Recreation Demand Models

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1. INTRODUCTION

Travel cost recreation demand models stem from Hotelling's [1947] simple, but penetrating, insight. Consumption of an outdoor recreation site's services requires the user to incur the costs of a trip to that site. Travel costs serve as implicit prices. These costs reflect both people's distances from recreation sites visited and their specific opportunity costs of time. Today, economic analyses of recreation choices are among the most advanced examples of microeconometric modeling of consumer behavior in economics.

The literature has gone through three stages. From Clawson [1959] and Trice and Wood's [1958] initial work, the first set of applications can be divided into two types: travel cost demand models estimated with zonal data (i.e. aggregate visit rates from population zones at varying distances from recreation sites) and activity participation models that are best interpreted as reduced form models. The first set of studies focused on the difficulties posed by using aggregate data, without specific socio-economic information about the recreationists involved, to measure recreation demand when the visit rates reflected both the participation and the use decisions.

To our knowledge, Burt and Brewer [1971] provided the first application of the travel cost method to micro data, estimating a system of demand equations for lake recreation. Their study initiated in the second stage of research with attention shifted to the opportunity cost of travel time, role of substitute sites, trip length, and site attributes in recreation demand.

Two subsequent contributions transformed recreation demand analysis in the third and contemporary stage. The first of these was Hanemann's dissertation and subsequent publications [1978, 1984, 1985] introducing the random utility model as a theoretically consistent method for resolving the mixed discrete/continuous choice problem he used to describe recreation demand.

This research outlined the theoretical landscape. However, the transformation would not have occurred without an unpublished EPA report by Bockstael, Hanemann and Strand [1987] that bridged the early work developed from a demand orientation to the new RUM and mixed discrete/continuous perspective on consumer choice.[1] These two research efforts ushered in the modern era in recreation demand modeling.

The primary focus of this chapter is on the methods used to describe individuals' recreation choices. We are interested in the economic assumptions made in descriptions of behavior and measures of the economic value of amenities. Before developing this summary, we discuss how outdoor recreation fits within consumers' overall expenditures.

Section three describes how we might ideally like to estimate consumers' preferences for recreation resources and the compromises implied by the models currently being used.[2] Econometric details are deferred until section five, after a discussion of the features of recreation data in section four. In section six we turn to conceptual issues in welfare measurement. We close in section seven with a discussion of a few research opportunities that seem especially important for the future.

2. WHAT DO WE KNOW ABOUT PREFERENCES FOR OUTDOORRECREATION AFTER 50+ YEARS?

For most environmental economists research on the demand for outdoor recreation is motivated by the need to provide measures of the economic values for the services of recreation sites (and the effects of changes in amenities on them) as part of informing regulatory policy and resource management decisions. Few analysts consider the overall importance of outdoor recreation in relation to consumers' other economic choices, and there is a reason. Evaluating outdoor recreation's role from this perspective is not an easy task.

While outdoor recreation often involves significant expenditures on complementary goods and services, comprehensive summaries of all of the time and travel resources allocated to outdoor recreation are difficult to develop. For the expenditures that can be measured, there is a fairly general argument supporting their use as indirect gauges of the importance of recreation, but no specific theoretical analysis suggesting a direct empirical relationship. As a result, our assessment is a collection of indirect measures, with a summary of what we know about consumer preferences for recreation, including value measures.

2.1 Recreation and Consumer Expenditures

Clawson and Knetsch [1966] used two different expenditure measures to gauge the importance of outdoor recreation in consumers' economic decisions. The first involved the fraction of recreation expenditures in all of personal consumption expenditures. These expenditures consist primarily of commodities associated with leisure time. While the components have changed dramatically over the 71 years of available data, the overall intent of the category appears to be an effort to identify expenditures on commodities or services that are associated with uses of one's leisure time. Between 1929 and 1959 recreation expenditures as a fraction of personal consumption increased from 5.89 to 6.53 percent.[3] Clawson and Knetsch's Figure 18 indicates that with the exception of the period 1930–1944 the pattern of growth in all recreation and outdoor recreation as a share of disposable personal income has exhibited a steady upward trend. This conclusion is consistent with Costa's [1999] evaluation using the historical record from the more detailed consumer expenditure surveys periodically available over the period 1888 to 1991. She finds that:

> "The share of household expenditure devoted to recreation rose from less than 2 percent in 1888 to 3 percent in 1917, 4 percent in the mid-thirties, 5 percent in 1950 and 6 percent in 1991" (p. 10).

Because she argues that this pattern indicates improving living conditions, it seems appropriate to use her general reasoning for other developing countries and conclude that increased income will likely lead to increased leisure and to expenditures on recreation related goods and services becoming a larger share of their consumers' budgets. Of course, this does not necessarily mean the increases in leisure are associated with outdoor recreation.

This question brings us to the second indicator suggested by Clawson and Knetsch. They examine the trends in fees paid for hunting licenses, fishing licenses, duck stamps, entrance fees at national and state parks, receipts from federal and state concessors and parks as well as personal consumption expenditures for sports equipment. Comparing these expenditures to disposal income yields a budget share (in percent terms) that nearly doubles over the period they consider from 0.38 in 1941 to 0.73 in 1959. While it is not possible to exactly replicate the components they assemble, using the National Survey of Fishing, Hunting and Wildlife Associated Recreation we can combine trip-related expenses (including equipment) for fishing, hunting and wildlife related activities in 2001. These amount to $179.4 billion dollars for the U.S. population 16 years old and older in this year. Compared to personal consumption expenditures (by type of expenditure) in that year, this amounts to 2.57 percent of that total – over three times Clawson and Knetsch's estimate for 1959. Thus, these data clearly support the conclusion that participation in outdoor recreation in the U.S. is associated with the overall increasing expenditures for leisure related activities.

Another way of measuring the expenditures motivated in part by environmental amenities is through a broad category of goods usually associated with travel. This category is often labeled tourism. Travel and tourism expenditures are somewhat different from the recreation expenditures identified earlier in the decomposition of the National Income and Product Accounts. In the case of tourism we are focusing more directly on expenditures away from home. Thus, to the extent travel and tourism are motivated by using environmental resources – recreation sites, national parks, etc. – these expenditures are more likely to be directly complementary to the uses of recreation sites. The Bureau of Economic Analysis developed satellite accounts for U.S. travel and tourism for 1992, 1996, and 1997. Their estimates indicate that this sector increased from 3.3 to 3.5 percent of gross domestic product (GDP) form 1992 to 1997. From 1992 to 1997 domestic tourism findal demand increased at an average annual rate of 6.9 percent, while gross domestic product increased by 5.6 percent.[4] Recreation and entertainment was the second fastest growing component of this aggregate, rising at an annual rate of 15.7 percent. These estimates do not include the time expended by tourists or the resources associated with maintaining the national parks, beaches, and other environmental resources that motivate the complementary expenditures on related goods and services.

Overall these indirect measures suggest that the importance of outdoor recreation activities in household consumption choices has grown over the past fifty years. By any measure, whether using complementary activities or the costs for access and equipment related expenditures, outdoor recreation is responsible for 2 to 6 percent of consumer expenditures and, very likely, accounts for at least as large a portion of an individual's leisure time.

2.2 Preferences for Recreation

Our title for this sub-section is deliberately vague. Applications of the travel cost logic can involve studies of specific recreation sites, recreational activities, or changes in the characteristics of recreation sites. In practice, this distinction is somewhat artificial because studies of recreation demand implicitly address all of these features. That is, when data are collected on recreation activities, the process involves recording the location, level of use, and usually the activities involved. How the findings are reported often depends on whether specific aspects of the experiences varied across sampled recreationists and the end uses for the analysis. These features limit our ability to generally characterize consumer preferences for outdoor recreation.

The recreation literature has grouped sites and activities into some broad composites. Water based recreation sites are divided into fresh- and saltwater locations, with activities such as sport fishing, boating, and swimming treated separately. Sport fishing is often further separated based on mode (boat or shore), use of charter services and, in some cases, whether a species is targeted. For recreation using land based sites (except those involving unique national parks, such as the Grand Canyon) the character of the site in describing the study is often considered secondary and the activity (e.g. hunting or hiking) used as the primary focus.

Based on this broad classification scheme, we construct table 2.1 using what is best described as a convenience sample of estimates for price and income elasticities and per day measures of the benefits from access to the site supporting the activity. Virtually all we know about price elasticity of demand is from research that is now nearly 30 years old.[5] A reviewer of an earlier draft of this chapter suggested that price and income elasticities from contemporary models may not serve the same role as in earlier studies. With micro level data, there is likely to be great variability in the estimated demand elasticities due to individual heterogeneity in tastes and opportunities. Differences in spatially delineated substitutes within a region condition the demand structure for sites in that region. When considered across studies, they introduce a source of variation in demand structures that may reduce the value of using elasticities as a summary measure of preferences. For example the price and income elasticities of demand for freshwater recreation trips in Minnesota, where there is a large array of alternative lakes, may be quite different than in the Southwest where, even if the recreationists could be assumed relatively homogeneous, the substitutes are distinctively different.

In this respect the spatial delineation in substitutes for recreation is different from market goods in most developed economies, where the existing supply network assures access to a comparable array of substitutes in most areas. Rather than serving as a reason to reconsider the use of elasticities, this seems to offer opportunities for research. Sensitivity of elasticity estimates to the features of the substitutes available, including the numbers of alternatives, their proximity, and attributes raises potentially interesting questions about adaptation. That is, we might consider how individuals adapt to these constraints. Do they substitute longer trips for day trips when there is limited access to a particular type of recreation site in their region? Alternatively, are there substitution patterns across classes of recreational activities that can only be detected by studying cross-region demand patterns? Finally, it is important to acknowledge that the same difficulties arise in comparing welfare measures across regions. Thus, the challenges posed by heterogeneity in taste and opportunity at the micro level of analysis do not necessarily change the value of considering the summary parameters beyond welfare measures that characterize preferences. They do, however, alter the way we interpret and use this information to understand behavior.

Meta summaries of the benefits reported in the recreation literature generally have followed Walsh et al. [1990] and Smith and Kaoru [1990a], focusing on the per-day or per-trip consumer surplus estimates. Rosenberger and Loomis [2000a, 2000b] offer the most complete summary, based on 682 estimates for a range of recreation activities in Canada and the United States reported in the literature between 1967 and 1998. Their table 1 provides a summary of the raw data for their analysis, based on average 1996 recreation values per person, per day for several categories of recreation.[6] In table 2.1 we report the average values from their summary for the activities that match our classification. For example, fishing is represented by 118 observations, with an average surplus of $34.74. Swimming is represented by only seven observations, with an average surplus of $31.66. Finally, big game hunting has an average surplus of $44.39 based on 170 reported surplus measures.[7]

A few recent papers have discussed preference characterizations beyond benefits measures, including Englin and Lambert [1997], Leeworthy and Wiley [1993], Hausman et al. [1995], and Herriges and Phaneuf [2002]. The first study combined a count data demand model with a catch equation and jointly estimated both relationships, taking account of the role of the expected catch in the trip demand. The primary focus of the paper is in recovering consumer surplus measures for site quality improvements as reflected through enhanced expected catch measures. The second paper uses a single equation travel cost demand model, based on data from the NOAA Public Area Recreation Visitors Survey, to estimate the demand for three California beaches. The initial specification considered only travel costs in demand models for individual beaches and implied own price elasticities ranging from –0.365 to –0.501. Re-analysis of a subset of the beach use data indicated statistically significant price and income elasticities, with an income elasticity estimate of 0.17.

The third study focused on using a random utility model to describe single trip behavior, which is then used to develop a price index for a seasonal demand model for recreation in Alaska. The authors report price elasticities as a gauge of the economic plausibility of their second step trip demand model for different types of trips in the area, finding own price effects from -0.80 to -3.38. The last study uses estimates of the own price and cross price elasticities to summarize the implied substitution patterns associated with different specifications of random utility models applied to the use of Iowa wetlands. Before presenting the estimates, Herriges and Phaneuf decompose the determinants of own and cross price elasticities for several popular specifications. This process offers general insight into how specification influences substitution. For example, they note in the case of the repeated nested logit (RNL) model cross price elasticities are constrained to be positive, and greater within nested groups than across groups. By contrast, the repeated mixed logit (RXL) model allows unconditional cross price elasticities to vary substantially with the mixing distribution. Within and between nest responses vary dramatically as the magnitude of the standard deviation for the mixing error varies from 0.1 to 10. In practice, these differences can be pronounced. For example, their application compares the RNL to the RXL frameworks and finds there are substantial differences with the RNL exhibiting larger (in absolute magnitude) price elasticities, but smaller cross price elasticities.

At least two conclusions and a note of caution emerge from this summary. First, it is clear that over the past fifty years we have accumulated considerable information about unit values of recreation activities and sites being used for these activities but relatively little about the structure of consumer demand. The early work suggests that most recreation demands are price inelastic. In a few of the recent studies water based and wilderness demands appear to have quite elastic demands, suggesting considerable sensitivity to pricing policy. This is also consistent with the Herriges and Phaneuf wetlands work.

This issue seems worthy of further investigation for at least two reasons. From a methodological perspective, modern travel cost studies have paid much greater attention to the time costs of travel. Smith and Kaoru [1990b] found that these decisions were important to the price elasticity estimates in the early work. This impact needs to be distinguished from one that suggests that increases in the implicit price of recreation have heightened the sensitivity of users to further price increases.

Second, we know very little about income elasticities. Costa's [1999] arguments were developed from the premise that the overall responsiveness of all recreation expenditures to income can be used to gauge rising standards of living. Estimates of income elasticities provide information on what individual preferences imply will be the types of recreation most likely to be affected by continued increases in real income.

Finally, it is worth noting that the elasticity concept in recreation is quite different than in other, more homogeneous commodities, and thus we should not be surprised by the range of estimates. The commodity definition itself between studies is highly variable, ranging over different activities and spatial definitions of "sites", and is typically based on the specific needs of the analysis. It is likely that these decisions (combined with the use of micro level data) contribute to the large and varying price elasticities found in recent studies. Likewise income impacts are less easily defined for recreation than other commodities, even when it is possible to estimate income elasticities. Income changes may in fact cause discrete changes in recreation behavior, such as moving to more luxurious or exotic activity/destination combinations, rather than the marginal effects captured by typical income response measures. Finally, efforts to estimate Hicksian surplus measures from incomplete Marshallian demand models have, as we develop below, forced analysts to impose restrictions that limit what can be learned about substitution and income effects in the interest of recovering a consistent measure for Hicksian consumer surplus (see LaFrance [1985, 1990] and von Haefen [2002]).

2.3 Policy Impacts

Policy uses of travel cost models have been extensive in the U.S. for at least the past thirty years. Three types of uses are especially noteworthy: project evaluation, resource management, and, most recently, damage assessment.

The first of these was the earliest and has continued. Generally it involves a public investment project, initially developed for hydroelectric dams with a mixture of outputs including power, flood control, and recreation. Sometimes a travel cost demand model for a site providing comparable recreation would be used to estimate the benefits from the new lakes created by the hydroelectric dam. Cicchetti, Fisher, and Smith's [1976] early analysis of downhill skiing in California was motivated by the larger task of evaluating the likely development benefits from Walt Disney Enterprise's proposed (at the time) development of a commercial ski resort at Mineral King, requiring access roads through the Sequoia National Park. More recently, the analysis requirements for federal re-licensing of hydro dams in the U.S. (under the Electric Consumers Protection Act of 2002) has generated interest among private power producers in the use of travel cost demand models to evaluate the recreation benefits from reservoir and downstream recreation.

Another recent area with direct policy application is EPA's proposed rulemaking associated with Section 316b of the Clean Water Act. This rule would establish national requirements that affect the location, design capacity, and construction of cooling water intake structures at power plants. A recent description of the economic analysis underlying the proposed Phase II regulations estimates recreational benefits from the improvements in catch associated with reduced losses to fish stocks through reduced entrainment and increased survival from cooling water facilities. The proposed rule uses a random utility model developed for the Ohio River and for several coastal regions. Measures of the per trip benefits from reducing impingement and entrainment were developed to estimate the recreational benefits of the regulations (relying on their impact on catch rates).

These policy uses are not exclusively confined to recent decisions. Indeed, the earlier benefit estimates for improving the catch of striped bass had a role in restricting the striped bass season to allow the stock to recover. Direct evidence for these uses can be found in the simple benefit-cost analysis of a moratorium on striped bass fishing that was presented and discussed as part of the Maryland legislative hearings leading to the Emergency Striped Bass Act.[8]

Somewhat surprisingly, travel cost demand models have not had an especially big impact in evaluating national water quality policies. Random utility models have been used to evaluate more site specific or regional policy issues, such as the reduction in sulfur dioxide emissions and associated acidic deposition (see Morey et al. [1990]) and non-point source pollution (Feather and Hellerstein [1997]). Travel cost (and contingent valuation) estimates have provided an important source of the monetary values for the recreation uses evaluated in the Forest Service's multiple use planning framework. Under the legislation defining the standards for forest management, recreation is to be given equal weight with sustainable harvesting of forest products.

Finally, the single most important recent role for travel cost models has been in natural resource damage assessments. Random utility models have played a key role in evaluating the effects of contamination and fish consumption advisories on the benefits associated with restoration. While much of this literature has not appeared in journals, it has nonetheless had a marked influence on the methodological issues associated with designing a random utility model.[9]

It is not clear that travel cost recreation demand models are having as large a policy impact outside the U.S. Pearce's [2000] review of environmental decision making in Europe identifies the travel cost method in his schematic outline of methods but does not provide specific examples where it has been used.

3. MODELING RECREATION BEHAVIOR

Our summary of travel cost models follows the evolution of the literature. We begin with a general description of models for individual choice and the assumptions that condition how restrictions on preferences and constraints influence what is learned from observable behavior. This section is developed independent of specific recreation models and is intended to motivate an evaluation of how modeling decisions constrain what can be learned about preferences. After this general overview, we outline the features of an ideal model and introduce the specific types of existing models. A detailed discussion of each class of model used in current recreation analysis then follows.

3.1 Modeling Preferences

The basic model for consumer choice used in recreation models begins with a general preference statement $u=u(\mathbf{x},q)$ and simple version of the budget constraint $m=\mathbf{p}'\mathbf{x}$, where $\mathbf{x}$ an n-vector of commodities, $\mathbf{p}$ is the corresponding price vector, m is household income, and q is some measure of environmental quality or a public good. When the analysis considers how q influences choice, the framework usually considers only one quality-differentiated, private good that is designated by one of the x's. When this static version of the consumer choice problem is adopted for outdoor recreation, prices do not result from a market exchange process. In the United States most site entrance fees are nominal charges, and the dominant component of price arises from the cost of traveling to a site.

This simple specification abstracts from time. In some consumer choice applications it is justified by arguing that $\mathbf{x}$, q, and m are rates -- quantities consumed by the individual per unit of time. This logic is inappropriate with outdoor recreation since the choice variables measure the use of recreation sites, requiring time to be introduced to characterize both the activities undertaken and the full costs of resource utilization. This need is accommodated by introducing a second constraint, the time budget, to the basic problem. The new constraint links a person's endowment of time to income via hours at work and activities involving time costs. Formally we can state the time constraint as $T=t_L+\Sigma t_i$, where T is total time available, t_{L} is time spent working, and t_i denotes the units of time allocated to the ith activity. Income is then given by $m=wt_{\mathrm{L}}+R$ where w is the wage rate and R is non-wage earnings.

