$$

This method offers a more robust description of the problem, but it is also possible that the additional required information may be more succinctly modeled by including the elasticity of substitution between trips and equipment as a second argument.

$$\Delta \text{benefit} \equiv f[e_2(x_2; c_2, p_x, p_y) - e_1(x_1; c_1, p_x, p_y), \sigma_{x,k}]$$

Where $\sigma_{x,k}$ is estimated via the form $\frac{\frac{dMRS}{d\left(\frac{p_x}{p_k}\right)} * \frac{p_x}{p_k}}{MRS}$. This

formulation is consistent with the model and offers

computational simplicity. As currently modeled, trips and equipment have a variable elasticity of substitution. Generic fixed elasticity of substitution estimates for various types of recreation (and their associated durables) could be developed and then applied in specific studies as a first approximation, with the understanding that developing an estimated elasticity specifically for the specific study would produce more accurate results.

Empirical Testability

With an appropriate data set, several features of this model can be tested. From (1), the signs and sizes of $x = x(k, p_X, p_K, w, I)$ and $k = k(x, p_K, p_X, w, I)$ can be evaluated using a simultaneous equations model. Of additional interest, a comparison of single and simultaneous equation estimations would offer insights into the size of the potential biases associated with ignoring this endogenous variable.

Data Requirements

The equipment stock equation assumes that equipment is homogeneous and that both gross and infinitesimal equipment changes are possible. While one could theorize how a very small increase in equipment stock could be gained (e.g. selling the 20-foot recreation vehicle and purchasing a 21-foot model), there is still the problem of homogeneity:

Technological innovations may render older equipment inferior in utility production to newer equipment. Both of these issues are recognized, but are not explicitly handled by this model. Any empirical analysis using this model will likely require that some set of descriptive physical attributes of the capital stock in question be chosen as representative of all of the physical characteristics of the equipment. Given this abstraction, the model's use of percentages in describing changes in the size of the physical stock provides a straightforward means of computing stock changes, and this measurement could be proxied by such things as linear length or engine size for recreational vehicles.

Another question facing the empirical user of this model is that of specifying and determining the use and non use consumption/deterioration rates. While this model hypothesizes an age- and vintage-invariant deterioration rate, actual deterioration may be exponential if the owner chooses to neglect frequent small maintenance tasks. Use consumption per trip (ϕ) is an important part of several of the first-order conditions presented in this model, and assigning different values to this variable could significantly alter cost and benefit estimates. Also, both rates imply that there are standard quality characteristics

applicable to every unit of equipment's utility production potential, and these characteristics all degrade at the same rates.

Of course, such rates may be utility production function- or even amenity-specific. In a specific study, these rates could be estimated by evaluating current market values for every piece of equipment, but these market prices are due to supply and demand conditions which are a composite of all possible uses for the capital. Also, for recreational equipment with multiple uses, estimating the portion of use consumption determined by the recreation one is studying is another difficulty, although for such related uses as fishing vs. non fishing boating, it could be argued that a time-based criteria would be acceptable.

CHAPTER 4

AN EMPIRICAL ANALYSIS USING THE ENDOGENOUS DURABLE EQUIPMENT TRAVEL COST MODEL

This chapter describes the data set used for this empirical example and documents an example of how the theoretical model can be implemented in a travel cost study.

The Data Set

The data used in this essay was collected as part of a research project conducted by Dr. James Kahn, sponsored by the New York Sea Grant Institute, and published by Kahn et. al. (1994). This research focused upon estimating the economic valuation of saltwater fishing along the Long Island, New York coastline.

This research utilized intercept surveys of Long Island recreational fishermen during the years 1985-87 (Kahn 1991). In 1985 surveys were conducted of charter and party boat fishermen, while in 1986 and 1987 the process included intercept surveys collected from all types of saltwater fishermen. Those interviewed were asked a number of socioeconomic questions, numerous detailed questions pertaining to their expenditures on travel and on-site trip

expenses, and questions concerning the number of saltwater fishing trips of each type (private, charter, shore, etc.,) taken in the previous 12 months. A copy of this survey is found in Appendix A.

Of particular importance to this empirical example, the surveys included several questions about boat size and boating costs. Respondents were asked about the length and horsepower of their boat, the market value of the boat, and yearly operating, maintenance, and other costs associated with using this boat. Categorical variables representing the individual's frequency of engaging in other saltwater-based recreation were also included in the survey.

Data Transformation and Creation of Variables

Over 2,000 surveys were collected in the course of Kahn's (1991) New York Sea Grant research. The original survey asked for the number of trips taken or planned for the entire year by type (party boat, charter boat, private boat, shore or pier, or other) and by season (Spring, Summer, Fall, or Winter). As the purpose of the empirical analysis of this essay involves the utilization of private fishing boats, the number of private boat trips were aggregated for the four seasons into a generic variable TRIPS. The records of those individuals who stated that

they owned a private boat were then selected from the data set. Individuals stating that they had traveled more than 250 miles to reach the site were excluded to focus upon recreational day trips. This subset, called the boating data set in the rest of this essay, became the observations used in this analysis and contained 367 observations. It is assumed that all private trips taken by these boat owners were taken on their own boat. This boating data set was analyzed using SAS version 6.10.