Clearly something is still missing from this basic story. Although time has been added to the model it will not affect choices because it has not been related to $\mathbf{x}$, $\mathbf{p}$, or q. One approach to provide a connection is to identify the time costs associated with each of the choice variables $\mathbf{x}$ and consider simultaneously the allocation of time to leisure and earning income needed to sustain market consumption. This extension necessarily implies we confront the tradeoffs between consumption of goods versus leisure time. Data restrictions have generally required most studies to assume some type of separability between the labor-leisure choices and goods consumption, or make simplifying assumptions concerning how individuals exchange time for money. This may in fact unrealistically constrain estimated preferences. When we consider the role of leisure, we often focus on time allocated to trips and not leisure as an argument of utility. Separability of labor/leisure choices from commodity choices implies that all goods are equal substitutes for leisure. In the case of recreation trips we might argue that the relationship is more likely to be one of complementarity. Thus, the separability restriction is important in limiting the relationship between goods and time consumption, and in the implied nature of the budget allocation process.

Becker's [1965] early description of the household production function (HPF) model and its role in how people allocate time is a useful pedagogical tool for summarizing how constraints on behavior are combined to structure implicit prices of each consumption choice. As specific examples of structural assumptions we consider ideas set forth by Bockstael and McConnell [1983], Larson and Shakh [2001], Provencher and Bishop [1997], and Blundell and Robin [2000] using the HPF framework. In each case our goal is to demonstrate how the different structures imply different implicit prices for recreation, which in turn condition what observed behavior can reveal about preferences.

In a simple HPF model an n-vector of final consumption goods **z** is produced in the household by combining time and purchased inputs. Suppose technology is given by the linear relationships

$$\begin{aligned} z_i &= a_i x_i \\ z_i &= b_i t_i . \end{aligned} \tag{3.1}$$

The preference function is now a function of **z** given by $u(\mathbf{z},q)$, where q is in this case linked to one of the z_i's. With other assumptions (e.g. weak complementarity and essentiality in production) Bockstael and McConnell [1983] demonstrate how some aspects of the amenity contribution to consumer values can be isolated.[10] Under the HPF model the consumer choice problem becomes

$$\begin{gathered} \max_{\mathbf{z}} u(\mathbf{z}, q) \quad s.t. \quad wT + R = \sum_i \mathit{p}_i z_i \\ \mathit{p}_i = (w/b_i) + (p_i/a_i). \end{gathered} \tag{3.2}$$

The p_i's can be thought of as exogenous implicit prices for a unit of z_i dependent upon the market prices p_i and w of the two inputs -- market inputs (x_i) and time (t_i). However, if we replace the fixed coefficient HPF with a neoclassical specification, the budget constraint becomes a more familiar looking cost function $wT+R = C(\mathbf{z},w,\mathbf{p})$, and Pollak and Wachter's [1975] argument on the limitations in the framework becomes more apparent. Prices may not be constants and may be functions of multiple *z*'s. While it is possible to argue for local linearization of the cost function, the key point is that we don't escape the need to impose structure on the technology to identify the features of preferences and construct the implicit prices for recreation. Also, this structure implies that time can be valued using the wage rate and that the income constraint corresponds to "full" income where all potentially saleable time is monetized.

In contrast Larson and Shakh [2001] present a two-constraint version of the model that implies a different time/good complementary relationship, and thus a different structure of the implicit prices for the recreation services. In their model the two constraints are separately maintained, with time and income budgets pre-determined from a non-modeled first stage allocation. The dual constraint consumer problem is formally given by:

$$V(m,T,q,p,a,b) = \max_{x} \; u(z,q) + l\left[m - \sum_{i}(p_i/a_i)z_i\right] + m\left[T - \sum_{i}(1/b_i)z_i\right], \quad (3.3)$$

where λ and *m* are the money and time constraint Lagrange multipliers and, for comparison, we maintain the technology structure from equation (3.1). We can recover the demand for recreation services z_i using the two forms of Roy's Identity:

$$z_i = \frac{-V_{p_i/a_i}}{V_m} = \frac{-V_{1/b_i}}{V_T}. \quad (3.4)$$

The two constraints imply there are two Slutsky symmetry conditions: one each for the equality of cross money-price and cross time-price effects. These conditions suggest a specific structure on how choices respond to the relative scarcity of time and money. The implicit price of recreation is a function of the market price of the purchased input, and an endogenously determined marginal cost of time given by the ratio of the Lagrange multipliers.

These two structures offer examples of mechanisms that control income and substitution effects in empirical models based on them. In the extreme of the Leontief technology of the first structure there is no substitution between goods and time in production. As a result, marginal costs of produced services are fixed multiples of prices and wages. Larson and Shakh relax the link between commodity prices and wages and the opportunity cost of time, yet here too potentially relevant constraints are not considered. Both models assume that each unit of the good consumed is temporally exchangeable with the other units (and independent of the past stock of experiences). However, a key feature of recreation behavior is its dependence on both the amount and the timing of available time. Time cannot be directly stored, although time can be indirectly transferred between periods by shuffling commitments. In addition, in any particular interval there are limits to how time can be used. For example, there are only so many hours of daylight, although Bresnahan and Gordon [1997] note that artificial light has changed the nature of this constraint. Furthermore free time is often available only in discrete bunches due to fixed work schedules and other commitments. This constrains the feasible choice set for allocation in a given interval. Each of these examples suggest that time is not the perfectly fungible commodity implied by the static and linear time budget constraint.

It is possible to spell out these temporal details in a dynamic framework as proposed by Provencher and Bishop [1997], following the Rust [1987] stochastic, discrete, dynamic optimization structure. However, to do so requires extensive information about how time constraints differ among people. In the Provencher and Bishop analysis, recreation consumers maximize the sum of expected current and discounted future utility subject to inter-temporal constraints. Preferences are time separable and stochastic due to the assumption of unobserved heterogeneity. Both the preference function and budget constraint are linear and defined over each day of the season. While their conceptual approach is clearly relevant to concerns about how conventional models treat time, the framework's ability to deal with them depends on whether the analyst can specify sufficiently rich time-related constraints to capture the effects of substitution through time. That is, does the available information and temporal structure imply implicit prices for recreation that are significantly different from the static models in their ability to capture the temporal effects limiting choice?

Related to this question, there are situations in which it is unreasonable to assume that people have time separable preference functions consistent with discounting. Instead, they behave in a choice context that "brackets" choices in time. Current choices are influenced only by contemporaneous or relatively near term alternatives. Read et al. [1999] describe choice bracketing based on a wide array of simple psychological "experiments" that examine choice behavior. They observe that bracketing effects are most likely cases of temporal bracketing. If their conjecture is plausible, it does not necessarily require we discard constrained utility maximization. Rather, it implies future research should investigate alternatives to the simple discounted, time separable specifications for preferences.

Our final example on the role of structural assumptions is based on Blundell and Robin's [2000] latent separability. This restriction is a generalization of weak separability, and serves to demonstrate how separability assumptions condition what can be learned from static behavior. Latent separability implies that purchased commodities can contribute to multiple household activities, provided at least one good is exclusive to each activity. For example, in water recreation boat ownership can be used to produce both fishing and water skiing experiences and thus can be expected to enter both production technologies. Nonetheless, the specific gear used in each activity is exclusive. This restriction (e.g. exclusivity of gear), together with homotheticity, can be used to recover price indexes for each household activity.

To illustrate how this impacts the pattern of substitution relationships, define $\tilde{x}^1$ as the demand for the exclusive good in one of these activities. Under latent separability the demand structure is given by

$$\tilde{x}^1 = g\left[p_{x_1}, \bar{p}, s_1\left(p_{x_1}, \bar{p}_x, \bar{p}, m, q \right) \right], \tag{3.5}$$

where p_{x_1} is own price, $\bar{p}$ is a vector of prices of the goods used in other activities as well as in this first activity, $\bar{p}_x$ is a vector of prices of goods exclusive to other activities, and s_1 is expenditures for the activity. Notice that p_{x_1} and $\bar{p}$ enter the demand function directly while $\bar{p}_x$ enters only the function $s_1(\cdot)$ describing the expenditures on goods contributing to the first activity. This relationship allows the cross price effect of any $\bar{p}_x$ and income m on the demand for $\tilde{x}^1$ to be used to recover how prices affect the allocations to activities as distinct from the demand for specific goods. This is illustrated for the jth element in the set of exclusive goods ($j \neq 1$) by the following equations:

$$\frac{\partial \tilde{x}^1}{\partial \bar{p}_{x_j}} = \frac{\partial g}{\partial s_1} \frac{\partial s_1}{\partial \bar{p}_{x_j}} \tag{3.6a}$$

$$\frac{\partial \tilde{x}^1}{\partial \bar{p}_{x_j}} = \frac{\partial g}{\partial s_1} \frac{\partial s_1}{\partial \bar{p}_{x_j}}. \tag{3.6b}$$

The ratio of these two partial derivatives provides information about the allocation process among activities as distinct from the properties of the individual demands. Repeating this for each exclusive good and using the second derivative properties of these ratios, we have sufficient restrictions to identify and re-construct the pattern of substitutions among goods.[11]

Weak separability is useful in cases where we can itemize a set of goods and services always used together. Blundell and Robin's logic shows that separability requirements need not be this limiting. One exclusive good (or service) per activity is often sufficient to inform (and restrict) the pattern of cross price elasticities in a set of demand functions. When combined with homotheticity, this restriction allows the definition of aggregate price indexes and does not impose the strong restrictions on income elasticities associated with homothetic weak separability. In the recreation context we can consider the impacts of this structure for how time and monetary constraints combine. For example, under this view the implicit price of a trip would be a latent variable that is not determined by a process exogenous to the individual's choices but rather as a reflection of those choices. This was Randall's [1994] basic point and provides a rationale for the Englin and Shonkwiler's [1995] proposal to treat travel cost as unobserved.

To this point we have said little about the modeling issues concerning the vector of amenities q, usually interpreted as attributes of recreation sites. The conceptual literature has focused primarily on the role of quality with a single private good (Bockstael and McConnell [1993, 1999]) or treated the quality attributes of each site as being linked to that site.[12] The linchpin of most travel cost demand approaches for linking quality attributes to preferences is weak complementarity. Introduced by Mäler [1974], this preference restriction maintains that the only means of deriving satisfaction from quality follows from consumption of the private, weakly complementary good. Thus, if x_j is related to q via weak complementarity the marginal value of q is zero when x_j is zero:

$$\frac{\partial}{\partial q}\left[u(x_1, x_2, ..., x_{j-1}, 0, x_{j+1}, ...x_n, q)\right] = 0. \tag{3.7}$$

This can be represented in equivalent terms with either the indirect utility function or the Hicksian expenditure function

$$\frac{\partial}{\partial q}\left[V(p_1, p_2,..., p_j^c,...p_{n,}m,q)\right] = \frac{\partial}{\partial q}\left[e(p_1, p_2,...\tilde{p}_j^c,...p_n,u,q)\right] = 0, \qquad (3.8)$$

where p_j^c and $\tilde{p}_j^c$ are the choke prices for the Marshallian and Hicksian demand respectively. These definitions assume that the choke prices exist or, equivalently, that the private good x_j is not essential.

The formal definition of weak complementarity can be explained further with Figure 3.1. In this graph the indifference curves relate the recreation good x on the horizontal axis to spending on all other goods z on the vertical axis. The curves are drawn to represent the same level of utility but each corresponds to a different level of the amenity q. That is, in this case each group of indifference curves varies the amenity while holding utility constant (e.g. $q_0 < q_1 < q_2$ and $\bar{U} = \bar{U}(q_0) = \bar{U}(q_1) = \bar{U}(q_2)$ and $\tilde{U} = \tilde{U}(q_0) = \tilde{U}(q_1) = \tilde{U}(q_2)$ with $\bar{U} < \tilde{U}$). Increases in the level of the amenity reduce the amount of x_j and z needed to reach the reference utility level. The "fanning" property of the graph arises from the non-essentiality of x and its weakly complementary relationship with q.[13] Thus, all curves meet at the point x=0. Movements between the curves in each group therefore do not reflect changes in income or well being (all the curves intersect at one income level on the vertical axis), but rather the substitutability between trips, the amenity, and spending on other goods. This property allows us to describe how changes in the amenity level, conditional on the pictured level of income, affects the tradeoff between the private goods x and z.

Weak complementarity restricts preferences such that a change in quality (or the public good) can be converted into an exact equivalent change in the price of the weak complement. As we discuss in section 6, this is a necessary condition for welfare analysis in recreation models. Smith and Banzhaf [2004] illustrate this preference restriction by showing that consumer surplus for a price change in general can be depicted using the spacing of the pivoted budget constraints describing the price change. For example, figure 3.2 shows an indifference map between two private goods with no quality dimension. For the case of a price increase for *x* the average of the distances CD and BA gives a first order approximation to the Marshallian surplus for the implied price change.

The indifference map in figure 3.3 shows how weak complementarity allows definition of the price change for the private good serving as the weak complement that is a Hicksian equivalent to the quality change. Utility is held fixed in the fanned indifference curves $\bar{U}$ as quality increases from q_0 to q_1. The quality change is represented as a price change by finding the price lines that are tangent to the two curves corresponding to q_0 and q_1. Since the utility level is fixed, the price change is a Hicksian equivalent change. That is, the price change is the amount by which the price of the weak complement would need to rise to maintain utility at the same reference level when there is a quality increase. A first order approximation to the Hicksian surplus for the price (and equivalently, the quality) change is given by the average of the vertical distances DC and AB.

Since we are not able to observe the Hicksian demand for the weak complement we must consider how the quality change is equivalent to an observable Marshallian price change leading to a new level of utility. This is shown in figure 3.3, where the price line tangency with $\tilde{U}(q_1)$ is for the higher quality but a new level of utility. The analysis of the average implied change in consumption of *z* at these two levels of the weak complement for the same price change is observable with a Marshallian demand. By including one further assumption restricting the size of income effects, it is possible to also recover the Hicksian welfare measure for the change in *q*. Typically this requires the Willig [1978] condition, discussed by Bockstael and McConnell [1993] and Palmquist [2003]. We develop this role for weak complementarity and the Willig condition in the context of welfare measurement in further detail in section 6.

3.2 An "Ideal" Implementation of the Basic Model

The prices for recreation goods are best interpreted as implicit prices that reflect a combination of monetary and non-monetary constraints limiting the consumer's choice at a point in time and over time. Each of the models in the literature constructs these implicit prices with different judgments on what are the most important monetary and non-monetary aspects to include. Thus, we begin with a baseline for comparison and specify a wish list of the most desirable features to include in a model of recreation choice.

Nearly all economic approaches for describing recreation behavior seek to estimate the Hicksian consumer surplus for some change in the access conditions or quality of recreation sites. Thus, an ideal model should allow Hicksian surplus measures to be recovered, requiring that we estimate structural parameters. Equally important, a desirable modeling strategy is one that recognizes a wide array of substitutes, including both substitute recreation sites and other uses of money and time. Since each individual is unlikely to be observed consuming all available substitutes during a single time horizon the model must allow for non-consumption or corner solutions, with the further possibility of changes that would imply a switch from non-consumption to positive consumption if one or more attributes change. Related to this feature, a consistent description of the participation decision requires some limitation on the use of separability. The model should describe the tradeoffs between outside goods and the recreation sites of interest, and allow changes in this tradeoff when access and quality conditions of the recreation sites change.

The model should consistently link site characteristics to site choices. Some site conditions, such as congestion, cannot be known in advance. Others are learned with experience. The process linking *ex ante* site quality perceptions and how these are modified with experience could be an important part of explaining some types of recreation behavior. These connections reflect a temporal learning process that may influence subsequent decisions. Related to this, short-term disruptions to a site's quality conditions can lead to inter-temporal substitution.

This is a long and demanding list of requirements and none of the available modeling frameworks can deal with all of them. Nonetheless, the literature has made impressive progress. For our description we identify five approaches to recreation demand modeling. The earliest of these are the single equation demand studies for individual recreation sites. These have largely disappeared from the literature, except in applications involving joint estimation with stated preference data or when they are used to illustrate some new econometric or modeling twist posed by available data, such as the work motivated by count data methods.

Recognition that a single, independent recreation site rarely exists led early researchers to consider demand system models for recreation sites (e.g. Burt and Brewer [1971]). Current literature focuses on the theory underlying incomplete and partial demand models to consistently recover preference functions appropriate for calculating Hicksian welfare measures (see LaFrance [1985, 1986, 1990] and von Haefen [2002]). Recent efforts have used these insights in extending single equation count data methods to multiple equations (Ozuna and Gomez [1994], Shonkwiler [1999], von Haefen and Phaneuf [2003]).

By almost any reckoning McFadden's [1974a] random utility maximization (RUM) model has become the workhorse of modern recreation demand modeling. One reason for this widespread adoption is the ability of the model to consistently deal with substitution, non-consumption, and non-market quality attributes in ways that offer measures of Hicksian consumer surplus. Nonetheless, limitations in the ability of random utility models to estimate seasonal benefits measures have led to research in Kuhn-Tucker (KT) models of recreation demand (e.g. Phaneuf, Kling, and Herriges [2000], Phaneuf [1999]). These models attempt to combine the desirable aspects of both the systems approach and the RUM model by adopting the generalized corner solution framework as the organizing principle. The last category of models can be loosely organized under the category of price index frameworks and uses the idea that with a quality-adjusted price index, the choice from a set of heterogeneous sites requires finding the one with the smallest quality adjusted price. Models in this category range from some ad hoc models of the demand for recreation sites or site characteristics to behavioral models comparable to the corner solution models.

3.3. Structure of the Primary Empirical Models Describing Recreation Demand

In this section we describe the critical features of each category of model identified above. We focus primarily on the economic issues outlining each model and discuss briefly the most important econometric issues that can arise in implementation. Later in the review we deal more specifically with econometric issues.

A. Single equation and demand system travel cost models

The earliest travel cost research used single equation models with aggregate, zonal data; more recent applications have almost exclusively used individual or household level data.[14] Single equation demand models have a simple specification $x=f(c,m,S)$ where x is total trips specified as a function of travel cost (*c*), income (*m*), and group or individual characteristics (*S*). Measures of recreation site quality are generally omitted because there is little ability to observe variations in site quality for a single site over a season.[15] Implementation of this model involves two classes of economic judgments: variable definition and measurement along with demand function specification and estimation. In the first class the most important decisions involve the opportunity costs of time, the role of on-site time (Shaw [1992], McConnell [1992]), and trip cost and multiple objective trips (Haspel and Johnson [1982], Mendelsohn et al. [1992], Parsons and Wilson [1997]). Judgments on specification and estimation relate to the evolution of single site models to system models. Included in this class are issues such as the treatment of substitutes and the role of on-site and substitute site quality, as well as restrictions necessary to recover estimates of preference functions from both single and multiple site models. We consider each of these decisions in turn.

Time, its opportunity costs, and its role in the demand for trips remain unresolved questions in recreation modeling. The most common practice is to value travel time at the wage rate or some fraction thereof. There has been and continues to be criticism of this practice (see Smith et al. [1983], Shaw and Feather [1999]), as well as alternative suggestions (e.g. Bockstael, Strand, and Hanemann [1987], Feather and Shaw [1999]), but little consensus on how this practice should be replaced.

Other sources provide more complete overviews of the development of the literature on the opportunity cost of time. We limit attention to two proposals for measuring these opportunity costs as a latent variable. First, Englin and Shonkwiler [1995] treat the various determinants of site visitation costs as components of a latent variable. The latent cost variable is estimated using distance converted to money travel costs, travel time, and the wages lost in travel as indicator variables. The approach uses factor analysis to estimate travel costs. These latent travel costs are measured with error that is assumed independent of the trip demand. Their proposal could be generalized with consideration given to variables describing time availability (e.g. vacation days), non-wage income, household composition, or any other demographics characteristics. However, it requires sufficient restrictions to identify the parameters of the latent cost function that are typically not available from theory.

Second, Feather and Shaw [1999] adapt Heckman's [1974] strategy for estimating the shadow wage by using contingent behavior questions about respondents' willingness to work additional hours along with actual working decisions. Individuals have either a flexible work schedule or are over or under employed in a fixed work schedule. Stochastic wage and shadow wage functions are specified as functions of exogenous variables, and, in the case of the shadow wage, hours worked. The relationship between the wage and shadow wage is determined by categorizing each individual's work schedule. With flexible work schedules hours are adjusted until the shadow wage is equal to the market wage. For over-employed individuals the fixed hours constraint implies the market wage is bounded from below by the shadow wage at zero hours worked and from above by shadow wage at current work hours. The relationship between the shadow and actual wages is then translated to a probability statement, and with contingent choice data, it is possible to use a maximum likelihood estimator to recover the structural parameters of the shadow wage equation. Feather and Shaw use predictions for each individual's hourly opportunity cost of time to construct the time cost component of prices to recreation sites.

Both approaches find results close to the simpler strategies. With Englin and Shonkwiler the estimates for opportunity cost of time are close to one-third of the wage rate. For Feather and

Shaw the shadow values are closer to the market wage. Although formal tests were not conducted, the results for both studies seem to imply that welfare estimates from either method would fall within the ninety-five percent confidence interval of the other more approximate methods based on the use of one-third of the wage rate. Thus, although some progress has been made in estimating individual's opportunity costs of time, we still lack a compelling replacement for the ad hoc strategies that dominate most recreation demand applications.

On site time also remains controversial. For conceptual purposes we can think of the challenges posed in modeling the role of on site time as consisting of two related components: addressing the endogenous nature of trip length and accounting for the opportunity cost of time spent on site. The latter issue is closely related to our previous discussion, although little work exists addressing specifically the measurement of the opportunity cost of on site time as distinct from travel time. The former issue is extremely difficult to deal with conceptually in that the distinction between the price and quantity of the recreation good blurs, resulting in a non-linear budget constraint and endogenous prices. Most recreation studies avoid the issue completely by assuming there is a constant (and exogenously given) amount of on site time necessary to produce the recreation experience. Alternatively, one might assume, as McConnell [1992] argues, that traditionally estimated demand equations can produce valid welfare measures in the face of endogenous on site time if there is an exogenously given "price" of on site time.[16]

The premise of the travel cost model is that the value of access to a site can be developed using the costs associated with getting to the site. This strategy requires that the resources given up in travel are for the single purpose of visiting the site of interest. Haspel and Johnson's [1982] early research identified concerns over violations of this assumption due to multiple purpose trips. If multiple objectives are satisfied in a given trip, then we can not attribute all resource costs to the site of interest for analysis. More recent research from Mendelsohn et al. [1992] has followed up on this by suggesting that multiple objective trips involving a set of recreation sites be defined as one commodity and included in the demand structure. This strategy precludes measuring benefit changes in aspects of the individual sites and does not describe why these composites were selected. Parsons and Wilson [1997] suggest treating the incidental activities as weak complements to the main activity of interest and allowing these benefits to be folded into the value of the main activity. This strategy involves making judgments on the importance of the collateral activities. It is unlikely to be appropriate when a primary activity cannot be identified or if there are substantial resource costs with the bundle of activities being considered. One future direction in this research will be to expand the definition of commodities modeled by including a recreation site as an individual objective and perhaps the same site as a component of a bundled objective containing other sites, with the appropriately defined prices for each.

The travel cost demand literature recognized early on that a single recreation site rarely exists and that usually there are substitutes available for any given recreation site. This motivates our second class of economic decisions, centered on judgments about specification and estimation. Concern about the effects of substitute sites motivated the first system of demand equations work. Early examples of this include Burt and Brewer [1971] and Cicchetti, Fisher, and Smith [1976]. Enthusiasm for the systems models waned due to estimation and conceptual issues. Moreover, Hof and King [1982] and Caulkins, Bishop, and Bouwes [1985] argued that it is not necessary to estimate a systems model to account for the effects of substitute site prices and quality measures in benefit estimates when interest centers on a single site.

Because there are often no measures of differences in the site quality conditions during the course of a season, a common practice has been to combine results experienced by different people at different sites. Two approaches can be found in the literature. Both are ad hoc. The varying parameter model (Vaughan and Russell [1982], Smith and Desvousges [1985]) assumes the parameters of individual site demand models are functions of site characteristics. A second group of studies uses regional demand models (Loomis, Sorg, and Donnelly [1986]) where recreation trip information for multiple sites is pooled and a simple demand model is estimated. The model can include site characteristics and has been specified with ad hoc measures of substitutes. Neither approach provides a consistent or utility theoretical link from choice to empirical demand analysis.

The emphasis on a utility theoretic link between the choice of specific recreation sites and their characteristics has motivated renewed attention to system estimation in recent literature (e.g. Shonkwiler [1999], Englin et al. [1998], von Haefen and Phaneuf [2003]). These studies employ the incomplete (or, more accurately, complete with an asymmetric structure) demand system strategy (LaFrance and Hanemann [1989]) to recover estimates of consumer preferences from a system of recreation demand equations by imposing the so-called "integrability conditions" on the functional form of the demand system. As LaFrance [1985, 1986, 1990] points out, these conditions essentially require a choice between allowing income effects or Marshallian cross price effects. LaFrance and Hanemann [1989, p.272] suggest "…it is generally impossible to measure unequivocally welfare changes from non-market effects using incomplete systems of market demand functions". This may in fact be too harsh a judgment. By specifying prices as quality-adjusted repackaging functions (Willig [1978]), von Haefen and Phaneuf [2003] show it is possible to link the non-market good to the private good in a utility consistent manner. Nonetheless these models are limited in their ability to parametrically capture substitution and income effects, and further investigation of utility-consistent techniques for linking the private and public goods is needed.

B. Random utility and related models

Introduced by McFadden [1974] and first applied to recreation models by Hanemann [1978], random utility maximization (RUM) models have become the dominant approach for describing consumer preferences for recreation.[17] Research in this area is so extensive that it is impossible to do justice to all of it, so we focus on four issues: the structure of the choice process, including the impact of error distribution and commodity definition decisions on preference estimates; the choice set definition, including the impact of expansive versus limited approaches to defining the available sites; nonlinearities in income, including discussion of the technical and conceptual challenges of allowing income effects in RUM models; and the link to seasonal demand.

The random utility model describes extreme corner solution decisions -- a choice of only one of a finite number of alternatives within a limited time horizon. Hanemann [1984, 1999] provides a careful description of the economic and institutional assumptions that link the RUM choice process to conventional demand and welfare analysis. Preferences are assumed to include a random component reflecting unobserved heterogeneity (from the analyst's perspective) in individual tastes.[18] The model begins with the specification of an individual's conditional indirect utility function for choice alternative k, in period t:

$$v_{kt} = V(m_t, p_k, q_k, e_{kt}), \qquad (3.9)$$

where m_t is the person's income or budget relevant for period t, p_k is the person's price to acquire alternative k (a recreation site visit), q_k is the vector of characteristics for site k and e_{kt} is the error. Price and quality can also be assumed to change with the time period of choice; typically, however, data have not been available to make this distinction.[19]

The RUM structure treats site choice as a separable process that is unaffected by other consumption decisions, except indirectly through the definition of choice occasion income. The decision rule is therefore simple: the consumer selects the choice alternative *k* that has the maximum utility for a given choice occasion. Formally this is given by

$$\underset{k \epsilon K}{Max}\left[V\left(m_{t}, p_{k}, q_{k}, e_{kt}\right)\right], \tag{3.10}$$

where *K* is the set of all choice alternative available. The analyst cannot observe e_{kt} and must also make assumptions about the form of the conditional indirect utility function. Empirical implementations of the framework rely on modeling the probabilities that each choice alternative is selected.

McFadden's development of the model assumes either a type I extreme value or a generalized extreme value distribution to describe the error. When the errors are assumed to be additively separable in equation (3.10), both specifications yield closed form expressions for the choice probabilities and permit maximum likelihood estimation. In the case of linear, separable, and independent type I extreme value errors these probabilities are given by

$$p_{kt} = \frac{\exp\left(\bar{V}\left(m_{t}, p_{k}, q_{k}\right)/t\right)}{\sum_{k \epsilon K}\exp\left(\bar{V}\left(m_{t}, p_{k}, q_{k}\right)/t\right)}, \tag{3.11}$$

where $V(m_t, p_k, q_k) = \bar{V}\left(\cdot\right) + e_{kt}$ and t is the scale parameter for the type I error.

The choice of error distribution in the RUM model constrains the substitution relationships among choice alternatives and the role of unobserved heterogeneity. The correlation structure among the random utilities that derives from similarities between the choice alternatives plays a role akin to what the restrictions on functional structure and constraints did in our description of the basic recreation model. In that case they reduce the dimensionality of the Slutsky matrix and restricted substitution relationships. Here, the assumptions about the error control the degree of substitutability between choice alternatives.

The independent and identical type I extreme value errors model is the simplest version of the RUM and implies the unobserved heterogeneity is independent across choice alternatives. This formulation maintains a person's choice process contains no unobserved elements that are common to each of the alternatives available; hence the random utilities realized are uncorrelated and do not reflect any stochastic substitution. This specification requires behavior consistent with the independence of irrelevant alternatives (IIA) condition, which arises when the ratio of an individual's choice probabilities for any two alternatives is unaffected by the systematic utilities associated with any of the other possible selections in the choice set.[20] As Ben-Akiva and Lerman [1985] suggest, IIA should be evaluated based on whether the specification adequately describes the unobserved heterogeneity of the individuals being modeled. For IIA to hold, all systematic relations between choice alternatives must be captured in the deterministic component of the random utility function.

Nested logit models employ the generalized extreme value distribution. They allow for correlation among the alternative utilities and hence non-zero stochastic substitution. This process requires grouping the available choice options into "nests" containing alternatives considered more similar. The extent of the correlation for the utilities of alternatives within a group is related to the relative size of the dissimilarity coefficient q_L. As the coefficient approaches one, the model collapses to a conventional multinomial logit, while values approaching zero imply higher levels of correlation. For example, a nested logit model with a two-level nest has probabilities of the form:

$$p_L = \frac{\left[\sum_{je J_L} \exp\left(V_{Lj} / q_L\right)\right]^{q_L}}{\sum_{me M}\left[\sum_{je J_m} \exp\left(V_{mj} / q_m\right)\right]^{q_m}} \qquad (3.12)$$

$$p_{i|L} = \frac{\exp\left(V_{Li} / q_L\right)}{\sum_{je J_L} \exp\left(V_{L_j} / q_L\right)},$$

where p_L denotes the probability of being in nest L, J_m denotes the set of alternatives in nest m, and $p_{i|L}$ is the probability of choosing alternative i conditional on nest L selected. The unconditional probability of choosing an alternative is given by by $p_{iL}= p_L \cdot p_{i|L}$. Considering two sites within the mth nest, Ben Akiva and Lerman [1985, p 287-290] demonstrate the correlation between their utilities is controlled by the size of the dissimilarity coefficient.

The nested logit is a restrictive model. As Morey [1999] points out, changing the error assumption to a generalized extreme value distribution does not eliminate IIA. It controls the patterns of interaction among alternatives. The ratio of an individual's choice probabilities for two alternatives will exhibit IIA for alternatives within the same group, and for alternatives in different groups if the alternative changing is not in either of the two groups represented by the pair. Of course, changes in alternatives in groups represented by the pair will impact the ratio of choice probabilities and thus do not adhere to IIA. It is important to recognize Morey's point as a conceptual one. We never actually observe information that would be necessary to test IIA for these nested components of the choice model. From the perspective of what we can observe – the choices among alternatives – the nested specification does relax the IIA assumption.

Correlation among random utilities is one of the motivations of Train's [1998] random parameter, or mixed logit model. Because the parameters of the deterministic proportion of the model are replaced with random coefficients that incorporate individual heterogeneity, the random component of each parameter will be shared across choice alternatives and very general patterns of correlation (and, as a result, substitution) will be possible. Herriges and Phaneuf [2002] use this insight to propose specific patterns of correlation by including random coefficients for dummy variables that vary by individual but are shared across choice alternatives. Allowing parameters to change is a more direct approach to controlling how the analyst specifies correlation (and thus ex ante substitution) in this framework.

The second dimension of the choice process incorporated in the random utility framework involves the link between choices through time in multiple choice occasion applications. As a rule, this is handled by assuming each choice occasion is independent. Income is arbitrarily distributed across these occasions. The income per choice occasion is important because it reflects how the prices of non-modeled goods impact choice. For repeated choice occasion random utility models there is no mechanism to introduce diminishing marginal rates of substitution. This is an important limitation because we normally expect that diminishing marginal utility of commodities is a key element in the explanation for substitution.

The last choice process issue is the definition of a choice alternative, which overlaps with issues of choice set definition discussed next. Definition of the choice alternative is equivalent to the specification of the commodity in ordinary demand analysis, and contributes to whether IIA or some nesting structure adequately describes substitution. Most studies use individual sites, aggregations of sites, or spatially defined areas as the choice alternatives. Kaoru and Smith [1990] first raised the issue of the effects of site aggregation on RUM models and their valuation measures. Subsequent work by Parsons and Needelman [1992], Feather [1994], Lupi and Feather [1998] and Kaoru et al. [1995] has been interpreted in some of the literature as yielding conflicting results, with the Kaoru et al. work typically found to be in conflict with the other findings. This view is somewhat misleading in that the different studies employ different aggregation strategies: simple and statistical aggregation.

Consider first the statistical aggregation approaches. Here the aggregate site arises as an average of the conditional indirect utility functions of the elemental alternatives. Trips, prices, and site characteristics are recorded for the individual sites, but are aggregated for the purposes of modeling and estimation. Implicit in this definition is the assumption that the elemental sites represent the correct commodity definition. This general structure describes Parsons and Needelman [1992], Feather [1994], and Lupi and Feather [1998]. The results suggest aggregation without accounting for heterogeneity parameters (i.e. the number of alternatives in each aggregate and the diversity in site attributes) can lead to substantial biases in estimates relative to estimating the model with the commodities defined as the individual sites.

Simple averages, by contrast, collect sites into spatial aggregates and do not assume information about the diversity in the values of attributes across elemental sites is known. Trips, prices, and site characteristics are recorded or measured for the spatial aggregate as if it were the true commodity being considered by the individual. Studies have typically compared welfare effects for specific applications and presented these as case studies. Some observations are possible from these, although without knowledge of the true commodity definition is it is difficult to know the best strategy in general.[21]

The consensus in the literature seems to suggest that welfare estimates from aggregated models exceed those from disaggregated models for quality changes that are constrained to be comparable across versions of the model. This popular view is probably too simple. Feather [1994], using simple averages, finds aggregate estimates to be about sixty percent of the compensating variation from the full model. This result is in agreement with Kaoru et al. but in contrast to Parsons and Needelman. Looking closer at the details of these studies, however, we find important distinctions in the aggregation of quality measures that can have direct implications for the possibility of constructing comparable policy changes across models.

For example, in the Parsons and Needelman disaggregate model, the fish species and water quality variables are all qualitative values indicating presence or absence of a species and extreme water conditions at individual lakes. These measures become proportions in the aggregate model. In the policy scenario proportions are set to zero to mimic the loss at the disaggregate level. In contrast, the Feather, Lupi and Feather, and Kaoru et al. studies use quality measures that are continuous. The translation from disaggregate to aggregate variables depends upon what each study assumes is known by the analyst. Thus, the policy scenarios need not be numerically equivalent.

The main message from these comparisons is one of caution. The majority of comparisons include substantial doses of judgment on the part of the researcher to arrive at the overall results. As a result, at this point we probably can not conclude unequivocally how the choice alternative aggregation affects welfare measurement, nor can we say much in general about the appropriateness of aggregate versus individual site commodity definitions. These decisions will likely continue to be based on the specific application and needs of the study.

In an innovative twist, Lupi and Feather consider partial aggregation as an alternative to complete disaggregate or aggregate models within a nested framework. Their approach treats popular and policy relevant sites as distinct alternatives with other sites treated in a variety of different aggregates. It parallels distinctions in ordinary demand models where price aggregates are used to represent a class of substitutes.

Their argument fits nicely into our suggestion that preference restrictions and constraints can be thought of as implying different implicit prices. Here the inclusive values associated with each of the nests in the various aggregation strategies can be thought of as different strategies for collapsing the information relevant to the individual's choice. Moreover, the extent of each model's stochastic substitution captured by the nesting of aggregate alternatives can be judged by the size of the square of the estimated dissimilarity parameters. Overall, this comparison suggests modest differences in implied substitution across the alternatives. Nonetheless, some of their findings suggest measures for the most aggregate models are smaller than the disaggregate and others the reverse outcome, implying the specific details of the aggregation of quality attributes and travel costs are likely to be important to interpreting any overall conclusions on site aggregation.[22]

Table 3.1 provides a detailed overview of the features and conclusions of studies evaluating the effects of analyst-imposed restrictions on the choice set. As in the case of the site commodity definition, it is difficult to extract many general conclusions from these studies because the evaluations are case studies and the points of comparison are the unobservable benefit measures. The evaluations focus on the sensitivity of estimated benefits to the choice set decisions, typically in relation to a broad or general choice set that could be defined for each application.

With these caveats, it appears choice set definitions reducing effective substitutes lead to increases in per trip welfare measures of quality changes or site losses.[23] This tendency includes nesting structure or other decisions that affect the correlation in random utilities for choice alternatives. The Parsons, Plantinga, and Boyle [2000] comparison of alternative "surgical" definitions of choice sets (in which the choice set is reduced by aggregating what are judged by the analysts to be policy irrelevant sites, while keeping sites of direct policy interest and their close substitutes as individual choice alternatives) also conforms to this general tendency. Indeed the only notable exception can be found in Kling and Thompson [1996]. Their nested models exhibit large differences in benefit measures for all the policies considered across the different nesting specifications. Hauber and Parsons [2000] and Jones and Lupi [1997] have contrasting results.

Three factors may help to explain these discrepancies. First, the most outlying welfare estimates for Kling and Thompson arise from models whose estimated dissimilarity parameters are likely to be outside the Börsch-Supan [1990] range for utility theory consistency, as developed by Herriges and Kling [1996]. Indeed, the authors acknowledge this issue. Second, their salt water fishing application has direct implications for the interpretation of their choice set. For private boat and charter boat models, the actual site alternatives are extensive. The identified sites are in some cases launch points.[24] This discrepancy between what can be observed and the actual site alternatives may be less dramatic for some of the fresh water applications considered by Parsons and his collaborators. Finally, the sites in Kling and Thompson have substantial differences in costs largely independent of travel distance that arise from mode (e.g. boat fees and fuel costs) that would not be as different across the alternatives in other studies. Each of these may imply the commodity is more diverse across choice alternatives than in other applications. Taken in this light, the Kling and Thompson results appear more consistent with our substitution argument. Their nest A is judged to have the greatest substitution, followed by B and finally C. The size of their benefit estimates where mode and policy scenario do not interact conforms in several cases to this ordering.

Several recent papers have suggested employing user provided information in the construction of the choice set. In addition to the Parsons, Plantinga, and Boyle surgical choice set, Peters et al. [1995] and Hicks and Strand [2000] use survey respondent reports on sites they were aware of to eliminate different alternatives for each user depending on their responses. Not surprisingly, the Parsons et al. [2000] study shows the implications for benefit measurement depend on how the model characterizes available substitutes as well as how the definition of the policy scenario impacts the number of affected users.