From preliminary analysis, it was seen that several of the variables important to this study had extremely wide ranges of values. For example, the stated market value of the boat (MVBOAT) ranged from 0 to over one million dollars. Non cost variable zero values were preserved. Missing values were found in approximately nine percent of all observations.

Household income was reported as values belonging to income ranges (e.g., between \$30,000 and \$40,000) with the highest range listed being for income greater than \$75,000, making this a censored set of grouped data points. Attempts to use a grouped data model to estimate actual income from the

censored, grouped observations were not successful⁶. These range values were translated into midpoint values for each range, with the exception of the highest income range, which was set to \$80,000, with the understanding that using midpoints leads to inconsistent results under repeated trials (Bhat 1994).

The boating data set included observations collected in June, July, and August of both 1986 and 1987. The survey asked for actual and planned trips for the entire fishing season of the surveyed year. Income observations collected in 1987 were not deflated to 1986 levels since they were only reported in income ranges. The reported market value of the boat for 1987 observations was not adjusted since the change in the consumer price index was less than one tenth of one percent for the closest category, sporting vehicles⁷.

⁶While the grouped data model did produce income estimates that expanded the right-hand tail of the grouped observation distribution, it also produced substantially larger estimates for those individuals who reported belonging to the lower income brackets, frequently moving these individuals to higher income classes.

⁷Bureau of Labor Statistics CPI figures found on Fedworld internet site: 1986 = 105.6, 1987=105.5, 1982-4 base year.

Trip costs were constructed as being the product of travel and onsite costs. Travel costs were estimated to be \$0.20 per mile for the round-trip distance to the site. Onsite costs were constructed as being the per-trip boat fuel and oil expenditures and, when applicable, launch fees for this trip.

Evidence of the size of the boating capital held is given in the survey by the boat's stated market value, its length, and the size of its engine measured in horsepower. There was insufficient data concerning boating maintenance costs, therefore it was necessary to estimate a hedonic marginal price of additional equipment. It is assumed that while the individual chooses the quantity of capital equipment to employ, the marginal cost of additional horsepower is exogenous to the individual.

A marginal price of horsepower was estimated using the following regression equation:

$$MV_{boat} = f(\ln(bhp), \ln(boat_length)).$$

This equation produced the equation (with significance levels shown below each variable):

$$\begin{aligned} \text{MVboat} = & -256,952 + 27,239 \cdot \ln(\text{bhp}) \\ & (0.0001) \\ & + 51,194 \cdot \ln(\text{boat_length}) \\ & (0.0001) \end{aligned}$$

$$R^2 = .2934$$

The marginal price of an additional horsepower $\left(\frac{\partial \text{MVboat}}{\partial \text{bhp}} \right)$ was estimated as $\frac{27239}{\text{bhp}}$, and this marginal price was estimated for all observations⁸.

Questions were also asked about the number of family and other individuals included in that trip. This number was aggregated for the observation (totcrew) and used as a proxy for the average crew size. Whereas a majority of the surveyed trips were identified as being day trips, approximately 70 of the observations listed these trips as being multiday events. Since the data on the number of trips take or planned for the surveyed year do not differentiate between single and multiday trips, all trips were assumed to be single day events.

⁸Marginal boating costs are positive and diminishing $\left(\frac{\partial \text{MVboat}}{\partial \text{bhp}} > 0, \frac{\partial^2 \text{MVboat}}{\partial \text{bhp}^2} < 0 \right)$.

The boating data set contained several categorical variables representing the frequency with which the respondent engages in other forms of outdoor recreation. Variables such as water-skiing (wski) and power boating (pboat) were available, with levels from zero (never engaged in) to 3 (frequently engaged in). These variables were felt to be potentially useful in representing non fishing recreational usage of the boat, since it is reasonable to assume that for many of the surveyed individuals, saltwater fishing is not the only reason for holding a given level of boating stock.

A recognized limitation of this data set is the paucity of site amenity quality variables. Whereas each site is uniquely identified, these identifiers could not always be pegged to a specific spatial location, thus additional site-specific information could not be gathered from other sources.

This data set did include a reported value for the number of fish the individual expected to catch on this outing (exptctch). Similar information has been used in other studies as a proxy for site quality (Vaughan and Russell 1984). However, the expected catch rate of an individual may depend upon the individual's fishing skills, making the

individual's expected catch an endogenous variable if such skills are acquired via more frequent fishing trips.

Therefore it was decided that a third equation would be included in the empirical model, where individual expected catch rates were determined by the site-level mean expected catch value (sitexptc -- a site amenity), trips, and other exogenous explanatory variables.

With the noted limitations, this data set does provide an adequate level of detail for examining the potential influence of endogenous boating durable equipment modeled within a travel cost framework.

A description of the variables used in this analysis is shown in Table 3, and descriptive characteristics for these variables are shown in Table 4.