Haab and Hicks [1997] specify an endogenous choice set model, treating the probability a site is in a person's choice set as independent of whether it is selected. Their estimates of the value of a quality change are smaller than what was estimated for the same quality improvements using a conventional multinominal specification. This finding is hard to evaluate because it seems unlikely that the probability a site would be in a user's choice set would be independent of the likelihood it would be chosen for a trip. Parsons, Massey, and Tomasi [2000] exploit this potential for correlation by defining familiar and favorite sites. They conjecture that not all sites contribute equally as effective substitutes and conventional approaches making this assumption may understate welfare gains or losses.

All our discussion of random utility models thus far has maintained the standard assumption of constant marginal utility of income. As noted above, this implies that the choice process is independent of income (and that Hicksian and Marshallian benefits measures are equivalent) under the standard logit and nested logit models, since income does not vary over alternatives and therefore drops out of the probability calculations. Many researchers have considered this assumption to be overly restrictive and have pursued alternatives allowing the marginal utility of income to vary. Ideally, the random utility model would allow income to influence the choice among alternatives, and would provide a consistent definition of the choice occasion income relevant to the decision being modeled. The literature has not realized this overall goal. As a result, we divide our discussion on this topic into two parts, considering first the technical challenges associated with employing models with income effects, and then noting the conceptual challenges in interpreting them.

The majority of the literature to date has focused on the technical challenges associated with estimation and welfare calculations in the non-linear nested logit model. Examples of this include Morey et al. [1993], Herriges and Kling [1999], and Karlstrom [1999]. These papers suggest techniques for calculating welfare measures given the absence of the closed form formula available in the linear case. Herriges and Kling offer the most comprehensive comparison of the effects on benefit measures of nonlinear income models. They compare three functional forms – linear RUM, generalized Leontief, and translog specifications – for the conditional indirect utility function and several nesting structures for the error distribution. Each is used to estimate sport fishing choices in southern California, using the Kling and Thompson [1996] data with an emphasis on mode choice (beach, pier, private or charter boat). Three measures each of the compensating variation for a price change, a quality change, and a choice set change were evaluated. The first uses the simulation method proposed by McFadden [1999], which estimates the expected value of the compensating variation for a given vector of observed characteristics by generating pseudo-random numbers from the assumed error structure, solving for the income compensation, and constructing the mean over the set of draws of vectors of pseudo-random numbers. This technique is computationally intense due the inability to directly resample pseudo-random numbers from the GEV distribution.

The second approach, labeled the representative consumer method, exploits the closed form for the expected value of the maximum function for a set of choice alternatives with common error distribution. While the compensating variation itself can not be expressed as a closed form expression in terms of site alternatives, the task of numerical approximation is less demanding than with the first method. The last method corresponds to bounds proposed by McFadden [1999] as simpler alternative to using the simulation method. While the Herriges and Kling findings are limited to one application, they seem to suggest greater sensitivity in the welfare estimates to the error distribution (i.e. nesting structure) than to non-linearity in income, especially when quality changes were being evaluated.

Recently, Morey et al. [2003] have proposed a simpler strategy based on using a piece wise linear spline function for income. In this case, the expected willingness to pay is readily approximated without addressing the challenges considered by Herriges and Kling. Their approximation is not an exact relation because any policy being evaluated could, in principle, cause an individual to move between income categories. Their application finds the simple approximation works well, provided the policy is small in relation to the income categories. This result brings us to a central issue, largely relegated to footnotes in discussions of preferences assumed to be nonlinear in income, namely, what is the relevant income measure?

There is very little research examining the process by which choice occasion income is defined. Nearly all studies to date define choice occasion income by some ad hoc division of annual income into choice occasion expenditures. In models that impose zero income effects this is innocuous. However, as our technical knowledge on non-linear income effects evolves and applications seek to employ the more general model, the question of choice occasion income will be more important. Benefits estimates in these cases will directly depend not only on the functional form for utility, but also on the way that choice occasion income is defined. This aspect of the non-linear income RUM model deserves further investigation.

We conclude our discussion by considering the links between choice occasion models and seasonal demand. Bockstael, Hanemann, and Kling [1987] first identified the need to develop consistent measures of season benefits from choice occasion models. They used a participation equation, specified as a function of the expected level of choice occasion maximum utility (i.e. inclusive value) estimated from the choice occasion model. Aggregate benefit measures were approximated as the product of RUM per trip benefit measures and estimates of the number of trips based on these models.

The intervening decade has seen the development of four alternative models closely related to this suggestion. Morey et al. [1993] expand the random utility model framework to the season by including a no-trip alternative along with the available sites. Seasonal benefits estimates are calculated as the product of choice occasions (which is assumed to be fixed and exogenous) and the per trip consumer surplus estimate. Proposals by Parsons and Kealy [1995] and Feather et al. [1995] also begin with the RUM and use it to estimate the predicted probabilities of trips to different choice alternatives. In Parsons and Kealy the predicted probabilities weight alternative specific prices and site attributes. These price and attribute indexes are then used as explanatory variables in an aggregate trip “demand” equation. Feather et al. use the same aggregate price but replace the expected value of the index of site attributes with the expected value of each index for the seasonal demand. Both approaches acknowledge the link to the trip demands to be ad hoc.

Hausman et al. [1995] take a different strategy in explaining their measure. Like Bockstael et al., they use a function of the inclusive value in their participation model, but they argue it offers a theoretically consistent price index. As a result, they suggest the analyst can begin with the RUM, derive the price index from the inclusive value, and then develop a consistent demand function that allows welfare measurement directly from the trip or participation model. Unfortunately this argument is incorrect. The reason follows directly from the logic of developing price indexes.

The economic approach for defining a price index must rely on an optimizing model of behavior and, generally, some form of homothetic separability as we discussed in describing the distinction between weak and latent separability (for early discussions of these issues see Samuelson and Swamy [1973]). A consistent price index follows from these assumptions. The associated quantity index cannot be defined independently from it. In the case of seasonal recreation demand, total expenditure on the set of site alternatives, described as an aggregate, must equal the sum of expenditures on each alternative over the season. When the aggregate quantity index is not derived from the price index, this condition will not hold. Consider the price index for Parsons and Kealy and Feather et al. and divide it into the total expenditure of recreation trips during the season. The process does not yield the aggregate quantity measure they propose – trips during a season. The same is true for Hausman et al. and their use of the inclusive value (Smith [1996]).

While none of these models is fully consistent, it may be the distinctions we are drawing are unimportant for some classes of problems. Unfortunately, this is not what the results to date suggest. Parsons et al. [1999] found fairly close consistency in mean benefit measures derived from the Bockstael et al., Hausman et al., and Morey et al. models. However, both the Parsons and Kealy and Feather et al. approaches were sensitive to the types of policy analyses considered and were generally different from the other estimates. Herriges et al. [1999] add further questions for the more stable of these approaches. Using a different application (fishing in the Wisconsin Great Lakes), they found the Hausman et al. strategy was sensitive to the preference specifications used and the form of the participation equation, with extremely large variations in the average value of seasonal benefits for a given policy scenario.

C. Corner Solution Models

The limitations of the random utility model for estimating seasonal benefits have motivated research on the Kuhn-Tucker demand models. Based on the work of Wales and Woodland [1983] and Lee and Pitt [1986], these models have been applied in primal and dual form by Phaneuf et al. [2000] and Phaneuf [1999], respectively. Corner solution models derive demand relationships from the specification of the consumer's choice problem. A key feature of the model is that binding non-negativity constraints or corner solutions are handled in a theoretically consistent way. The primal version of the model uses the individual's Kuhn-Tucker utility maximization conditions to derive directly the probability of observing a set of observed choices. In the dual model the virtual prices implied by corner solutions are compared to actual prices to derive the probabilities of observing the person's site visitation pattern.

To illustrate the basic logic, consider the primal problem. The consumer's maximization problem for the *n*-vector of recreation site visits **x** is given by.

$$\underset{\mathbf{x},z}{Max}\{U(\mathbf{x}, z, \mathbf{q}, e; g)\} \quad \text{s.t.} \;\; \mathbf{p}'\mathbf{x} + z = m, \quad \mathbf{x} \geq \mathbf{0}, \tag{3.13}$$

where e is an n-vector of random errors, g is a vector of utility function parameters to be estimated, z is spending on all other goods (with the price normalized to unity), and the remaining notation follows from the previous section. Assuming spending on all other goods z is strictly positive the Kuhn-Tucker first order conditions can be written as

$$\begin{gathered}\frac{U_{x_i}(\boldsymbol{x}, z, \mathbf{q}, e; g)}{U_z(\boldsymbol{x}, z, \mathbf{q}, e; g)} \leq p_i \\ x_i \geq 0 \\ x_i\left(U_{x_i}(\boldsymbol{x}, z, \mathbf{q}, e) - p_i U_z(\boldsymbol{x}, z, \mathbf{q}, e)\right) = 0, \quad \forall i,\end{gathered} \tag{3.14}$$

where U_x and U_z denote the derivatives of utility with respect to x_i and z, respectively. A link is made to estimation by assuming the utility function allows the first order conditions to be restated as

$$\begin{gathered}e_i \leq g_i(\boldsymbol{x}, z, \mathbf{q}, \mathbf{p}; g) \\ x_i \geq 0 \\ x_i\left(e_i - g(\boldsymbol{x}, z, \mathbf{q}, \mathbf{p}; g)\right) = 0.\end{gathered} \tag{3.15}$$

The form of g_i depends on the specific function used to describe individual preferences. Given an assumption on the distribution for e, the probability of observing the revealed outcomes for each individual in the sample can be stated. For the case where the first K goods are positively consumed the probability is given by

$$pr(x_1,...,x_K,0_{K+1},...,0_N) = prob(e_1 = g_1,...,e_K = g_K, e_{K+1} \leq g_{K+1},...,e_N \leq g_N)\,. \tag{3.16}$$

Maximization of the likelihood function, defined using these probabilities, allows recovery of estimates of the parameter vector g and characterization of preferences up to the unobserved error term.

Most applications of the primal and dual versions of corner solutions model have been limited to relatively small choice sets. For example, the Phaneuf et al. [2000] primal study uses a modified Stone-Geary utility function and generalized extreme value (GEV) error structure in a four-site model. In this case two sources of site substitution are included: one due to the parametric form of utility and the other due to the GEV nesting structure assumed. Phaneuf and Herriges [1999] estimate a larger dimension model (fifteen sites) but assume the errors are independent extreme value. The Phaneuf [1999] dual study uses multivariate normal errors and a homogeneous translog indirect utility function, which limits income effects in the model but permits relatively general substitution patterns.

Both models are computationally demanding and have thus far seen limited application. However, von Haefen et al. [2003] have demonstrated that with strategic separability assumptions and random parameters in the primal model it is possible to expand the choice set to larger dimensions, allow relatively rich patterns of stochastic substitution, and compute the required welfare calculations. These developments suggest the model can be used for a wider array of policy relevant applications. Von Haefen et al. rely on an innovative and efficient sorting rule based on the numeraire good that uses separability and quasi-concavity of preferences when each set of discrete choices is made.

Two extensions in their logic would expand the potential range of policy applications. First, it would be desirable to consider relaxing their additive separability assumption using latent separability along with exclusive goods to evaluate whether large sets of goods could be accommodated. We believe this line of inquiry might pay off. Second, an appealing feature of the corner solution model is the ability to exploit discontinuities as information. In the applications to this point the discontinuities have been confined to restrictions implied by zero consumption of a subset of the goods available. Restrictions on the role of quality as imposing information at discontinuities offer another potential extension. For example, water quality must exceed a threshold to support game fish. Below that level it does not contribute to enhancing game fishing activities. Another higher level is required for swimming. Past specifications of recreation models have tended to focus on continuous effects of quality or to consider only recreation sites that serve a dominate activity. When we use sites that can support multiple activities, it may be possible to specify exogenously restrictions that imply quality has an exclusive role in some recreation activities at different quality levels. Corner solution models, generalized to describe how these types of quality influences specific activities in discontinuous ways offer another area for future research.

Expanding the model to allow more general error assumptions and parametric forms for utility raises comparable dimensionality issues that have been discussed in the context of the multivariate probit model and flexible functional form issues, respectively. Nonetheless, this class of models consistently integrates choice at the extensive margin among many sites with conditional usage decisions and is at the frontier of recreation demand modeling. Overall, the primary limitation on these models remains at the stage of implementation. We can relax some of the early dimensionality constraints, but too do so requires restricting preferences. What remains is to accumulate experience with the tradeoff in terms of the impact of these restrictions (and some of the alternatives we have suggested) versus the simpler but less consistent alternatives. At this stage, this modeling framework seems to offer payoffs worth the effort of strategic simplifications in the choice complexity it accommodates.

D. Price Index Models

Our last category of models is a mixed set that includes a class with ad hoc connections to a consistent behavioral model and others more directly linked. What unifies them is that each is organized around the assumption of a price index that captures the full effects of variations in site attributes.

The first is the hedonic travel cost model, introduced by Brown and Mendelsohn [1984], and adapted by several authors for a range of applications. The hedonic travel cost model attempts to draw an analogy with hedonic price models but was subject to considerable criticism when explained in these terms (see Bockstael, Hanemann, and Kling [1987], Bockstael and McConnell [1999], Smith and Kaoru [1987]). While Englin and Mendelsohn [1991] and Pendelton and Mendelsohn [2000] have proposed answers to some of the criticisms, basic issues remain unanswered.

The hedonic cost framework begins with the assumption that there exists a price frontier linking travel costs to the characteristics of the recreation site, usually the measures of quality attributes or disamenities considered in the site selection models of a RUM analysis. The slope of this function, with respect to each attribute, is interpreted as a marginal price. Each individual, in principle, is assumed to face a different price locus so that the variation in marginal prices along with differences in site choices and selected levels of characteristics are used to estimate inverse demand function for characteristics.

In contrast to applications of hedonic methods for housing prices or wage rates, one must ask what process leads to the hedonic cost function in travel cost applications, since there is no market equilibrium at work. While one might argue the specification of this function is simply one way to characterize the locus of alternatives available to recreationists (see Smith et al. [1991]), this does not answer how one composes the set of sites that defines the locus.[25] Moreover, in practice most authors have estimated the locus for each of a set of origin zones, rather than an individual user. Using a set of origin zones leaves the hedonic cost function without a clear economic interpretation. Pendleton and Mendelsohn [2000] have argued that the choice between a RUM and the hedonic travel cost boils down to econometric considerations.

Unfortunately, the focus of their attention is on differences in the functional form used to describe consumer preferences and not the source of the cost function.

Smith et al. [1991] offered a strategy for estimating these cost functions that precludes negative prices and treats the function as an efficient locus describing the “prices” of obtaining attributes. However, they do not explain how the analyst is to determine for each individual which sites define this locus or the economic rationale for describing choice alternatives as a continuous cost locus. Until these concerns are explained benefit measures derived from the model are unlikely to be considered as an economically meaningful alternative to the RUM framework.

The second approach is theoretically consistent but also relies on a price index. Introduced by von Haefen [1999], it adapts the Chiang and Lee [1992] framework for discrete-continuous choices. Trips are augmented by a function of a site’s quality characteristics (q_k) along with an error to reflect individual heterogeneity. Maximizing a utility function that assumes trips can be converted into equivalent units, after adjusting for observed and unobserved heterogeneity, yields (with the appropriate preference function) a site selection rule based on the quality adjusted prices for each site. Like the RUM model, an individual is assumed to select a best site. In this case, however, the selection applies for the full time period assumed relevant to individual decisions. With only one application to recreation site choice, it is too early to judge whether the framework will be competitive to RUM or the other more popular models.

E. Overall Prognosis on the Modeling Strategies

A few specific conclusions have emerged from our overview of the primary recreation models. First, the current and dominant modeling strategy is some form of the random utility model. While RUMs will almost certainly always have a place in recreation due to their simplicity and flexibility to work with many different data types, the framework will always have limitations in describing seasonal behavior. As such some variation of the incomplete demand or corner solution models is likely to become the preferred candidate for future applications in this area.

Second, as recreation has become an incubator area for many microeconometric innovations research has tilted toward a focus on econometric and other technical issues in estimation and welfare measurement. This process has redirected attention away from what might be termed the fundamental economic issues in the choice process. This tendency is best seen in the sophisticated approaches to incorporating unobserved heterogeneity and dealing with corner solutions, while ad hoc assumptions on the opportunity cost of time are maintained. Finally, there are topics identified as research areas that have received little current attention. For example, the impacts of separability and time horizon decisions have not been fully explored. Models based on the RUM strategy have focused considerable effort on nonlinear effects of income on utility without considering how the relevant income is determined in relation to other consumption choices. The importance of separability and the time horizon relevant for inter-temporal choices clearly are relevant to progress on this issue. Also, the issue of multiple purpose trips and activity bundling has received little recent attention. For example, in most popular beaches 40 to 50 percent of the recreationists are children. Are their gains from improved conditions (or losses from a beach closure) adequately represented in conventional models? There are also stark differences in the outdoor recreation patterns by gender. Dual earner households must balance a complex set of work, housework, and leisure tradeoffs. One would think that recreation choices would offer a clear set of opportunities for understanding household behavior. To our knowledge, only one application has begun to consider this issue (McConnell [1999]).

4. RECREATION DATA

The data available for describing outdoor recreation behavior in the past fifteen years have transformed the practice of recreation demand modeling. Early applications relied on visitor counts at a site that provided only limited information on the visitor's origin, usually in the form of aggregate zones.[26] These counts were normalized by the population of the zone and treated as measures of the overall population's use rate, or as the product of the rate of use of recreationists and the participation rate among the population as a whole. Nothing was observed about users' income or socio-economic characteristics.

The availability of micro data reporting individuals' recreation behavior changed everything. It became possible to consider differences in the opportunity cost of time and other variables across individuals. Past experience, equipment ownership, and a host of economic and demographic factors could, in principle, be exploited to specify more precise demand models. With this opportunity came new problems of analyzing demand at an individual level. Consistent economic models needed to take into account zero or infrequent consumption, quantity measures that were discrete count variables, incomplete records of the consumption of other goods, as well as an array of other features.

Three types of recreation data sources are now available: household surveys, user group surveys, and on site surveys. In addition to national surveys, many states conduct periodic specialized surveys of fishing or hunting activities.[27] Moreover, in recent years, natural resource damage assessments have prompted efforts to collect both one-time surveys of recreationists and panel surveys of behavior over time.

There are few examples of comparisons of the characteristics of respondents or the results from these different sources of data. One notable exception by Teisl and Boyle [1997] compared the results derived from three samples corresponding to our classification: a general population survey, an intercept of marine anglers, and a sample of licensed inland anglers who indicated they also participated in marine fishing. The objective was to evaluate the effectiveness of each approach in developing a representative sample of marine anglers. They conclude that the use of a population of licensed anglers for another type of fishing yields a sample equivalent to the group of interest in terms of tests comparing groups' socio-economic characteristics and fishing activities. Such comparisons are potentially important because of the cost of developing samples of recreation site users using general population surveys.

In the remainder of this section we consider four aspects of recreation data. These include data collection as an economic process, combining revealed and stated preference data, linking site characteristics to behavioral data, and measuring distances for travel cost estimation.

4.1 Data Collection as an Economic Process

Data collection should be viewed as an economic process of information gathering subject to two types of constraints: the resource constraints of the study and constraints on the time individuals will devote to survey responses. There is increasing recognition among economists that many of the issues raised in designing effective contingent valuation surveys are also relevant to the collection of revealed preference information. In short, respondents may not interpret questions asking for reports of their activities as intended by the analysts who use those responses. As a result, focus groups and cognitive interviews have become a part of the design of special purpose recreation surveys. Unfortunately, there have been few systematic comparisons of the effects of different approaches for asking about recreation behavior. Three related aspects have been studied: the effects of time span on the accuracy of reports of past recreation activity, the advantages of diaries versus one-time surveys for recreation expenditures, and the extent to which econometrics can correct for on-site sample selection problems.