Recreational Characteristics From This Sample

Taken from mean values, annual travel-based costs total \$4,967.37 (48.3351499 trips at \$102.77 per trip), and the estimated marginal cost of boating capital is \$381.42 per horsepower. The mean individual from this sample is 41 years old, with some college education and considers himself to be a better-than-average angler, expecting to

**Table 3. Description of Variables:
Endogenous Durable Equipment Model**

Variable	Description
trips	The number of fishing trips taken or planned for the season.
bhp	The size of the boat engine in horsepower.
tripcost	Travel and onsite trip expenses.
boatcost	Marginal price of horsepower
hhinc	Household income.
skill	Self appraised fishing skill level (1 for novice, 2 for average, 3 advanced).
exptctch	Individual's expected catch for this trip.
sitexptc	Mean value of expected catch responses by all individuals surveyed at a given site.
age	Age in years.
exper	Fishing experience in years.
educ	Education level completed, (from 1 some high school to 4 college degree).
dnotwork	Dummy variable for those unemployed, students, retirees, or homemakers.
dhouse	Dummy variable for home ownership
totcrew	Number of people going on this boat trip.
pboat	Frequency of engaging in power boating (from 0 for never to 3 for frequently).

**Table 4. Descriptive Statistics:
Endogenous Durable Equipment Model**

Variable	N	Mean	Std. Dev.	Min, Max
trips	367	48.3351499	34.9929648	1, 206
ltrips	367	3.5848407	0.8756379	0, 5.33
bhp	359	165.5376045	186.0543505	0, 1500
hhinc	367	46410.08	22806.90	0, 80000
lhhinc	365	10.5781480	0.6826674	8.52, 11.29
tripcost	367	102.7693925	165.4321002	2.4, 1643.22
boatcost	358	381.4152642	522.1677425	18.16, 6809.75
totcrew	367	2.7166213	1.5824590	1, 13
exptctch	367	8.2561308	12.8051735	0, 115
sitexptc	367	8.1106266	4.8469535	0, 66
age	366	41.7568306	13.5605550	6, 73
skill	367	2.4741144	0.6391253	1, 3
educ	363	2.8650138	1.0196761	1, 4
dnotwork	367	0.1771117	0.3822844	0, 1
d house	367	0.0871935	0.2825035	0, 1
pboat	366	1.4125683	0.7113602	0, 3
exper	361	25.5429363	3.9969823	0, 62

catch 8.26 fish. He⁹ is accompanied by 1.7 additional individuals in his 166 horsepower boat.

Functional Form

A linear functional form was chosen for the theoretical model, with recognition that the choice of functional form of the demand equation (linear, log, etc.,) may influence both the success of the regression results and the size of consumer surplus estimates (Zeimer *et. al.*, 1980). Bockstael and McConnell (1980) noted that the area under the ordinary demand curve was sensitive to the functional form of the demand equation. Stynes, Peterson, and Rosenthal (1986) state that the "(e)stimates of per visit consumer surpluses and price elasticities derived from log transformed models will be unbiased, while estimates of total consumer surplus or total visits at given prices will be biased" (p. 97). Adamowicz *et. al.* (1989) found that log-log and linear-log functions produces much tighter variances than did linear and semi-log forms in their travel cost model using simulated data. But Kling (1988) used simulated data to show that, for the purpose of measuring changes in amenity value, the linear travel cost utility formulation performs reasonably well compared to

⁹The vast majority of the individuals surveyed were male.

more complicated equations. A linear travel cost model was chosen for the comparison single-equation model.

A Single-Equation Travel Cost Comparison Model

In order to compare the performance of the endogenous durable equipment simultaneous equation model, the following single equation equivalent was estimated:

$$\text{trips} = f(\text{bhp}, \text{tripcost}, \text{boatcost}, \text{hhincome}, \text{exptctch}, \text{totcrew}, \text{age}, \text{skill}, \text{educ}, \text{exper}, \text{dnotwork}, \text{dhouse})$$

The model was estimated using SAS® PROC REG, with the following results (significance levels are listed below each coefficient):

trips =	-7.987279 (0.8045)	- 0.031273*tripcost (0.0149)
	+ 0.022781*bhp (0.0775)	- 0.0032*boatcost (0.3914)
	+ 4.827125*lnhhinc (0.1246)	+ 0.387046*exptctch (0.0061)
	- 0.510372*age (0.0113)	+ 11.275275*skill (0.0004)
	- 5.923185*educ (0.0022)	- 4.248623*dnotwork (0.4447)
	- 7.338493*dhouse (0.2738)	+ 1.046649*totcrew (0.4003)

$$+ 3.441043 * \text{pboat} \quad + 0.278334 * \text{exper}$$

$$(0.1887) \quad (0.1528)$$

$$R^2 = 0.1156.$$

The results are consistent with what one would expect. Higher trip costs reduce the number of trips taken, while increasing site amenity values increase the number of trips taken. Younger individuals, those reporting higher levels of fishing skill, and lower educational achievement are associated with taking fewer trips.

The boating capital variable bhp is nearly significant and shows that a 50 horsepower increase in the mean boat size would produce an additional fishing trip. While it is not significant at the 95% confidence level, household income has the correct sign despite the censoring of the upper bounds of the income variable.

In order to estimate consumer surplus, the demand equation for this model is $\text{trips} = 50.32318011 - 0.031273 * \text{tripcost}$. Consumer surplus for the mean individual is estimated at \$36.53.

To evaluate the change in consumer surplus, a 25% increase in expected catch was hypothesized. For this increase in mean expected catch (from 8.2561308 to 10.3201635), it is

estimated that mean trips will increase to 49.1340255 (a 1.6529% increase) and consumer surplus will increase to 37.748895 (a 3.3329% increase).

The Endogenous Durable Equipment Simultaneous Equations Travel Cost Model

Following the relationships hypothesized in the theoretical model, the empirical model hypothesizes that the individual simultaneously optimizes his boating durable equipment holdings and the number of recreational boat fishing trips. The number of trips taken are partially determined by his productivity at the fishing site (measured in expected catch) and the quantity of boating capital employed on these trips. Boating capital held is partially determined by the number of fishing trips taken and other nonfishing recreational uses for the boat. The individual's fishing productivity is modeled as an endogenous variable, similar to McConnell (1979), since his site choice affects his fishing productivity.

$$\text{trips} = f(\text{bhp}, \text{tripcost}, \text{hhincome}, \text{exptctch}, \text{age}, \text{skill}, \text{educ}, \text{dnetwork}, \text{dhouse})$$

$$\text{bhp} = f(\text{trips}, \text{boatcost}, \text{hhincome}, \text{totcrew}, \text{age}, \text{pboat}, \text{dnetwork}, \text{dhouse})$$

$$\text{exptctch} = f(\text{sitexptc}, \text{trips}, \text{age}, \text{skill}, \text{exper}).$$

Based upon the theoretical model, the expected relationships are listed in Table 5.

Table 5. Expected Relationships

Expected Relationship	Description
$\frac{\partial \text{trips}}{\partial \text{bhp}} > 0, \frac{\partial \text{trips}}{\partial \text{exptctch}} > 0$	Boating capital and site amenity levels are positively related to trips taken.
$\frac{\partial \text{trips}}{\partial \text{tripcost}} < 0, \frac{\partial \text{bhp}}{\partial \text{boatcost}} < 0$	Trip costs are negatively related to trips taken and boating costs are negatively related to boating capital held.
$\frac{\partial \text{trips}}{\partial \text{bhp}} > 0$	Trips taken and boating capital are complements in boating utility.
$\frac{\partial \text{trips}}{\partial \text{income}} > 0, \frac{\partial \text{bhp}}{\partial \text{income}} > 0$	Income is positively related to trips taken and boating capital held.

This model was estimated using SAS[®] PROC SYSLIN with trips, bhp, and exptctch treated as endogenous variables. All exogenous variables (and several other socioeconomic variables) available for use as instruments, fulfilling the order condition for each equation. The model produced the following results, with significance levels listed below each coefficient:

$$\begin{aligned}
\text{trips} = & 20.636007 & + 0.089492 * \text{bhp} \\
& (0.5592) & (0.0007) \\
& - 0.060459 * \text{tripcost} & + 1.710634 * \text{lnhhinc} \\
& (0.0006) & (0.6258) \\
& + 0.476016 * \text{exptctch} & - 0.354310 * \text{age} \\
& (0.0009) & (0.0231) \\
& + 10.593827 * \text{skill} & - 4.597741 * \text{educ} \\
& (0.0005) & (0.0193) \\
& - 4.041234 * \text{dnotwork} & - 8.337510 * \text{dhouse} \\
& (0.4796) & (0.2144)
\end{aligned}$$

$$R^2 = 0.1162.$$

$$\begin{aligned}
\text{bhp} = & -468.4624 & + 28.662294 * \text{ltrips} \\
& (0.0041) & (0.2880) \\
& - 0.096641 * \text{boatcost} & + 42.568642 * \text{lnhhinc} \\
& (0.0001) & (0.0043) \\
& + 31.993246 * \text{totcrew} & - 20.074523 * \text{pboat} \\
& & (0.1090) \\
& + 1.546625 * \text{age} & - 42.158775 * \text{dnotwork} \\
& (0.0301) & (0.1115) \\
& + 4.910491 * \text{dhouse} \\
& (0.8817)
\end{aligned}$$

$$R^2 = 0.2610.$$

$$\begin{aligned}
\text{exptctch} = & -25.178823 & + 1.315464 * \text{sitexptc} \\
& (0.0001) & (0.0001) \\
& + 0.511058 * \text{trips} & + 0.196010 * \text{age} \\
& (.0001) & (0.0732) \\
& - 3.509170 * \text{skill} & - 0.043974 * \text{exper} \\
& (0.0895) & (0.6907)
\end{aligned}$$

$$R^2 = 0.1479.$$

These results show the expected relationships, with the exception of the household income variable in the trips equation, which was found to be insignificant. The positive relationship between trips and bhp in both the trips and bhp equations suggest that trips and boating capital are complements, supporting the theoretical model.

Another interesting result can be seen in Table 6 by comparing the parameter estimates of tripcost and bhp with those reported in the single equation model. The durable equipment model produces a steeper estimate of tripcost and bhp than was found in the standard formulation, and these estimates fall outside the traditional model's 95% confidence intervals.

Table 6. Confidence Limits Comparison for Selected Parameter Estimates¹⁰.

Variable	Single Equ. Lower Limit	Single Equ. Upper Limit	Simult Equ. Estimate
tripcost	-0.05631	-0.006236	-0.060459
bhp	-0.00244	0.047999	0.089492

¹⁰Where the confidence limits were calculated using the formula: C.L. = Param_Est $\pm$ (Std_Err * t(340,0.975)).