As part of an evaluation of the design of the Fishing, Hunting and Wildlife Recreation Survey, Westat Inc. (see Westat [1989]) evaluated alternative time periods for reporting past activities. The analysis concluded that information collected for a three-month period was more accurate than annual summaries of both the level and timing of activity.

There is little direct experience with the degree of cooperation and accuracy of panels in publicly available recreation surveys. Early general discussions of panel data construction, such as Sudman and Ferber [1979], provide detailed accounts of the difficulties of getting and sustaining cooperation and accuracy.[28] They note that requesting written records can reduce initial cooperation. Their early discussion argues that accuracy issues are most serious for diary studies, where panel members record purchases or activities daily. A time-in-sample bias is also noted by Bailar [1989]. He suggests that respondents are "trained" by their exposure to the survey. They may also learn that some responses will lead to additional questions. This learning may lead to responses intended to avoid the added questions. Hanemann [1995] used this background together with evidence from one-time surveys to critique the Montana Outdoor Recreation Survey conducted by RTI from July/August 1992 through July/August 1993 in seven waves. Respondents were asked to record all recreation trips taken every two months during this time span. These data were used as part of the Upper Clark Fork Basin natural resource damage case. While there is some evidence of a time-in-survey bias discussed in Hanemann's critique, this is not a controlled experiment evaluating panels and diaries.[29] Overall, these general warnings and the example cited suggest that modeling efforts to develop dynamic models that seek to describe the temporal pattern of recreation use must devote equal attention to the challenges in collecting accurate temporal records on recreationists' behavior.

Choice-based samples provide a different type of challenge. Manski and Lerman [1977] study the econometric treatment of these choice-based samples for RUM analyses. The primary issue arises in this case because on-site samples are used to collect information about site usage. The authors conclude that sample exogenous maximum likelihood estimation can be used for these types of data, treating the sample as exogenous but allowing for adjustment of the alternative specific constants, using knowledge of the relative size of the sampling fraction in comparison to the population fraction with each choice alternative. This adjustment will yield maximum likelihood estimates for the multinomial logit (Cosslett [1981]). More generally, Manski and Lerman [1977] have also shown that consistent estimates can be derived for a wider array of choice models by weighting the sample likelihood function in inverse proportion to the ratio used to adjust the alternative specific constants (i.e. using the population fraction relative to the sample fraction for each choice alternative).[30]

4.2 Combining Revealed and Stated Preference Data

Two lines of applications have developed from Cameron [1992] and Morikawa's [1989] independent proposal to use revealed and stated preference data jointly in estimating individual preferences.[31] The first uses the restrictions implied by constrained utility maximization to combine revealed and stated preference responses, which provide complementary pieces of information for recovering preference estimates. The second "stacks" data from the different sources and seeks to estimate a single model using the two types of observations, which represent two different ways of getting the same type of information necessary to recover preference estimates. We focus on the first strategy as a vehicle for illustrating how survey question format influences and conditions microeconometric modeling using the resulting data. We then conclude with a brief discussion of cases where stated preference surveys are designed to provide data that address issues in the available revealed preference information, such as collinearity or a limited range of variation in important quality attributes.

To illustrate the first situation, consider the Cameron framework. Using data available from a sport fishing survey, she combined a conventional travel cost trip-demand model with responses to the following discrete response contingent valuation question: “If the total cost of all your saltwater fishing last year was $*T* more, would you have quit fishing?” The bid amounts included one of eleven different values ranging form $200 to $20,000 (the average expenditures for the season were estimated to be $507). Her analysis models the response to this question by allowing the number of trips to optimally adjust to the added fixed cost T. Under this interpretation respondents are assumed to solve the following optimization problem:

$$\max_{x,z} U(x,z) \quad s.t. \quad m = px + z + T, \tag{4.1}$$

where x is the number of recreation trips priced at p, income is given by m, and z represents all other spending. The solution to this problem is compared to the solution when trips are constrained to be equal to zero. This implies the binary choice problem based on a utility difference is given by

$$\Delta V = U\left[m - T - p \cdot x(p,m,T), x(p,m,T)\right] - U(m,0). \tag{4.2}$$

This is certainly a reasonable way to interpret the economic behavior underlying responses to the stated preference question. However, other interpretations are possible, which would suggest different model estimation. Respondents could have interpreted the question to imply that they could not adjust the number of trips taken during the year and were offered an all or nothing choice costing $\$T$ dollars more. In this case, the behavioral model underlying the discrete response CV would be different, given by

$$\Delta V = U\left[m - T - p\overline{x}, \overline{x}\right] - U\left[m, 0\right], \tag{4.3}$$

where $\overline{x} = x(p, m),$ the level of consumption fixed at the original level of price and income.

A second example of the issues associated with how we use revealed and stated questions arises with the two Haab, Huang, and Whitehead applications (Huang, Haab, and Whitehead [1997] and Whitehead, Haab, and Huang [2000]). They combine reports on past participation and level of use responses under current conditions with expected use without a quality change and with a program to improve quality. By using this design they can test for differences between revealed and stated preference responses before considering a quality change. They found no difference in travel cost, substitute price or income coefficients in their models for past and expected trips with current quality.

A quality improvement is found to increase expected demand. It appears both papers consider the same survey and the comparison of methods used raises another issue. In the initial paper (Huang et al. [1997]), they consider the use questions along with a binary choice contingent valuation question on improved quality. In the subsequent paper they focus on demand (both revealed and stated) without the payment for the program. As a result, they implicitly raise the issue of how many stated preference questions should be used in a single model of preferences. The financing of the program could be deducted from income available for recreation and never explicitly modeled. The authors do not raise this issue, but it is clearly one for further consideration as the stated preference approach moves toward adapting the multiple question conjoint framework to meet the needs of economic models.

These two examples are not criticisms of past work. Rather, they serve to highlight the general issue that the questions asked in any data collection effort (RP/SP or RP alone) need to be both clear to the survey respondents and link in as unambiguous terms as possible to a specific description of a consumer's choice.

Adamowicz et al. [1994] provide an example of the second RP/SP joint model, where a stated preference choice survey is designed to expand the range of variation in site characteristics. In contrast to other applications of the joint estimation logic, data combinations in the RUM framework usually focus on specific policy problems requiring an expansion in the attribute set beyond what can be observed in nature. In this study the objective is to evaluate alternative flow regimes for specific rivers in the study area of southwestern Alberta, Canada. A conjoint choice survey is administered to a subset of the sample contacted for the RP information about water based recreation. A wider range of flow conditions and water quality can be considered with the expanded attribute set. As a rule, these applications apply fairly standard linear RUM specifications and do not consider the issues posed by explaining both the site choice and level of use. The only methodological issue typically addressed is the relative size of the scale parameter in the RUM logit models, which can be identified by restricting structural parameters in the jointly estimated choice models to be equal. As we note below, this focus could certainly expand as we consider how to evaluate the ways individuals simplify complex choice tasks. For example, it is possible to conceive of SP models helping to inform the process of organizing complex decision processes that might underlie RP data on behavior.

4.3 Linking Site Characteristics to Behavioral Data

One of the most important uses of travel cost models has been to estimate consumers' willingness to pay for improvements in the quality of recreation sites. Several aspects of quality have been considered, including pollution related amenities (i.e. water pollution measured with technical or perception based indexes), resource management related quality (including congestion), catch measures for fishing, and tree cover and site conditions related to hiking and low density recreation.

There are behavioral modeling and data issues that arise in each of these examples. We consider three aspects of the data issues. The first concerns whether pollution measures are based on technical or subjective indicators. Technical measures of quality include chemical or biological measures, while subjective measures often collapse multiple chemical measures into one variable. In other cases subjective measures involve the use of qualitative variables such as the water quality ladder.

Evaluations of which approach is best have led to mixed results. Bockstael et al. [1987] found that subjective perceptions of water quality were often based on features of water bodies that were not closely aligned with the pollution related quality indexes. Only in the case of water clarity (where secchi disk readings may be used to measure turbidity) is there likely be a reasonable level of consistency. More recently McDaniels et al. [1998] report survey results also suggesting that water quality perceptions by individuals differ from technical measures of water quality. By contrast, in the case of landscape amenities, including visibility (Stewart et al. [1983], Rowe and Chestnut [1990]) and marine debris (Smith et al. [1997]), there appears to be good correspondence between people's subjective ratings and technical indexes of quality. [32]

Common sense suggests that site users focus on observable attributes directly related to their activities. Thus, to the extent algae blooms and fish kills are closely linked to nutrient loadings, water recreationists will be likely to consistently identify extreme conditions by observing these outcomes. For acidity, fecal coliform, or hazardous materials there are unlikely to be observable measures that people can use to gauge quality conditions. In these cases, public warnings (a type of subjective quality measure) are the only sources of information. For example, one of the most widely used information measures has been public fish consumption advisories. Jakus et al. [1997] is the first published study to evaluate if these advisories influenced recreationists' choice of sites. Most studies since this initial work have evaluated model specifications including warnings by examining benefit measures associated with removing warnings from affected sites. A simpler strategy is to ask how large the imputed price increase would need to be for an equivalent effect on the likelihood of visiting a site with advisories.[33]

The literature suggests per-trip consumer surplus measures for removing advisories between $1.46 and $7.40 (in 1998 dollars), with most estimates in the lower part of this range. By contrast, the equivalent price measure would attach greater importance to the advisories, suggesting they are equivalent to an increase of about $5.00 per trip. Unfortunately, there has been little direct information collected about what recreationists actually do when faced with consumption advisories. Both of these comparisons rely on interpreting the estimated coefficients as if the fishing parties know about the advisories for the sites they are using.

These examples illustrate the challenges in specifying models and interpreting estimates based on both technical and subjective measures of recreation amenities. Bockstael and McConnell [1999] challenge analysts to go beyond a strategy that stops after finding significant and properly signed coefficient estimates on quality measures and think further about the construct validity of models with respect to the specification of quality variables. This task may involve the use of cognitive interviews or focus groups to determine what types of measures are expected to provide a behavioral footprint, as well as further research investigating proper strategies for defining amenity levels entering preference functions.

Our second quality data issue concerns the relationship between an amenity level and recreation behavior. We assume and observe that people respond to quality differences across sites. However, they can also respond to heterogeneity in quality at a given site. These adjustments arise by changing how they use a site. For example, people may visit on weekdays rather than weekends, purchase larger and more powerful fishing boats to allow consideration of a larger range of areas for fishing from a given access point, or select more difficult trails to avoid the congestion effects associated with meeting other recreational parties. Most of our information on these types of adjustments stems from sport fishing and the estimation of catch models as examples of produced quality (Smith et al. [1993], McConnell et al. [1995], Schuhmann [1998]). However, there is some evidence of these types of responses in selecting the timing of use for fishing in Alaska (Carson, Hanemann, and Wegge [1989]), trails for rock climbing (Jakus and Shaw [1997], Grijalva, Berrens, Bohara, Jakus, and Shaw [2002]) and locating and timing in deer hunting (Schwabe et al. [2001]).

Our last issue concerns the linking of quality measures to recreation sites. Often the monitoring of variables related to quality does not directly overlap with the recreation alternatives we wish to consider. For example, catch rate estimates are based on ex post creel surveys. Similarly, pollution concentration may be measured for locations different than the areas where people recreate. This is particularly troublesome in the case of water quality applications, since transport models describing the inter-connections between spatially separate locations are not well developed.

Faced with these issues and the variety of different technical measures available the analyst must decide how to impute and attach the characteristics thought to influence behavior to the recreation commodities defined. This decision overlaps substantially with the commodity definition issue discussed above. There are few studies examining the implications of these decisions. The most complete is von Haefen [1998], who studies the issue as it relates to water quality impacts on recreation. He finds that defining the recreation commodities based on hydrological boundaries (watersheds) and linking water quality measures originating in the watershed to trips to that watershed, provides a more consistent link than geographical boundaries such as counties. Phaneuf [2002] provides an application of this logic to the issue of TMDL regulation design in North Carolina.

4.4 Measuring Travel Distances and Costs

A key element in all travel cost models is the distance assumed relevant for each individual's trip to a recreation site. The actual practice of measuring distance has changed dramatically with access to modern micro computer based software such as GIS packages (i.e. ARCVIEW) or routing software used in planning trucking routes (e.g. PC Miler). On the whole, most analysts believe respondents are reasonably accurate about the distance to the recreation site they recently visited (or where they were interviewed, if the data are collected in an intercept survey). Bateman et al.'s [1996] study recently confirmed this conclusion, suggesting that the highest resolution GIS computations are quite close (on average) to respondent reports.

There are, however, two aspects of distance measurement that have not been explicitly discussed in the literature. First, respondents' reports of the distance to the sites they visit will not provide information about the alternatives they considered but did not visit. This is also closely related to the definition of the commodity and the set of alternatives discussed in the previous section. The issue here concerns what is the correct measure of distance to the alternative sites. Should we assume people know the technical distance measures if they have not visited the site? And what distance measure should be used when we typically only know the respondent's zip code? Answers to these questions are especially important to RUM and hedonic travel cost models where the substitute site distances can be very influential in estimating the choice model.

The second question concerns the appropriateness of distance in the construction of imputed prices.[34] Distance measures generally rely on travel by auto to the site. This strategy generally means that the nature of the commodity is different for local recreationists, with one-day visits, in comparison to those coming from a greater distance. Certainly the early results of Smith and Kopp [1980] and Haspel and Johnson [1982] support this argument. Parsons and Hauber [1998] have offered a detailed comparison across distance zones that indicates the analysis should distinguish visitors who travel great distances from local users. These concerns are especially important as applications consider prominent national and international recreation and eco-tourism sites, where for larger distances, airline fares are not systematically related to distance and multiple objective trips are more likely to be dominant considerations for modeling.

Distance also becomes a concern for the case of very local recreation. Deyak and Parliament [1975] noted over twenty-five years ago that time costs are more likely to be a constraint in this case. In these cases, it is not simply an issue of the marginal value of additional time, but the availability of discrete blocks of time to complete activities – a short hike or jog, game of golf, or bike ride. Thus, it would seem that activities at great distance from one's residence and those very close that support local (e.g. day to day) activities set boundaries on the plausibility of the use of distance related costs as the implicit price in travel cost models for recreation demand. The reasons underlying these limitations both stem from the way time constraints and the value of time influence individuals' decisions about how to allocate leisure to different types of recreation.

5. ECONOMETRIC ISSUES IN RECREATION DEMAND MODELING

The econometric issues identified as part of recreation demand modeling are too extensive to do justice to all of them. Our discussion in this section focuses on the interaction between econometric and economic issues.[35] A particular area we consider is how error terms enter each econometric model and how they are interpreted. One common strategy holds that the errors represent unobserved heterogeneity in preferences, while a second considers them as measurement errors that are unimportant to preferences.[36] We examine this issue as it relates to single equation, multiple equations, and RUM models. The section concludes with discussion of temporal models and non-parametric methods as they relate to recreation.

5.1 Single Site Demand Models

The earliest single site models relied on ordinary least squares with aggregate zonal data. Two early econometric issues have persisted in generic terms in the current literature on single site demand models. The first concerns the extent of the market, and the second is associated with the interpretation of visitation decisions as the product of an average seasonal usage for recreation participants and a probability of participating. Smith and Kopp [1980] raised the first issue by using a test for the stability of a simple travel cost model as the origin zones used to estimate that model are expanded to progressively further distances. The logic underlying the economic question posed in their test parallels recent work on single equation, pooled site models of demand (Loomis et al. [1986]) as well as the composition of the choice set in the RUM framework (see table 3.1 and the related discussion). This early work concerns the definition of a recreation site and substitute alternatives and the conditions when trips to the site could be considered homogeneous measures of quantity demand. These concerns parallel the definition of a choice alternative and the choice set in random utility models. Bowes and Loomis

[1980] raised the second issue and address it as an adjustment for heteroscedasticity. Their discussion of the relationship between the decision to participate in recreation and the level of use parallels recent work comparing repeated discrete choices versus various forms of the linked RUM and trip equations discussed earlier (see Parsons et al. [1999]).

The development of count models for use in recreation analysis evolved from these issues based on the characteristics of contemporary, individual-based recreation data, which typically provide trip counts in non-negative integers, often with "excess zeros" if the survey contains non-participants. Combinations of probability models were designed first to account for these characteristics of the data.

This perspective is illustrated by using the count data model as a starting point for a discussion of hurdle models.[37] For the Poisson model the probability that individual *i* makes y_i visits to a recreation site is given by

$$pr(Y_i = y_i) = \frac{e^{l_i}\, l_i^{y_i}}{y_i\,!}, \qquad (5.1)$$

where Y_i is an integer outcome reflecting the fact that trips must be taken in non-negative whole number increments, l_i is the expected number of trips that is typically parameterized as $l_i = E(Y_i) = \exp(X_i b)$, X_i is a vector of individual characteristics thought to affect the expected demand for trips (i.e. travel cost, income, site quality variables, etc.) and b is a vector of unknown parameters to be estimated. A restrictive characteristic of this model is that the conditional mean and variance are equal (although estimates of the parameters of the conditional mean are robust to mis-specification of the higher moments). Thus, over-dispersion, a common empirical observation in many recreation data sets, is not consistent with the assumptions of the statistical model. In response to this limitation, many analysts have employed the negative binomial generalization in place of the Poisson. This formulation allows inequality of the conditional mean and variance.

Nonetheless, the simple Poisson and negative binomial distributions typically do not place enough probability mass at zero to account for the empirical regularity of excess zeros in many types of recreation data set. Hurdle models address this by using multiple data generating processes to explain the likelihood of individuals being one of three types: nonusers, potential users, and users. Nonusers will never visit a site, even if the price is sufficiently low. Potential users' utility functions contain trips to the sites, but they are assumed to face a price at or above their choke price. In the double hurdle model the recreation decision is assumed to depend on two sets of explanatory variables (X,Z) such that the demand for trips y_i is given by $y_i(X_i,Z_i)$. It is further assumed that the latent (unobserved) variable D_i summarizes the individual's decision to recreate such that the number of trips to the site is zero if $D_i \leq 0$. A convenient assumption is that $\Pr(D_i=0)=\exp(f_i)$, where $f_i=\exp(-Z_i g)$ and g is a vector of parameters to be estimated. If consumption is positive, then observed consumption equals desired consumption such that $y_i=y_i*$. The probability of not making a trip is thus given by

$$pr(y_i^* \leq 0) + pr(y_i^* > 0) \times pr(D_i \leq 0). \qquad (5.2)$$

The first term is the probability of being a nonuser and the second term is the probability of being a potential user; that is, someone with positive desired consumption, who faces an additional hurdle that may prevent consumption. Correspondingly, the probability of taking a positive number of trips is given by

$$pr(y_i^* > 0) \times pr(y_i^* \mid y_i^* > 0) \times pr(D_i > 0). \qquad (5.3)$$

The functional form of these probabilities is derived from the probability statements for D_i and Y_i.

Count data models and their generalizations to include hurdles and excess zero corrections adopt our second error interpretation that the stochastic components in recreation demand models are incidental to the economic description of behavior. Rather than explicitly modeling the presence of unobserved heterogeneity in the form of an additive error, count data models parameterize the first moment of a distribution that is assumed to generate individual trip realizations so it matches the form of the reports provided in available micro data. Estimation recovers a characterization of the conditional mean of the distribution that generates the (unobserved) actual trip taking behavior, and should therefore be interpreted a representative consumer's behavioral function rather than the result of individual optimizing behavior (see von Haefen and Phaneuf [2003]).