In order to estimate the consumer surplus for the mean individual, the demand equation for this model is:

$$\text{trips} = 54.27584682 - 0.0060459 * \text{tripcost}.$$

Consumer surplus from recreational trips, for the mean individual, is estimated at \$70.62. One can also measure the consumer surpluses associated with the ownership of durable equipment. The demand equation for boating horsepower is calculated at:

$$\text{bhp} = 125.9676718 - 0.096641 * \text{boatcost}.$$

This equation produces a boating equipment consumer surplus estimate for the mean individual of \$1,234.11, an upper bound for the consumer surplus attributed to saltwater fishing-related ownership. Thus, these recreational fishing trips provide the mean individual with up to \$1,304.73 in consumer surplus for that year.

To examine comparative static estimates, the same hypothetical 25% increase in mean expected catch was estimated. The following demand equation for the system of equations was used:

$$\text{trips} = 35.5315056 + 0.089492*\text{bhp} + 0.476016*\text{exptctch} \\ - 0.060459*\text{tripcost}.$$

$$\text{bhp} = 61.07482663 + 28.662294*1\text{trips}.$$

A 25% increase in expected catch will lead to an increase in trips by 1.386431442 trips (a 2.868% increase) and consumer surplus for the mean individual by \$4.11 (a 5.819% increase) to \$74.73. Consumer surpluses associated with the ownership of durable equipment is estimated to grow to \$1,344.55 (a \$110.44 or 8.949% increase) due to the increase in mean trips¹¹. Since this is a comparative statics estimate, all of the increase can be attributed to trip-related utility. A comparison of these model estimates are shown in Table 7.

Conclusion

In this empirical analysis using the travel cost model with endogenous durable equipment, this model suggests that, as theorized, recreationists consider boating horsepower as a

¹¹ The 1.386431442 increase in trips was added to each trips observation and the natural logarithm calculated for use in this estimation.

**Table 7. A Comparison Of Standard and
Durable Equipment Model Estimates.**

Model	Predicted Change in Trips	Consumer Surplus (Static Est.)	Predicted Change in CS
Trad. TCM Model	0.7988756 (1.653%)	\$36.53	\$1.22 (3.333%)
Dur. Equip. Model Trips Equ.	1.386431 (2.868%)	\$70.62	\$4.11 (5.819%)
Dur. Equip. Boating Capital Equ.		\$1,234.11 (upper bound)	\$110.44 (8.949%)
Pct. Diff. Betw. Trad. TCM and D.E. Model (Trips Equ.)	73.55%		236.89%

complement of recreational trips in utility production. A comparison of this model with a comparable single-equation formulation suggests that, in the case of Long Island sportfishing, durable boating capital should be treated as an endogenous variable, and by doing so, the estimated consumer surplus for sportfishing trips is greater than in a single-equation model. In addition, the size of the comparative statics consumer surplus estimate of net recreational benefit from boating capital is evidence of the need to explicitly model durable recreational capital.

CHAPTER 5

DISCUSSION AND SUGGESTIONS FOR FUTURE RESEARCH

This chapter first discusses additional issues in the TCM with endogenous durable equipment. Following this is a discussion of each model's potential use in policy evaluation, and possible areas of future research.

Travel Cost Models With Endogenous Durable Equipment

Combining CV Data and Travel Cost Models

Dichotomous-choice contingent valuation questions are sometimes used in conjunction with travel cost surveys to determine the respondent's willingness-to-accept (WTA) for a complete loss of access to the recreational site (see Cameron 1992). This combination allows the investigator to more fully characterize the recreational demand function. However, in the case of recreation involving large durable equipment holdings, it would appear that failing to incorporate the resale value of the individual's equipment would bias the net benefit estimates.

For example, using the HHPF-TCM approach, the individual is assumed to be indifferent between $U_0(\bar{x}, \bar{y}; M) = U_1(0, \tilde{y}; \tilde{M})$ (with M representing income and $\tilde{M} = M + \text{WTA.}$), where $\tilde{y} = \bar{y} + \frac{(\tilde{M} - M)}{p_y}$.

But equipment holdings complicate the analysis. If an individual chooses his equipment holdings based upon expected recreational use, then the hypothetical decision to stop visiting a recreational site may involve a recalculation of desired stock holdings and a partial or total sell-off of his equipment stock. Given this possibility, it would appear that the individual's elicited WTA for loss of the site may be as large as $\tilde{M} - M = (w + p_x)x + kp_k + \text{value of net benefit}$. This difference could be particularly confounding if there is a wide variation in respondent's understanding of the scenario and cognition of their ability to adjust their equipment holdings¹².

While granted, this is not a major issue, the travel cost model with durable equipment may offer a refinement for these CV-TCM models¹³.

The Time Path of Equipment Accumulation and Utilization

While this model is designed to examine movements between equilibrium points, the life-cycle of recreational decisions can also be seen in its operation. Once the decision has been made to engage in a type of recreation,

¹²A possibility that I realize is also inherent in use of this model.