Taking this further, one might ask if the underlying process could be derived from a single consistent constrained optimization framework. Haab and McConnell [1996] implicitly raise this issue by asking whether consistent welfare measures can be derived from count and zero inflated models. A few observations suggest this is not strictly the case. First, one cannot distinguish user/nonuser status from the identification of an individual as a non-participant at a specific site without assuming the people involved (i.e. users and nonusers) have different preference functions. This outline can arise with restrictions on a model's parameters, its functional form or through observed heterogeneity. But these people must be different – the same neoclassical constrained optimization problem will not deliver the three-part distinction outlined with a double hurdle model. Second, the division of explanatory variables determining participation and consumption can only arise from an interpretation of the underlying behavioral functions as approximations. In a fully consistent model with non-participation, a comparison between the market price and the individual's reservation price, derived from all arguments in the utility problem, implies an extensive margin of choice between conditional utilities representing participation and non-participation. Importantly, the same factors determine participation and consumption. Thus, the only argument for separate determinants of participation and demand must stem from interpreting the two functions as local approximations at different points and as such they appear to arise from different preference functions.

This discussion is not a criticism of the count or the hurdle framework. These models were originally designed to improve the fit of reduced form demand equations to the types of micro data available for specific recreation sites, and have subsequently proven useful in a variety of contexts. The point is simply that in the absence of further behavioral information we do not know if the relative importance of a hurdle function intended to take account of excess zeros (relative to what would be implied by the error distribution) is due to a measurement issue or an underlying feature of behavior. This question in fact hints at a larger issue. Beyond hurdle models, contemporary recreation analysis has had little to say about the behavioral process in which individuals acquaint themselves with recreation opportunities that they may decide to use in the future. While it is intuitive that some sites are not part of individuals' decision sets, little conceptual research exists on how to model this process in a utility-consistent manner.

5.2 <u>Systems of Recreation Demand Equations</u>

Early applications of demand systems used zonal data and assumed multivariate normal errors. With micro data the primary challenge has been how to deal with the requirement that trips must be positive or zero.[38] We discuss how three systems approaches have evolved in the literature to address this issue: count demand, share, and Kuhn-Tucker models.

Count data demand system models grew naturally from their single equation counterparts. Ozuma and Gomez [1994] were the first to apply a seemingly unrelated Poisson regression model in a recreation context. Unfortunately, the specification of their incomplete demand system does not adequately account for the restrictions required to develop consistent Hicksian welfare measures (see LaFrance and Hanemann [1989]). More importantly in terms of future applications, generalization of their estimator beyond the two-site model represents a non-trivial challenge. Later applications such as Englin et al. [1998] use specifications for the system of expected demands that are consistent with integrability conditions and simplified the error structure (via assuming independent Poisson distributions for each equation) to allow estimation of a larger dimension problem. Shonkwiler [1999] further addresses these issues in the context of a multivariate generalization to a count model that allows for both positive and negative correlation and incorporates the parametric restrictions for consistent welfare measures from an incomplete demand system.

All of these generalizations should be considered statistical approaches to accommodating count data within a system of demand equations, in that while they provide distributions that allow a non-zero probability of observing zeros, they do not explain the source of the zeros as corner solutions. Indeed, in applying the integrability conditions to the sets of demand models we are implicitly relying on interior solutions with some measurement issue responsible for the zeros. When excess zeros confound our ability to estimate these models it seems reasonable to ask whether the data are suggesting the decision of whether or not to participate is an important part of the process.

An early alternative to this approach was Morey's [1981, 1984, 1985] share model, which sought to describe the share of total trips across sites. The total seasonal number of trips for each individual was assumed to be determined outside the model. The modeling strategy involves choosing a utility function and deriving the associated trip share equations, which are then used to parameterize the location parameters of a multinomial distribution. Morey argues that the multinomial is an appropriate distribution for shares, since it allows positive probability for shares only in the unit interval, including the endpoints, which allows for corner solutions. In a recent update to this idea, Morey et al. [2001] employ a nested CES indirect utility function along with the multinomial distribution to estimate models based on shares of trips and shares of expenditures for Atlantic salmon fishing. The structure of the nested CES function divides the seasonal recreation decision into steps captured through price aggregates for each "nest". The first nest determines whether or not to participate in salmon fishing, subsequent nests determine the area (i.e. Maine versus Canada) and then, conditional on the area, the final nest determines the site. The structure uses the ability to define price aggregations from each homogeneous of degree one CES sub-function to sequence the structure describing the share parameters. For example, the indirect utility function (and top level nest) for the alternatives model is given by

$$V = -\frac{1}{B}(P_{NF}^{1-s} + P_{F}^{1-s})^{1/(1-s)} \tag{5.4}$$

where P_{NF} and P_F are the price aggregates for the non-fishing and fishing options, s is the elasticity of substitution between fishing and non-fishing, and B is a utility function parameter. The upper level nest implies price aggregates

$$P_F = (P_M^{1-s_F} + P_C^{1-s_F})^{1/(1-s_F)} \tag{5.5}$$

where P_M and P_C are the price aggregates for the Maine and Canada areas and s_F is the elasticity of substitution between fishing areas. Finally, the area price aggregates are

$$P_M = \left(\sum_{j=1}^{L_M} h_j^{s_M} P_j^{1-s_M} \right)^{1/(1-s_M)} \tag{5.6a}$$

$$P_C = \left(\sum_{j=1}^{L_C} h_j^{s_C} P_j^{1-s_C} \right)^{1/(1-s_C)}, \tag{5.6b}$$

where L_M and L_C denote the number of sites in Maine and Canada, the h_j*'s* are site quality measures, the P_j*'s* are travel costs, and s_M and s_C are the elasticities of substitution between sites. The preference specification yields a multiplicative form for the share of choice occasions to a site as given by

$$s_{Ml} = \left(\frac{(1/P_F)^s}{(1/P_F)^s + (1/P_{NF})^s} \right) \times \left(\frac{(1/P_M)^{s_A}}{(1/P_M)^{s_A} + (1/P_C)^{s_A}} \right) \times \left(\frac{(h_l/p_l)^{s_M}}{\sum_{k=1}^{L_M} (h_k/p_k)^{s_M}} \right). \tag{5.7}$$

This share is then used to parameterize the multinomial distribution.

The model assumes the site choice is made from a seasonal perspective. However, we do not avoid an important conditioning factor: the number of choices between fishing and non-fishing alternatives is determined outside the model. Thus, as in the case of the repeated random utility framework, we fall short of a full utility-consistent model linking site choice, level of use of each site, and total amount of use in relation to prices and income. While the nested CES utility function allows substantial flexibility in characterizing a wide array of substitution patterns, it seems unlikely to overcome the limitations that have prevented share models from offering a compelling basis for describing multiple site seasonal recreation demand. As demonstrated by von Haefen and Phaneuf [2003] however, the Morey et al. nested CES model may be useful when applied in the count data demand system framework.

The only currently available system model that interprets the stochastic components as unobserved heterogeneity and allows a behaviorally consistent description of corner solutions is the Kuhn-Tucker model in either its primal or duel form. These features, however, come at a cost in that this class of model is conceptually and computationally more complex than the competing count data and share model frameworks. Estimation requires the integration of multiple dimension probability integrals, while welfare calculation involves solving for each respondent's demand levels given simulated realizations of the unobserved heterogeneity. Von Haefen et al. [2003] discuss how these tasks increase in complexity, requiring sophisticated computational techniques, as the number of sites and the flexibility of the deterministic and stochastic components of the model increases.

As described in section 3 Kuhn-Tucker models can be specified beginning with either a direct or indirect utility function. The two approaches are conceptually dual to each other but empirically unique in how the error specification is exploited to provide the link between the econometric and behavioral models. Both, however, allow preferences to exhibit substitutability through the functional and stochastic components of the model. Econometric issues in this area center on striking a balance between increasing functional and stochastic flexibility to more realistically model preferences, and maintaining the tractability necessary for practical estimation. Related to this, the practical advantages of the consistent Kuhn-Tucker specification over computationally less demanding system models are not yet fully understood. In one application evaluating this von Haefen and Phaneuf [2003] find that welfare measurement is more sensitive to model fit and other factors than the choice of count data versus Kuhn-Tucker model estimation.

5.3 Random Utility Models

In the random utility framework the errors in the model are interpreted as unobserved heterogeneity and, given the relative sparseness of the parametric specification, play a large role in determining the amount of substitution that can be captured. The distributional assumptions restrict the correlations between the random utilities associated with choice alternatives. In the simple multinomial logit this correlation is zero. For the nested logit model the utilities of alternatives have non-zero correlations, consistent with common elements affecting how each individual makes choices. These correlations can be related to the dissimilarity parameters across nests (see Ben-Akiva and Lerman [1985]). Aside from the heuristic parallel between substitution relationships there is little explicit guidance from economic theory that can be offered for selecting among nesting structures.

In recognition of this limitation the multinomial probit model is often mentioned as a replacement for the nested logit specification. It would relax restrictions limiting the types of substitution relationships that can be accommodated. Historically, the model has imposed significant computational burdens. Simulation estimation (see Stern 1997]) has helped to increase its feasibility and led to a few applications in the area of recreation demand (see Chen and Cosslett [1998]). Nonetheless use of the probit model for practical applications remains rare.

One alternative to the nested logit adopts a statistical approach to incorporating heterogeneity, arguing that individuals fall into one of a discrete set of latent classes, determined by their attitudes or perceptions. Boxall and Adamowicz [2002] describe an application involving past wilderness users (in a conjoint setting) where a simple RUM describes choice among a discrete set of site alternatives and then a multinomial logit characterizes the probability of membership in one of a discrete set of types of groups of individuals, each with different preference and scale parameters for the choice model. In this setting the probability of selecting a site is the product of the site choice probability (given the unique preference parameters associated with membership in one of the latent classes) and the probability an individual is a member of that class given her characteristics, attitudes, or perceptions. Thus the probability that person *n* chooses site *i* is given by

$$p_n(i) = \sum_{s=1}^{S} p_{ns} \cdot p_{n|s}(i), \tag{5.8}$$

where p_{ns} is the probability that person *n* is in group *s*, $p_{n|s}(i)$ is the probability that person *n* chooses site *i* given membership in *s*, and *S* is the number of potential "preference" groups. The framework usually describes the determination of preference or membership groups as a statistical approach to preference discrimination because the number of groups must be determined from fitting criteria, rather than as a maintained assumption about the form of preference heterogeneity.

Provencher et al. [2002] have recently applied this model to allow for temporal correlation in trips. They compare the results with a mixed logit model (described next) and find that the benefit estimates from latent class models evaluated for different membership groups generally bracket the mixed logit average estimate for the scenarios considered. A choice between the models rests in part on whether the analyst is prepared to use a finite set of alternative types of individuals (preference groups) to describe unobserved heterogeneity. With the mixed logit, each individual is assumed to have different preference parameters and, using the Herriges and Phaneuf [2002] suggestions, could be used to represent the extent of substitution among choice alternatives. Substitution patterns are also altered with the latent class model but the outcomes will depend on the statistical decision rule used to select the number of groups and thus cannot be easily interpreted a priori.

A second alternative to the the nested logit model that has received significant recent attention in recreation demand is the mixed, or random parameter, logit model (McFadden and Train [2000], Train [2003]). This approach mixes additional source of randomness into the basic logit format. It can be used to approximate any discrete choice model derived from random utility maximization.

Train [1998] outlines the basic logic as a variation on the multinomial logit model. The setup of the model is the same as was described in section 3, where the errors enter linearly and are assumed to follow independent type I extreme value distributions. In Train's generalization the parameters of the utility function are random variables with known distribution. This formulation can be interpreted as introducing unobserved heterogeneity in preferences. The probability a person chooses site *i* on choice occasion *t*, conditional on the utility function parameters b and the explanatory variables x_{it} is

$$L_{it}(b) = \frac{\exp(b\, x_{it})}{\sum_{j=1}^{J} \exp(b\, x_{jt})}. \tag{5.9}$$

When b is a random variable, drawn from the distribution $f(b;q)$ where q is a parameter vector, the researcher can only form an expectation of the probability in equation (5.9):

$$P_{it}(q) = \int L_{it}(b) \cdot f(b;q)\, d b. \tag{5.10}$$

If the data includes multiple choice occasions $L_{it}(b)$ in equation (5.10) is replaced by the product of the conditional probabilities of the observed site selections, and the unconditional probability of the sequence of choices is defined. By restricting the values of the random parameters to be constant across choice occasions for each individual, the mixed logit model allows for a cross-choice occasion stochastic relationship that is absent in the simpler repeated choice models.

The likelihood function is defined in terms of these expected probabilities. As a practical matter, estimation requires simulation since no closed form exists for the probability in equation (5.10). Train [2003] describes this process in detail. Heuristically, multiple realizations of the vector ***b*** are drawn from the distribution defined by a candidate set of values of q. P_{it} is computed for each draw. A simulated estimate of the expected probability, $\tilde{P}_{it}$, is then given by

$$\tilde{P}_{it}(q) = (1/R)\sum_{r=1}^{R} P_{it}\left(b^{r};q\right), \tag{5.11}$$

where R is the number of repetitions. The simulated probabilities are then used in place of the probabilities in (5.10) to form to likelihood function. Standard maximum likelihood search routines are then employed to estimate the parameter vector q.

The mixed logit model is attractive under the error components interpretation of the random parameters, fitting into our first interpretation of the errors as reflecting an unobserved component of preferences. It also provides a bridge between the nested logit model and the multivariate probit model in specifying more general patterns of error correlation and stochastic substitution. Recently Herriges and Phaneuf [2002] have examined the implications of defining the mixed logit random parameters, interpreted as error components, to capture a diverse pattern of stochastic substitution among the available sites. Comparing price elasticity matrices from the multinomial logit, nested logit, and mixed logit they find dramatic improvements in the richness of elasticity estimates that can be characterized using the most general mixed logit models. Herriges and Phaneuf conclude from their application that, in spite of the increased computational burden, mixed logit models are worth the added cost when compared to the benefit of the increased realism they add to preference estimates.

Of course, in general uses of the model it is important to select distributions for the b's consistent with the economic interpretation of the parameters. This is clear in some cases and not in others. We might, for example, be willing to select a distribution that restricts the parameter on travel cost to be negative such as the log-normal, but will be less clear about sign restrictions for parameters associated with quality attributes. It is clear, however, that simulation techniques provide important flexibility and offer the prospect for more complex interrelated decision models. What is less clear is the economic basis for selecting among the alternatives. It may well be that composite strategies exploiting jointly estimated models with revealed and stated preference data, where the latter focus is on the choice process rather than site attributes, offers the best short term basis for reducing the dimensionality of the problem. That is, this approach would select alternatives that are now technically feasible based on what appears to correspond to the decision rules people use to bracket choice alternatives or otherwise simplify complex choice sets.[39]

5.4 Dynamic Models

The models used in recreation analysis nearly always assume temporal exchangeability, although common sense suggests this is not in reality true. Provencher and Bishop [1997] offer the first attempt to use Rust's [1987] integrated discrete dynamic programming framework to describe dynamic trip decisions over a season. Observed choice results from the maximization of the expected present value of utility, subject to a budget constraint defined over the season. Following Rust they assume independent type I extreme value errors, which implies the probability of taking a trip depends on the current value of the utility function with additional terms added to each choice alternative to reflect the discounted contribution of the next period's utility, conditional on the current decision. Backward recursion allows the discrete dynamic programming model to be solved for each potential set of preference parameters. Maximum likelihood estimation of the model's parameters requires that all the possible solutions be evaluated. Intuitively the estimation task requires that the different possible use profiles (for alternative values of the model's parameters) be compared with the observed record for each person. The estimator selects the vector of parameters with the highest value of the log likelihood function.

Provencher and Bishop assume a linear utility function and a simple daily budget constraint, avoiding a labor/leisure choice or other specific time constraints.[40] The angler's choice problem is whether to take a salmon-fishing trip each day at the application site (Lake Michigan). Weather, expected catch, exogenous features of each person's constraints (interacted with a dummy variable that identifies weekdays throughout the solution time span) and the out-of-pocket costs of a trip influence these choices.

Empirical tractability requires their application to consider only participation choices and not site selection decisions. Most of the specific time related variables and out-of-the-pocket costs are exogenous for each respondent. While the model does allow for some learning with experience and the exogenous characteristics of specific days to influence individuals' participation decisions, these characteristics suggest changes in spending or in the work/leisure allocation and numerous other adjustments (e.g. re-allocating existing income) cannot be accommodated in a computationally tractable model. Thus, one might ask whether there are gains from this more complex, but temporally consistent, formulation over simpler alternatives.

Adamowicz's [1994] adaptation of Pollak's [1970, 1976] habit formation model offers one such alternative. By assuming consumer's choices can be described in terms of stocks of visits to recreation sites, his framework demonstrates that a random utility model can be reformulated in terms of "dynamic prices" to reflect habit formation or variety seeking. These prices reflect the role of accumulating consumption into a stock measure and its implications for the budget constraint. To illustrate, consider a simple two-good model. In the Adamowicz framework the terms entering the utility function are stocks of recreation goods consumed over T time periods. Utility is therefore given by $U(W_{11},W_{21},\ldots, W_{1T}, W_{2T})$ where W_{it} is the stock of the ith good at time t, determined by the equation of motion $W_{it}=d_iW_{it-1}+X_{it}$ with X_{it} being the current period consumption of good i and d_i reflecting the durability of the stock. The sign of d_i determines if good i is a variety seeking (d_i positive) or habit formation (d_i negative) good. Maximization of this utility function subject to the equations of motion and an intertemporal budget constraint implies the demands for current period consumption are functions of temporally adjusted prices, given by $\tilde{P}_{it} = P_{it} - d_i P_{it+1}$. If preferences are assumed to be separable over time, attention can focus on the demand for current period consumption as a function of the temporally adjusted prices and income. For good 1 in our example this is given by

$$X_{1t} = f(\tilde{P}_{1t}, \tilde{P}_{2t}, \tilde{m}_t) - d_1 W_{1t-1}, \qquad (5.11)$$

where $\tilde{m}_t = \sum \tilde{P}_{jt} X_{jt}$.

Adamowicz uses this framework to motivate an empirical discrete choice problem for multiple choice occasions. The model is an approximation reflecting the general spirit of the habit formation model. For the linear conditional indirect utility specification, site choice decisions are based on dynamic prices and the stocks of all past consumption for the different sites. In our two-good model this implies conditional indirect utility functions of the form

$$\begin{aligned} V_{1t} &= a_1(\tilde{m}_t - \tilde{P}_{1t}) + a_2(d_1 W_{1t-1}) + a_3(d_2 W_{2t-1}) + e_1 \\ V_{2t} &= a_1(\tilde{m}_t - \tilde{P}_{2t}) + a_2(d_2 W_{2t-1}) + a_3(d_1 W_{2t-1}) + e_{2.} \end{aligned} \tag{5.12}$$

Re-arranging terms and substituting for $\tilde{P}_{1t}$ and $\tilde{P}_{2t}$ we have the final form of the empirical model:

$$\begin{aligned} V_{1t} &= a_1(\tilde{m}_t - P_{1t}) + d_1\left[a_2 W_{1t-1} + a_1 P_{1t+1} + a_3\left(d_2/d_1\right)W_{2t-1}\right] + e_1 \\ V_{2t} &= a_1(\tilde{m}_t - P_{2t}) + d_2\left[a_2 W_{2t-1} + a_1 P_{2t+1} + a_3\left(d_1/d_2\right)W_{1t-1}\right] + e_2. \end{aligned} \tag{5.13}$$

The distinction between this approach and the Provencher-Bishop formulation depends on the distinctions between the added terms to reflect forward-looking behavior. In our simple example, where prices are travel costs including vehicle and time costs, we expect that the primary changes in P_{it+1} will depend on how the time constraints vary over the course of the proposed inter-temporal planning horizon. Weekdays and weekends can have distinctive effects based on each person’s decisions about whether and how much to work. Predefined fishing tournaments and weather can also be allowed to displace the net costs of a trip.