¹³Cameron (1992) implicitly acknowledged the influence of equipment holdings as a cross-check.

the process of accumulating the desired quantity of equipment is bounded by the budget constraint. The new user may either draw down on savings, borrow the money (decrementing B), or fund new purchases entirely out of income, all of which reduce available moneys for recreational trips. Although in this model all units of equipment are homogeneous and identically suited for its use in recreation, it is possible that there is some minimum quantity of capital necessary before the recreation can commence¹⁴, and that, depending upon the individual, it may take several time periods for this stock to be accumulated, opening the possibility that future expectations of engaging in the recreation will drive current period equipment purchases even though no recreational trips are possible in the current period.

For the individual planning to stop participating in this activity, the model shows that he will reduce and eventually end his maintenance and restocking expenditures as he shifts his spending to other utility-producing activities. This decision reduces spending and augments available income by $(\delta + \phi x)P_k$ per season. If recreational

¹⁴Since the model uses fractions as the units of capital equipment, one cannot use the variables in this model to specify an initial equipment quantity.

trips are a normal good, this extra available income may actually increase the number of trips taken above the equilibrium level before the reduction in available equipment stock becomes a binding force in driving down desired trips¹⁵.

On a smaller scale, these entry and exit processes are at work when an external change in site amenity levels or affinity for the recreational activity leads to a movement in the equilibrium levels of trips and equipment holdings. If trips may be adjusted more quickly than equipment holdings, temporary disequilibriums may exist, as shown in Figure 5, until equipment holdings reach their new equilibrium, suggesting a lagged or dampened short-run trips response to amenity changes.

Empirical Results

The travel cost model with endogenous durable recreational equipment estimates a statistically significant steeper demand function for trips and larger static and comparative statics consumer surplus estimates than a comparable single-equation model, results which support the

¹⁵The magnitude of this possible increase will depend upon the specific use and nonuse consumption/deterioration rates.

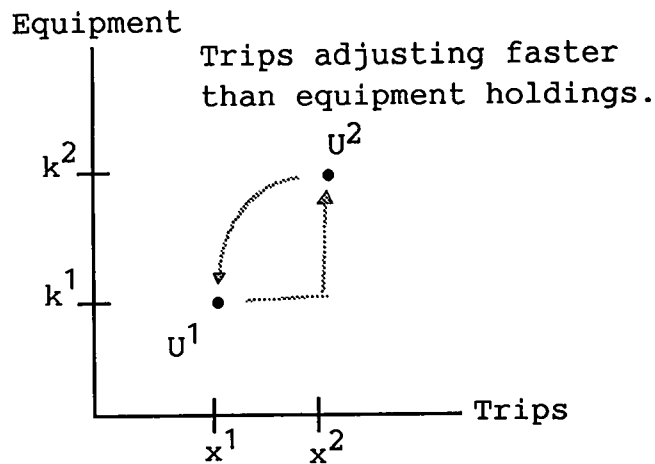


Figure 5

**Increased/Decreased Trips With
Lagged Stock Adjustment.**

theoretical model. The size difference in these estimates support the hypothesis that failing to explicitly model durable recreation equipment in the travel cost framework may lead to underestimation of net benefit.

Policy Implications

The ability to simultaneously examine changes in recreational trips and changes in durable equipment ownership can be useful in policy evaluations, especially if the policy is analyzed in terms of the wider viewpoint of increases in the area's economic activity. For example, in the case of an analyst evaluating a proposed water quality improvement which increases the demand for fishing trips and therefore boating equipment, the increase in equipment may represent a quantifiable increase in the

economic activity of local equipment sales and maintenance industries.

This model suggests that in cases where the recreation involves large durable equipment holdings, policy analysis must examine more than just those variables which directly influence recreational trips. Improvements in conditions which affect durable equipment ownership, such as amenities related to non-fishing recreational boating use will influence recreational fishing trips.

Also, the failure to explicitly model durable equipment may lead to incorrect benefit-cost analysis figures. Proposed amenity improvements could be decided against while these improvements do offer cost-effective benefits.

Future Research

There are several possible areas of future research for expanding the use of this model. First, studies should be designed and implemented to capture detailed durable recreational goods ownership and use data for different forms of recreation. This detailed data should cover a sufficient number of years in order to be evaluated as a time series. From this data, estimates of investment, nonuse depreciation, and per trip consumption can be

derived, and from these estimates generic estimates of the elasticity of trips with respect to equipment (σ_{xx}) can be calculated.

This data may lead to a better capital accumulation/use equation in the theoretical model, such as an equation which could more explicitly describe the concept of individuals shifting their boat usage from other activities (consumption captured in δ) and fishing (consumption captured in ϕ).

Future work is also needed in the role of durable recreational equipment technological improvement and resultant productivity gains, when this productivity measure is also a modeled site amenity characteristic. Does a global positioning system receiver which allows the sportfisherman to more quickly return to his most productive fishing location and sonar fishfinder which allows him to more quickly identify schools of fish increase his fishing utility more than a more powerful or spacious fishing vessel?

Topics in estimating participation rates should also be examined. Are the conditions that makes one take up an equipment intensive sport different than the ones that

don't require this level of investment, with individuals opting instead for a related alternative activity, such as the case of boat vs. shore fishing?

These areas of possible future research will enhance the usability and attractiveness of this model.

The Hedonic Travel Cost Model with Congestion as the Equilibrating Mechanism

The theoretical model describes the role of site congestion as an equilibrating mechanism in hedonic travel cost models. As shown in theory, congestion may reduce the individual's utility of experiencing site amenities, and this reduced utility may translate into lower willingness-to-pay estimates.