Provencher et al.’s latent class application also offers another way of dealing with inter-temporal linkages by describing trip decisions as part of a Markov process and specifying seasonal trip taking behavior using the simulated likelihood associated with the product of the integrals for all the trips that can be taken in a season by each recreationist. The correlation structure for the errors, together with the evolution of the state of exogenous variables is the way dynamics will be represented in these models. In their application, the authors find correlation in unobserved heterogeneity occurs when potential trip occasions are small. Thus, the overall effect of assuming temporal independence for welfare measurement was small in their application. It did appear to be quite different across the groups described as their latent classes.

To some extent, all of these efforts overlook another key element in the dynamics, which motivated early discussions of preservation versus development (Krutilla [1967] and Krutilla and Fisher [1975]). In these theoretical analyses, individuals' demands for some types of recreation changed with experience. Learning by doing created inter-temporal effects akin to adjacent complementarity as discussed by Becker [1992] in distinguishing habits from addiction.[41] There has been very little empirical work on this dynamic process. It is implicit in the Adamowicz [1994] specification, but is a part of the hypothesized stock effects in preferences and is maintained, not explained, by the model. Thus, future research could seek to more accurately specify the temporal constraints facing individuals and the internal production (to the individual) of experience capital and its effect on leisure time choices.

Finally, we would expect that different individuals would select into jobs with more or less discretion. This argument suggests the introduction of unobserved heterogeneity in model parameters of the Adamowicz model might be more effective in capturing these types of differences than in generalizing the time constraints (for everyone) in the Provencher-Bishop model. Given its significant computational demands, future efforts might focus on how large the differences between ad hoc adjustments to static choices need to be in order to warrant full scale dynamic optimization models.[42] They might also consider the importance of learning and behavioral choices that would allow the analyst to evaluate the importance of experience capital for choice over time.

5.5 Non-Parametric Methods and Models

There have been two primary strands of research on non-parametric methods in recreation modeling. The first seeks to relax the distributional and parametric restrictions associated with random utility models. The second adapts Varian's [1982, 1983] tests for the predictions of revealed preference theory to evaluate individual choices in the context of neoclassical demand theory. The basic logic associated with these two disparate applications is similar. They acknowledge that parametric models will include additional restrictions associated with features of the functional form or the assumed error distribution that do not arise from the choice process. As a result, it is reasonable to ask how sensitive the results are to these restrictions by considering approaches that limit the restrictions imposed on the data to a set of conditions implied by economic theory.

We begin with a discussion of non-parametric econometrics in recreation demand. While there has been some interest in applying non-parametric and semi-nonparametric methods in contingent valuation applications (see Haab and McConnell [1997]) and in micro demand analysis (see Hausman and Newey [1995]), to our knowledge there have been no applications to demand system recreation models. Huang and Nychka [2000] have developed a non-parametric multiple choice method for applications in a choice occasion setting. Their analysis extends Wahba's [1990] continuous spline smoothing to the discrete choice setting. Using river recreation sites, they found large discrepancies in the Hicksian per trip consumer surplus for the loss of access to one of seven sites from what was estimated with a simple logit.[43] The mean non-parametric estimate for the WTP to retain a site was 60% of the RUM measure, and simple confidence intervals did not overlap.

These results contrast with the Herriges and Kling [1999] study discussed earlier. Both relax the constancy of the marginal utility of income. The Herriges and Kling parametric model found little difference in welfare estimates for a variety of types of changes. Their study involved a more comprehensive comparison of model specifications, distributional assumptions, and welfare scenarios. Given the difficulties in dealing with a large number of variables in the framework of a cubic smoothing spline, it seems likely that generalizations of the linear in income RUM model will continue to be based on parametric models combined with generalized error structures. In the context of demand models, where the deterministic component carries a proportionately heavier weight, there may be opportunities to consider whether the sensitivity found by Hausman and Newey [1995] in estimates of the equivalent variation for price changes for gasoline is paralleled in recreation demand models.

The second type of non-parametric methods involves Varian's [1982] algorithms for detecting violations of the strong axioms of revealed preference theory.[44] His approach requires at least two sets of price and quantity choices. With two goods the revealed preference responses should, given different sets of relative prices, be consistent with convex indifference curves. If we observe two selections of the two goods at different prices it should never be the case that one combination goods is selected when the second is feasible, followed by the choice of the second at the new prices when the first remains affordable. The logic implies that when the vector of consumption goods $x_1 = [x_2^0, x_1^0]$ selected under one price set is superior to another vector of consumption goods x_2 we should expect to find $P_1^0 x_1^0 + P_2^0 x_2^0 \geq P_1^0 x_1^1 + P_2^0 x_2^1$. Varian defines a constant *e* such that $e(P_1^0 x_1^0 + P_2^0 x_2^0) \geq (P_1^0 x_1^1 + P_2^0 x_2^1)$ when *e=1*. If we let *e* be the amount of budget reduction that will just satisfy the inequality, then *e* can be used as an index of efficiency and is the basis of the subsequent tests of revealed preference models.

Adamowicz and Tomasi [1991] were the first to propose using this idea with travel cost models. Their initial study compared the performance of travel cost and contingent valuation responses in terms of their consistency with revealed preference. The travel cost analysis treated each of the trip choices (for hunting bighorn sheep) made by an individual as independent. They evaluated the revealed preference axioms for each individual by comparing the price and quantity, travel, lodging, food, and other hunting related items for people with multiple trips. A key consideration in applying these non-parametric indexes for market goods is the exogeneity of prices. For the travel cost model, one of the most important components of the price – the travel cost (including the opportunity cost of travel time) is determined by individuals' time constraints, labor/leisure choices, and a host of other unobservable factors. Given this qualification, it should not be surprising that the percentage of observations with violations of the axioms is sensitive to the treatment of the opportunity cost of time, with the largest number of violations when it is ignored.

A subsequent analysis of the same survey by Boxall, Adamowicz and Tomasi [1996] considers the same tests applied to the prices for each of ten sites, comparing the results for the season across respondents (rather than across trips for each of the multiple trip takers). Conclusions about consistency depend on the treatment of the opportunity cost of time. Nonetheless, comparisons across people reveal a much larger number of violations, on the order of 76% of the comparisons.

It is hard to judge how these results should be interpreted. If we assume people act rationally, then the results offer evidence of the limitations in conventional imputation practices with travel costs measurement and modeling, confirming Randall's [1994] critique of the method on conceptual grounds. If we accept the notion of the appropriateness of our price imputation, then we have a strong critique of conventional demand analysis applied to a representative individual and potential support for dealing explicitly with individual heterogeneity.[45] Of course, interpretation is not free of qualifications. The tests build in maintained assumptions including: simple cost-sharing rules among party members, separability of recreation from all other goods (which makes little sense for the labor/leisure choice), and comparability in the goods purchased in broad categories (across trips).

6. MEASURING CONSUMER SURPLUS WITH TRAVEL COST MODELS

Models of recreation behavior have primarily been used to estimate the welfare impacts of changes in the resources that support recreation. The early literature focused on the resources themselves (e.g., the benefits of opening a new hiking trail or the loss from closing a fishing site). During the last decade attention has shifted to measuring the benefits associated with changes in quality attributes of recreation sites, including water quality, fish or other species abundance involved in consumptive use, and scenic attributes of recreation sites. Other chapters in the handbook deal with the theoretical issues associated with welfare measurement in non-market valuation. In the following two sub-sections we consider the issues that arise specifically in attempting to recover estimates of these measures with recreation demand models. We first discuss the restrictions needed to relate Hicksian and Marshallian benefits measures, followed by a discussion of welfare measurement in extensive margin models with unobserved heterogeneity.

6.1 Price versus Quality Changes

Substantial discussion has been dedicated to understanding how Hicksian measures of the monetary value of a price or quality change can be measured when Hicksian demands are not observed. Willig [1976, 1978], Hausman [1981], LaFrance and Haneman [1989], and Bockstael and McConnell [1993] have helped to clarify most of the basic concepts. Techniques for price changes by and large have paralleled the development in other areas of applied welfare analysis (see Just, Hueth, and Schmitz [2004] for an overview of this literature), while quality changes have presented more unique challenges.

Two approaches have typically been used in demand models to relate Hicksian and Marshallian measures of benefits from price and quality changes: bounding and integration conditions. The first involves developing bounds on the size of the discrepancy between the observable Marshallian and unobservable Hicksian values for price and quality changes. For price changes, these conditions follow directly from Willig [1976] and formalize the intuition that the discrepancy depends on the magnitude of the change in relation to income, and the importance of income effects on demand.[46] For quality (quantity) changes, bounding the discrepancy requires some careful adaptation. Randall and Stoll [1980] outlined the bounds, but two further considerations are important – the income elasticity of the marginal willingness to pay (Hanemann [1991, 1999]) and the ability to connect quality changes to a private commodity (see Willig [1978] and Bockstael and McConnell [1993]).

Most of the attention in travel cost demand models has implicitly or explicitly focused on integration as a means of relating Hicksian and Marshallian surplus measures. The central insight follows from the recognition of Roy's Identity as a differential equation relating the expenditure function to ordinary demand:

$$\frac{dy}{dp} = -\frac{V_p}{V_y} = x(p, y), \tag{6.1}$$

where p is the travel cost (price), and y is income. For single equation demand models satisfying the integrability conditions we can recover Hicksian consumer surplus for price changes from the analytical or numerical integral of equations such as (6.1). When we move from a single equation to an incomplete demand system, the conditions for integrability restrict the form of the demand functions more directly (see LaFrance and Hanemann [1989], LaFrance [1990], and von Haefen [2002]), but still allow recovery of the preference function. Direct specification of the direct or indirect utility function, and estimation of the implied demand equations to recover the parameters of the utility function, is also consistent with the integration logic described here.

Measurement of the Hicksian surplus for a quality change is more demanding, requiring both weak complementarity and the Willig condition. In section 3 we used a fanning of constant-utility indifference curves around zero consumption of the private good to illustrate how weak complementarity directly simplifies the treatment of a change in quality. It allows the quality change to be converted to a price change for the private good serving as the weak complement. This price change is the one that holds utility constant with a quality improvement. In practice, we cannot measure it. So, the challenge applied analyses must face is to asses whether a Marshallian consumer surplus measure of the benefits attributed to the quality change can be used to approximate the desired Hicksian price change. The answer lies in adding the Willig [1978] condition. Under weak complementarity and the Willig restriction the Marshallian surplus per unit of the private good will, in the limit, exactly measure the desired price change with a quality change. The Willig condition does so by restricting the way changes in income can influence the marginal value of quality changes.

Figure 6.1 taken from Smith and Banzhaf [2003] illustrates the effects of weak complementarity and the Willig condition. This figure repeats their graphical interpretation of how weak complementarity allows quality changes to be expressed as equivalent price changes. Here the Marshallian consumer surplus for the quality change from q_0 to q_1 measured at income level T corresponds to the average of CD and FE. The Willig condition allows higher incomes to increase the consumer surplus a person realizes from the same quality increase. However, it restricts the size of the increase in consumer surplus to be proportional to the increase in the demand for the private good from the increased income. In figure 6.1 the Willing condition implies that

$$\frac{X_0 - X_1}{X_0} = \frac{(E'F' + C'D') - (EF + CD)}{(EF + CD)} \tag{6.2}$$

must hold, where the average of $E'F'$ and $C'D'$ is the Marshallian surplus for the quality change at income level T'.

Said another way, calculating quality change welfare measures requires we integrate over both price and quality, and defining a line integral to the differential equation requires restrictions consistent with path independence. Palmquist [2003] suggests that the Willig condition restrictions are equivalent to requiring that the elasticity of the marginal willingness to pay for quality with respect to income (e.g. the price flexibility of income) will equal the income elasticity of demand of the weak complement.

Analytically this relationship plays a role similar to Hausman's logic for price changes. In general, the integral over price does not allow the analyst to determine how the constant of integration for the indefinite integral in equation (6.1), with quality included in the demand function, will change. Without this information we don't have enough information about the quasi-expenditure function to recover the Hicksian willingness to pay for the quality change. Larson's [1991] adaptation of the Hausman logic for quality changes with linear demands implicitly uses the Willig condition to remove the quality term from the constant of integration. Ebert's [1998] integration of the Hausman, LaFrance, and Hanemann work (with the implicit logic from Larson [1991]) argues that the integrability problem with multiple incomplete demand functions and associated quality can be resolved if we have consistent estimates of the marginal willingness to pay functions for each non-market quality attribute. His argument suggests replacing the Willig condition with additional information akin to additional differential equations relating expenditures required to hold utility constant to quality change.

6.2 Valuation Measures With Extensive Margin Choices and Unobserved Heterogeneity

Random utility models as discussed in section 3 rely on a different set of techniques to arrive at measures of Hicksian welfare measures, since the decision rule is based on the extensive margin and is explicitly influenced by unobserved heterogeneity that must be accounted for. In particular, following the notation from section 3, the individual's unconditional indirect utility function on a given choice occasion t is defined by the maximum function $V_t(\mathbf{p},\mathbf{q},m,e) = \max\{V_{1t}(p_1,q_1,m,e_1),...,V_{Kt}(p_K,q_K,m,e_K)\}$, where K is the number of choice alternatives. Given this form of the preference function, the choice occasion Hicksian willingness to pay measure cv is implicitly defined by

$$\begin{aligned}\max\{V_{1t}(p_1^0,q_1^0,m,e_1),...,V_{Kt}(p_K^0,q_K^0,m,e_K)\} = \\ \max\{V_{1t}(p_1^1,q_1^1,m-cv,e_1),...,V_{K't}(p_{K'}^1,q_{K'}^1,m-cv,e_{K'})\},\end{aligned} \tag{6.3}$$

where superscripts 0 and 1 denote initial and changed prices, respectively, and K' denotes the number of alternatives under changed conditions. Inspection of equation (6.3) suggests the willingness to pay measure will be a function of the unobserved heterogeneity, and thus a random variable from the perspective of the analyst. Once the parameters of the model are estimated, welfare calculation in the random utility model involves computing the expectation of willingness to pay for each individual in the sample. How this is done depends critically on the specific assumptions of the model.

If the conditional indirect utility function is linear in income and the errors type I extreme value, resulting in the multinomial logit model, the choice occasion welfare measure is given by the familiar difference in log-sums formula

$$E(cv) = \frac{\ln\left[\sum_{k=1}^{K} \exp(\bar{V}_k(p_k^0, q_k^1)\right] - \ln\left[\sum_{k=1}^{K'} \exp(\bar{V}_k(p_k^1, q_k^1)\right]}{b}, \qquad (6.4)$$

where $\bar{V}_k$ is the deterministic component of utility evaluated at the estimated coefficients, and b is the (constant) marginal utility of income.[47] This form makes clear the fact that the Hicksian welfare measure we estimate in RUM models is in fact no different (and no less restrictive) than the Marshallian consumer surplus measure that has been criticized in other contexts. Since the log-sum expression is the expectation of maximum utility under the extreme value distribution, the numerator in equation (6.4) is simply a measure of the expectation of the change in utility resulting from a change in prices or quality levels. Dividing by the marginal utility of income converts the change in utility into a money-metric measure of the utility change.

In contrast to the simple linear in income logit and nested logit models, a closed form expression for willingness to pay is not available when we generalize the random utility model to mixed logit and probit error distributions, or specify non-linear income models. Herriges and Kling [1999] provide a detailed discussion of welfare measurement in these models. For the case of the more general error distributions it becomes necessary to use Monte Carlo integration to calculate the expectation of maximum utility under initial and changed conditions. For each individual in the sample this is accomplished by simulating pseudo-random values from the error distribution and calculating the utility levels (as a function of the errors) under initial and changed conditions. Repeating this for several draws of the error, and taking the average of utility levels over all the draws, provides simulated measures of the expectation of maximum utility under initial and changed conditions. Dividing the difference between these measures by the marginal utility of income provides an estimate of the individual's choice occasion willingness to pay.

Non-linear income models present an additional level of complexity as we noted earlier. In these models, willingness to pay is no longer defined as a money-metric measure of utility difference. Rather, as a true Hicksian measure, it is necessary to compute the level of income that equates realized utility under initial and changed conditions. This implies that not only must the errors be simulated, but for each draw of the error the income differential *cv* defined in equation (6.3) must be solved that equates the indirect utility functions under initial and changed conditions. Typically this will require numerical methods. The expectation of an individual's willingness to pay is calculated by averaging the income differentials over all draws of the error.

The measures of willingness to pay discussed thus far in this sub-section can be considered unconditional, since the expectation of willingness to pay is calculated based on the unconditional distribution of an individual's unobserved heterogeneity. However, as suggested by von Haefen [2003], it is also possible to compute the expectation of willingness to pay based on the conditional distribution of unobserved heterogeneity. This strategy relies on the notion that, once the model is estimated, an individual's observed choice provides limitations on the support of the distribution that generated the person's behavior. Conditional welfare measures are calculated using Monte Carlo integration by first simulating the errors subject to these limitations such that the realized values are consistent with the choices observed in the sample at baseline prices and quality. This is followed by calculation of the utility levels under initial and changed conditions. As previously, the simulated expected utility levels are given by the average of utility levels over several draws of the error, and the welfare calculation computed by dividing the difference in utility by the marginal utility of income.

The RUM framework, regardless of the error assumptions and welfare calculation technique, delivers choice occasion willingness to pay measures. Calculation of seasonal benefit measures requires an assumption on the relationship between choice occasion selections among alternatives, and the amount of use over the course of a season. For example, Bockstael, Hanemann, and Kling [1987] assume that the quantity response to changes in price or quality is zero, and calculate the seasonal measure by multiplying the initial use by the WTP per trip. Morey et al. [1993] divide the season into a fixed number of choice occasions, during each of which respondents choose to participate in recreation or not, and if so, which site to visit. In this case the seasonal measure is the choice occasion WTP times the number of choice occasions.

An advantage of the Kuhn-Tucker class of models is that it avoids this issue by characterizing behavior over the course of an entire season. Welfare analysis, however, presents technical challenges similar to those described above for non-linear income RUM models. Phaneuf and Sideralis [2003] provide an intuitive overview of the steps necessary to compute willingness to pay for price or quality changes in KT models. Heuristically the process is as follows. With estimates of the utility function parameters, the solution to a consumer's problem (consisting of the combination of visited sites, the level of visits to these sites, and utility obtained) can be solved given a realization of the error in the model. Thus, we begin by simulating pseudo-random values for the errors and solving the consumer's problem under initial and changed levels of price or quality. Following this, an iterative process adjusting income in the consumer's problem under changed conditions is used to arrive at the income differential that equates the utility levels under the initial and changed prices and qualities. This income differential represents willingness to pay for the individual for the current draw of the error. Repeating this process for several draws of the error, and averaging the income differentials, provides an estimate of the individual's expected willingness to pay for the price or quality change.