This model offers researchers the ability to use comparative statics techniques in a hedonic travel cost framework to estimate the willingness-to-pay for changes in amenity levels. This is a very useful addition to the hedonic travel cost literature, and will increase the number of specific studies where a hedonic travel cost model may be appropriate. The distance between a visitor's home and the site will not change due to an improvement in

site amenity levels, but site congestion will rise, and the individual's response to increased congestion is, as seen in the theoretical model, similar to a price increase.

Policy Implications

The ability to use this hedonic travel cost model for comparative static estimates will permit policy makers to focus upon more specific amenity issues. Decreased visibility may be evaluated in the willingness to pay by recreationists for scenic views.

As shown in this model, the role of congestion suggests that those elements of congestion which are under the site owner's control, such as parking, may be a powerful tool in enhancing recreationist's enjoyment of all amenities. If the visitor's perception of congestion is significantly influenced by parking area or trail capacity, improvements in these areas will effectively improve the recreationist's utility derived from all site characteristics. To this extent, site congestion could be viewed as a "superamenity", and should be given a priority in policy analysis and decisions.

Future Research

This theoretical model should be tested using an appropriate data set. Data requirements include amenity ratings or quality variables for each site and variables which permit congestion measurements for all of the sites available to each recreationist. These recreation sites should offer a rich variety of amenity levels for each site characteristic. While survey information may be used where visitors rate various amenities using an ordinal scale, such as a one-to-ten rating gradient, it is suggested that initial empirical studies designed to test the theory use characteristics measured in physical units.

Better definitions and models of congestion are needed. In order to better understand the linkage between perception and physical measures of congestion, future studies are necessary which take detailed survey and quantitative information on the site amenity characteristics, and the user's perception of congestion pressures. The recreationist's perception of what constitutes crowded is possibly different for the rural Eastern Tennessee fisherman than it is for the individual living in the New York City metro area.

Conclusion

As shown in the models presented in this dissertation, the explicit modeling of endogenous RHS variables may offer several advantages to the researcher who wishes to use a travel cost model to estimate recreational benefits. These models present a fuller description of the recreationist's decision process. Individuals balance their desire for recreational trips with their desire for satisfactory quantities of equipment to employ in these outings, and the utility they receive from each is tied to the quantities they hold of the other. Recreational site users are willing to pay for larger quantities of site amenities, but their enjoyment is tempered by the increased crowds which come with higher amenity levels. A correctly-modeled endogenous variable, offering a fuller view of the problem, allows the researcher greater detail in analyzing economic or demographic shocks. An increase in luxury item sales taxes which alters the fisherman's equipment holdings can be analyzed for the projected change in sportfishing trips. The congestion-corrected hedonic travel cost analysis may be used to evaluate the monetized benefits a proposed site amenity improvement.

Alternately, this work shows the potential problems of failing to adequately model important endogenous RHS variables. The standard travel cost framework may underestimate static and comparative statics consumer surplus estimates (in the case of the durable equipment model) or the hedonic travel cost model's marginal implicit willingness-to-pay for site characteristics.

These models are but two examples of how endogenous variables may be used to create better travel cost models, and it is hoped that this work will lead to further refinements of the travel cost modeling methodology.

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Appendix

Survey Form Used In 1986

This survey is designed to gather information to help us better understand the importance of the coastal recreational resources to the Long Island Region. Please try to answer the questions as accurately as you can. These surveys are confidential and will be used only for research purposes. We do not ask your name, so you can be confident of your anonymity. Thank you for your help in conducting this important research. If you already filled out a survey at your fishing club or in *The Fisherman*, please fill out this one as well as they are designed to provide different types of information.

THIS SECTION TO BE COMPLETED BY INTERVIEWER:

date _____ time of interview _____ weather conditions _____
place _____ mode _____
comments: _____

-
- (1) How old are you? _____
- (2) How many years of experience do you have in coastal recreational fishing? _____
- (3) Place an "F" next to the activities in which you participate frequently, place an "O" next to the activities in which you participate occasionally, and an "N" next to the activities in which you never participate.
- | | | |
|----------------|---------------------|---------------|
| hunting _____ | power boating _____ | tennis _____ |
| swimming _____ | sail boating _____ | golf _____ |
| hiking _____ | water skiing _____ | jogging _____ |
| camping _____ | snow skiing _____ | other _____ |
- (4) What kind of fisherman would you consider yourself?
novice _____
intermediate _____
advanced _____
- (5) What is your sex?
male _____ female _____
- (6) What is your marital status?
single _____ married _____ divorced _____ separated _____
- (7) What is your residential zipcode? _____

(8) Which best describes the place in which you live?

	owned	rented
house	_____	_____
townhouse	_____	_____
apartment or condo	_____	_____
mobile home	_____	_____
other	_____	_____

(9) What is your annual income?

	YOUR INCOME	YOUR TOTAL FAMILY INCOME
0 \$10,000	_____	_____
\$10,001-\$20,000	_____	_____
\$20,001-\$30,000	_____	_____
\$30,001-\$40,000	_____	_____
\$40,001-\$50,000	_____	_____
\$50,001-\$75,000	_____	_____
over \$75,000	_____	_____

(10) What best describes your educational level?

some high school _____	finished high school _____
some college _____	college degree _____

(11) Are you currently employed? yes _____ no _____

(11a) If yes, which category best describes your occupation?

education _____	farm manager _____
other professional _____	enlisted military _____
manager _____	military officer _____
operative _____	clerical _____
service _____	skilled laborer _____
farm laborer _____	other laborer _____

(11b) If not employed, are you

a student _____	retired _____
a homemaker _____	disabled _____

(12) Do you own a boat? yes _____ no _____

(12a) If yes, is it a power boat _____, sail boat _____, other _____.

(12b) How long is the boat? _____

(12c) What horsepower? _____

(13) What is the market value of your boat? _____

(14) How much do spend annually on your boat for:

Fuel and oil _____	Mooring or slip fees _____
Registration fees _____	launching fees _____
maintenance _____	insurance _____
boating accessories _____	winter dry dock _____

(15) How much will you spend on recreational fishing equipment (rods, reels, lures line, hooks, sinkers, etc.) during 1986? _____

The following questions apply to THIS SPECIFIC fishing trip.

(16) Who is accompanying you on this trip?

spouse _____ children (number) _____ others (number) _____

(17) How much did you (or will you) spend while on land during this fishing trip? (If you are part of a group, list only your share of the cost)

	on Long Island	elsewhere in NYS	outside of NYS
bait	_____	_____	_____
food and drink	_____	_____	_____
lodging	_____	_____	_____
tackle	_____	_____	_____
gas and oil	_____	_____	_____
parking	_____	_____	_____
tolls	_____	_____	_____
rail transport	_____	_____	_____
bus transport	_____	_____	_____
air transport	_____	_____	_____
other	_____	_____	_____
camp site fees	_____	_____	_____

(18) Is today's fishing trip part of a multiple day fishing trip?
yes _____ no _____

(18a) If yes, how many days? _____

(19) What is the one-way distance from where you live to this place? _____

(20) What species do you most prefer to fish for? _____

- (21) What species are you primarily fishing for? _____
- (22) How many of this species do you expect to catch? _____
- (23) If you aren't fishing for your preferred species, what is the reason?
 wrong season ___ too expensive ___ not plentiful enough ___
 too inconvenient ___ other (specify) _____
- (24) If you were fishing for your most preferred species, how many
 would you expect to catch? _____
- (25) Please rate the following attributes of this place.

	bad	average	good
cleanliness	_____	_____	_____
safety	_____	_____	_____
access	_____	_____	_____
congestion	_____	_____	_____

We would now like to find out about your actual and planned fishing activity for all of 1986. The regions referred to are shown on the map on the last page of the survey. Please list the **NUMBER** of fishing trips of the five different types which you have taken or are planning to take during each season in 1986.

SPRING (March, April, May)

Region	on charter boats	on party boats	on rented boats	on private boats	from shore dock, pier
1 W. Atlantic	S ₁₁	S ₁₂	S ₁₃	S ₁₄	S ₁₅
2 E. Atlantic	S ₂₁				
3 L.I. Sound	S ₃₁				
4 Between the Forks	S ₄₂				
5 Shinnecock & Moriches Bays	S ₅₁				
6 Gr. South & Jamaica Bays	S ₆₁				

SUMMER - (June, July, August)

Region	on charter boats	on party boats	on rented boats	on private boats	from shore dock , pier
1-W. Atlantic					
2-E. Atlantic					
3-L.I. Sound					
4-Between the Forks					
5-Shinnecock & Moriches Bays					
6-Gr. South & Jamaica Bays					

FALL - (September, October, November)

Region	on charter boats	on party boats	on rented boats	on private boats	from shore dock , pier
1-W. Atlantic					
2 E. Atlantic					
3-L.I. Sound					
4 Between the Forks					
5-Shinnecock & Moriches Bays					
6-Gr. South & Jamaica Bays					

WINTER
(January, February, December)

Region	on charter boats	on party boats	on rented boats	on private boats	from shore dock , pier
1-W. Atlantic					
2-E. Atlantic					
3-L.I. Sound					
4 Between the Forks					
5 Shinnecock & Moriches Bays					
6-Gr. South & Jamaica Bays					

One last question , and then we're done.

(27) If it were possible for you to make an expenditure which would increase fish abundance, how much would you be willing to pay for a 25% increase in abundance of your three favorite fish species?

	Species name	willingness to pay
1 st favorite	_____	_____
2 nd favorite	_____	_____
3 rd favorite	_____	_____

Thank you very much for your help in conducting this research. We appreciate your time and cooperation.

VITA

Scott Rickard was born in Eaton, Ohio on June 21, 1960. He attended the Eaton public school system, graduating from Eaton High School in 1978. He then attended Miami University while working as a technical writer for several defense contractors, graduating with a Bachelor's of Applied Science in Systems Analysis in 1984. After graduation, he spent six years writing programmer reference manuals for computer companies, before returning to graduate school at the University of Tennessee, Knoxville in August, 1990 to pursue a Doctor of Philosophy degree in Economics. In 1992-4 he held a research assistant position in the Regional Studies Laboratory of Oak Ridge National Laboratory, Oak Ridge, Tennessee. The doctoral degree was awarded in August, 1997.

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