Welfare measurement in mixed logit and non-linear income RUMs, Kuhn-Tucker models, and all uses of conditional welfare measurement highlight the importance and influence of unobserved heterogeneity in contemporary recreation demand models. This is consistent with other areas of applied economics, where accounting for unobserved heterogeneity in applications has taken on greater importance as computer power and micro data sets have become increasingly available. Welfare analysis in these models also highlights the different ways that contemporary approaches address the extensive and intensive margins of choice and the relevant income constraining decisions. The modeling alternatives at the frontier of recreation analysis are generally non-nested and employ different strategies for dealing with these three dimensions. The details of these decisions matter for how behavior is characterized.

Nowhere is this point more apparent than in attempts to compare the welfare measures derived from each model. Ideally, one would like to conclude that for certain classes of problems a particular modeling approach employing particular strategies for unobserved heterogeneity, the extensive and intensive margin, and income constraints will be most effective. Experience with each line of research in applications and controlled simulation evaluation has not been sufficient to offer this type of summary judgment. In fact, the complexity of the models themselves presents challenges for model comparisons that have not been fully addressed in the literature.

One simple proposal that would advance our understanding is to call for meta-summaries of the measures from each application. Here, we are not suggesting a summary across approaches, but instead within a modeling alternative across the welfare scenarios and dimensions of heterogeneity (see Banzhaf and Smith [2003]). This approach might offer a simplifying first step to help analysts understand how each feature of the modeling alternatives is influencing the outcomes for specific types of uses of the model.

7. RESEARCH AHEAD

Recreation demand analysis has evolved over the last fifty years from its beginning as a practical proposal to help a beleaguered Director of the National Park Service (Hotelling [1947]) to prominence in a recent Nobel lecture (McFadden [2001]). The years between have witnessed the evolution of techniques from simple aggregate demand models to sophisticated analyses of individual level choices. The latter blend economic theory and microeconometrics to describe mixed discrete/continuous demands for multiple sites. While the progress in the last fifteen years has been particularly rapid, it is nonetheless possible to close with a few comments on future research challenges that seem especially relevant given the accumulated experience of the past nearly sixty years.

Table 7.1 provides groundwork for our suggestions by outlining previous reviewers' suggestions for research needs. Many of these recommendations remain relevant today. A few of the most important in our view include accounting for the opportunity cost of time, the role of inter-temporal constraints (and opportunities) in individual choice, the definition and measurement of the amount of recreation produced and consumed by each individual, the problems associated with multi-purpose trips, and the treatment of the quality attributes of recreation experiences.

To this list we add some further issues centered on four themes. First, there is a need to evaluate the importance of what might be labeled the "balancing judgments" that inevitably accompany empirical research. These arise in many areas but are not usually acknowledged as a general class of decisions needed in the face of multiple competing goals. For example, contemporary microeconometrics has emphasized the importance of individual heterogeneity and incorporating explicit recognition of its influence in modeling and estimation. Recreation demand models certainly face these issues. The challenge arises in matching the modeling choices with the available information and needs of each application. Most contemporary models favor treating individual diversity in tastes, knowledge, and constraints as unobserved heterogeneity, characterized with random parameters. The prospect of using observed characteristics of individuals as indicators of latent variables (or classes) is usually regarded as less desirable because it is more restrictive. However, the random parameter models may also be regarded as restrictive by some analysts. They generally assume heterogeneity is captured with specific (and arbitrary) continuous distributions.

Some methods are selected because they represent methodological innovations rather than important features of a problem. This highlights the importance of understanding how a decision on method balances the ultimate use of results, the character of the information available to meet those needs, the sensitivity of findings to how each approach uses available information, and the objectives facing the analyst who undertakes the research.

Similarly, in another example, the data available for recreation trips is often reported as counts rather than as continuous measures of use. A consistent model allowing for multiple corner solutions might require (for tractability) assuming continuity in the measures of use for interior choices. A statistical model of counts might have difficulty in characterizing the role of unobserved heterogeneity motivating the diverse consumption patterns across individuals. Balance in this example might require ignoring one aspect of model implementation, given theory and data, in order to assure another can be met with the practical demands of a research project. Sometimes the literature appears to favor complexity in technique over what might be termed “face value” or plausibility of the resulting economic characterization of choice.

Certainly we feel recreation modeling has served an important role as an incubator for microeconometric research. However, complexity should not outpace the ability to assure that new techniques in fact enhance understanding of choice behavior. This observation is not in itself a research issue. The task of designing methods to evaluate research outcomes is. It requires delineating the objectives of a class of research and designing measures that allow comparison of the key assumptions and results of each model and estimation specification in these terms. What assumptions are consequential to the objectives? And how do modeling and specification judgments influence the robustness of the results?

Our second theme centers on temporal issues. Our review has suggested several examples of how recreation choice and behavior involve time in a number of different ways. Time intervals are not fully exchangeable. Different time intervals convey attributes such as daylight, temperature, seasons, or even order (i.e. first thing in the morning, late in the evening, beginning of a season, etc.). Both the attributes of time and its order can be important to economic models.

Most recreation models have been based on static behavior. This strategy stems from the large conceptual, computational, and data collection burdens of working with fully temporal models. Future research might be directed not only at developing tractable dynamic methods for recreation, but also at understanding the degree to which behavior characterized by static approaches can approximate behavior that is influenced by the attributes and order in which time is used. A particularly important area in this dimension is to more fully consider the impacts of a richer set of time constraints, recognizing that time is only partially fungible and often is available only in discrete blocks.

Related to this, most studies of choice set determination and extent of the market are based on cases studies of researcher-defined choice boundaries. Introspection suggests, however, that an individual's choice set is in fact endogenous and based on a dynamic information gathering process. Today's endogenous choice set and spike models with adjustments inflating the probability of zero use are statistical approaches to addressing the fact that many individuals may in fact never consider a recreation site included by the analyst in the choice set. Utility consistent conceptual and empirical models that account for the effects of the search costs on the process of determining individual choice sets have been lacking in recreation analysis and offer a topic for future research.

Over longer times people learn and change their behavior. This learning can be through formal education, direct recreational experiences, and indirect experiences that are acquired by reading or viewing materials related to potential interests. Changes in the availability of time over time and in experiences are what Krutilla [1967] argued would be likely to change the relative importance of amenities to produced goods. Recently Costa and Kahn [2003] suggest there have been increases in the value of climate amenities. While expenditures for desirable climate conditions have not changed (based on their hedonic models) the price to purchase preferred climatic conditions (controlling for other locational attributes) increased by six fold in their example, rising from $1,288 to $7,547 to purchase San Francisco's climate over that of Chicago. Some meta analyses of benefit measures suggest time trends in these models that display similar types of changes in broad terms. Time plays many different roles in the analysis of market choice. It should not be surprising that the challenges in reflecting the multiple roles for time and distinguishing the impact of changes on other dimensions of constraints are great.

Our third and forth themes are related, and center on the role that data and policy analysis can play in recreation applications. On the data side, research on combining revealed and stated preference data should continue, both from the perspective of study and model design. Likewise revealed preference data collection should adopt the construct validity criteria used in contingent valuation. Finally, methods need to be developed that allow practitioners to readily draw on multiple sources of existing publicly available data, either alone or combined with small purpose-generated survey data, to address specific policy questions.

This suggestion stems from Heckman's [2001] call for parsimonious models. If we begin with the premise that travel cost models are developed primarily for use in the evaluation of policy, then the research challenge involves developing models that allow public policy analysts to tailor the available results (based on these data) so that they can be used to address their specific questions.

This latter suggestion overlaps with the role that policy demands play in recreation analysis. There are two ways in which policy can and should play a role in recreation modeling. The first has received a fair amount of attention and involves benefit transfer. The second is relatively new and relates to the opportunities created by policy experiments.

Benefits transfer – the use of results from one study to inform a decision in another area – is a large and increasing use of recreation results in policy analysis. It is certainly not surprising to suggest that research on consistent methods for benefits transfer should continue. Our proposal calls for a change in orientation. Why not stress the development of models and data that can be consistently augmented with special purpose information relevant for each problem? Under this view, the ideal would not be one large multi-purpose survey and model to address all problems. Rather, it would be a platform with a sufficiently detailed structure to permit special purpose issues to be addressed by using targeted data collection efforts that could be linked to the base model and data. The goal would be adapting the methods of sample matching developed by Rosenbaum and Rubin [1983] and evaluated extensively by Heckman and his collaborators to meet the challenges posed in developing information for policy on the demand for and value of recreation resources.

This strategy would combine matching methods with joint estimation. Samples might include both revealed preference and stated preference information, linked through a description of behavior and tailored to the policy issue of interest. Multiple data sources could be used to estimate consumer preferences using joint estimation/matched samples estimators. With joint estimation we can take advantage of the scale of a larger set of background information and yet tailor the model to address details of the potentially smaller policy case. This strategy combines the structural features of joint estimation (as introduced by Cameron [1990]) with the lessons from meta analysis (Walsh et al. [1990], Smith and Kaoru [1990], Smith and Pattanayak [2002]) and preference calibration (Smith et al. [2002]) to assure that consistent structures are imposed in using past results to estimate consumer demand and measure benefits of policy interventions.

The literature in environmental economics has begun to explore the advantages of quasi-random experiments (see Chay and Greenstone [2003] and Greenstone [2002] as examples), our second role for policy activities in research design. Recreation models may also benefit from linking data collection to policy. The National Park Service changed fee schedules at a number of its major parks without adequate effort to collect and evaluate the responses. The Grand Canyon has an ambitious management plan to alter the role of automobiles within the park and no specific plans to track attendance and usage. Recent concerns about snowmobiles in

Yellowstone prompted calls for evaluations ex ante of regulations, but no specific proposals for data collection and evaluation ex post.

Several national databases together with differences in state regulations provide opportunities for using these differences to evaluate recreation behavior. Snyder et al. [2003] have done this recently with fishing licenses. Restrictions on timing of hunting and the design of lotteries for access to some specialty hunting are other examples (see Scrogin and Berrens [2003]). Some of these studies have exploited insights from the quasi-experimental design literature. Our point is that many more opportunities abound.

In many respects an important lesson from the recreation demand literature is that the diversity of opportunities in the U.S. and around the world has created opportunities to use non-market choices among these alternatives to learn about individual preferences for environmental quality. Economists working in this area have certainly seized them. The result has been a rich harvest of insights that extend greatly beyond the domain of recreation demand. Contributions to this literature have addressed some of the most interesting modeling issues in describing and understanding consumer choice. As the access to micro level data increases, we expect the lessons being learned in modeling recreation behavior will be of increasing interest to environmental and mainstream economists alike.

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Notes

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[1] Several other researchers were recognized as contributing to this report and were co-authors on subsequent papers. They were C.L. Kling, K.E. McConnell, and T.P. Smith.

[2] Parson's [2003] has developed an excellent and more detailed hands-on description of travel cost methods that nicely complements our chapter's emphasis on model development and assumptions.

[3] These estimates use Clawson and Knetsch's reports in Appendix Table 1 for personal consumption expenditures on recreation and expenditures for sports equipment relative to the total consumption expenditures from *Historical Statistics of the United States* for these two years.

[4] Domestic tourism final demand is defined as total tourism demand, less travel by U.S. residents abroad, and less business tourism demand (see Kass and Okubo [2000]).

[5] Smith and Kaoru's [1990b] meta analysis of price elasticity estimates from travel cost studies is somewhat more recent, but is also largely summarizing older research. They found that, in general, sites classified as rivers and forests were more likely to have price elastic demands, while state parks tended to have inelastic demands (each compared to coastal and wetlands). Perhaps the most relevant aspect of their analysis was the sensitivity of the estimates to the modeling judgments used in developing them. The presence of substitute price measures and the treatment of the opportunity cost of time were especially important choices. To our knowledge, no one has pursued this line of research in subsequent updates to the meta statistical summaries of empirical studies of recreation demand.

[6] Rosenberger and Loomis [2003] provide a nice discussion, summarizing the characteristics of these meta studies as part of evaluating their potential role for benefits transfer.

[7] A concern with their approach arises because they combine Marshallian and Hicksian measures of consumer surplus without adjustment for the differences. Smith and Pattanayak [2002] discuss the implicit assumptions underlying this practice. For our purpose here there is little alternative but to assume that the income effects are inconsequential and their composite estimates indicative of the relative importance of the activities.

[8] The history of the process was confirmed via private correspondence with Ivar Strand. Some of the early results are discussed in Norton, Smith and Strand [1983].

[9] Notable examples include the evaluation of damages in the Clark Fork River case in Montana (see Desvousges and Waters [1995]) and a component of the damages attribute to the Green Bay case in Wisconsin (see

Breffle et al. [1999]). The Parsons et al. [2000] discussion of "surgical" choice sets was also motivated in part by the discussion in these cases in this context. A surgical choice set presumably implies a design of the specific sites used in a RUM analysis to highlight a subset of particular interest for a policy evaluation or damage assessment.

[10] Bockstael and McConnell [1983] did not require a fixed coefficient production technology. We have also taken the simple route by assuming the same number of *z*'s as *x*'s. Altering this restriction adds complexity to the notation but does not change the basic point.

[11] The logic parallels directly the work of Chiappori [1988] in a different context. See Smith and Van Houtven [2004] for further discussion. In this context, it can be seen as an extension to the early work of Bockstael and McConnell [1983] demonstrating that within a household production framework, if one input is essential to all production activities it is possible to use the demand for that input to recover measures of the value for changes in public goods that were weak complements to one or more of the final service flows. If we assume that q is a weak complement to one (or more) of the activities identified as satisfying latent separability, then with the exclusive input to that activity an essential input we have the same result.

[12] An exception to this general form was offered by Bockstael and Kling [1988] who assumed that quality was linked to a set of goods as a weak complement. Their structure was analogous to forming a Hicksian composite commodity in the linked goods.

[13] Weak complementarity does not necessarily imply the smooth shape in the fan, only the intersection of these quality distinguished indifference curves at the same point. Thanks are due to Michael Hanemann for pointing out that this description adds information in specifying a shape for each indifference curve beyond what is actually implied for weak complementarity. We use these forms here because they embody conventional assumptions about preferences.

[14] Reviews of this early work can be found in Ward and Loomis [1986], Fletcher et al. [1990] and Smith [1989].

[15] The Loomis et al. [1986] regional demand model pools recreation sites described by a single model and is discussed further below.

[16] McConnell's [1992] creative solution suggests specifying the budget constraint by $m=x(p_x+p_t t)+p_z z$, where x is the number of trips, p_x is the money price of trips, p_t is the price of on site time, t is the amount of on site time, and z and p_z are the numeraire and price of the numeraire good, respectively. Roy's Identity in this case leads to a behavioral function for trips given by

$$x(p_x, p_t, p_z, m) = V_{p_x} / V_m ,$$

which can be estimated as a function of the price of on site time. McConnell further shows that the area behind this curve approximates the true welfare effect of a price change.

[17] Two excellent sources for the derivation and assumptions of simple and nested RUM structures in a recreation context are Morey [1999] and Herriges and Herriges [2003]. Ben-Akiva and Lerman [1985] provide an excellent general review.

[18] The standard assumption is that choice is deterministic from the individual's perspective and random only to the analyst. In contrast one could assume, as Hausman and Wise [1978] suggest that random errors reflect a changing state of mind for the consumer or they reflect errors in measurement for the independent variables affecting choices.

[19] Schwabe et al. [2001] is one notable exception in a study of the effects of seasonal attributes in the context of hunting site choice.

[20]The IIA property arises from the structure of the multinomial logit probability. Note from equation (3.11) that the odds of choosing alternative *k* over alternative *j* on occasion *t* is $p_{kt} / p_{jt} = \exp(\bar{V}_{kt}) / \exp(\bar{V}_{jt})$. Thus, the ratio does not depend on alternatives other than *k* and *j*, and the odds are the same regardless of the availability of other alternatives. Train [2003] provides an excellent discussion on IIA and its impacts on substitution patterns in the logit model.

[21] Comparing welfare effects from estimated models is the common metric for judging the impacts of modeling decisions in recreation demand in general. This presents a perennial difficulty, however, in that the comparison is based on an unobservable baseline and appeals to intuition are needed to differentiate results. This feature of the literature to date suggests that greater efforts to specify more objective measures of comparison between models would be worthwhile. Specific to the question of aggregation, Kaoru et al. [1995] propose using the Hausman – McFadden [1984] test for IIA as one appropriate basis of gauging a proposed aggregation.

[22] No one has specifically discussed the potential implications of differences in the measurement of travel costs across aggregations in each of these studies. Some examples indicate there were clear differences in practices used. Parsons and Needelman alter their measures of travel cost to consider the centroid of the aggregate site. Kaoru et al. [1995] use the measured travel cost to the disaggregated site selected and the average of the travel costs to the sites in an aggregate for the substitute sites that were not visited.

[23] The Hauber and Parsons [2000] comparison of choice sets defined through distance contours found that benefit measures were invariant outside the equivalent of 1.6 hours. This finding is also consistent with our summary because progressive increases in travel costs with distance imply that the set of sites added at greater distances contribute less and less to what might be termed effective substitutes because they are all priced out of consideration.

[24] There are also a smaller number of site alternatives in the Kling-Thompson choice set (26 mode/site alternatives) than in any of the evaluations conducted by Parsons' applications. The later are typically in the

hundreds, and often involve a randomization scheme to compose the choice set for estimation (as in Hauber and Parsons [2000]).

[25] The Smith et al. application proposes interpreting the cost function as a frontier – the locus of least cost ways (sites) of acquiring the desirable characteristics are restricted to be positive. The use of regression methods to estimate the hedonic cost function does not preclude negative marginal prices for attributes (see Bockstael et al. [1987] and Smith and Kaoru [1990]). Englin and Mendelsohn [1991] suggest that such prices can reflect satiation and do not, as other authors have argued, invalidate the method. Bockstael and McConnell [1998] have observed this explanation raises the prospect that the consumer choice problem is not well defined. Allowing for satiation implies that the set of sites defining the locus cannot preclude situations where less of a site characteristic actually costs more.

[26] See Clawson and Knetsch [1966], Cesario and Knetsch [1970], and Cicchetti, Fisher, and Smith [1976] as examples of demand analyses relying on these data.

[27] The Public Area Recreation Visitors Survey (PARVS) is an example of a long term effort coordinated by H. Ken Cordell of the U.S. Forest Service to collect on-site recreation surveys for forest service areas and in coordination with NOAA, for beaches around the U.S. Vernon R. Leeworthy has been especially active in developing well-documented recreation databases relevant to NOAA's activities. Daniel Hellerstein has focused efforts at the Economic Research Service on related activities for recreation sites relevant to agricultural policy.

[28] For a more recent summary of the issues in implementation see Tourangeau et al. [2000].

[29] Hanemann notes that of 224 individuals who reported participating in fishing in the first wave, only 64 reported participating during the last wave. While this change seems like a large decline, the paucity of temporal records on recreation use makes it difficult to judge in unambiguous terms.

[30] McFadden [1996] has recently considered the relevance of this result for intercept and follow-up samples. He concludes from simulation experiments that simple adaptations to the weighted maximum likelihood, or including selection effects to account for the follow-up success rate, result in substantial errors in both the parameter estimates and the estimates of willingness to pay when compared with the correct intercept and follow-up likelihood function.

[31] Cameron's research was actually completed in 1989 and was circulating as a discussion paper for some time prior to publication. There are important differences in the two studies. Cameron's combines a continuous travel cost demand with a discrete response contingent valuation question. Morikawa's analysis focuses on random utility models applied to model choice in transportation, using both revealed and stated preference choice data.

[32] In an unpublished Ph.D. thesis Egan [2004] uses a mixed logit random utility model to investigate the factors influencing site choices for one-day trips to freshwater lakes in Iowa. He finds direct support (e.g. statistically significant parameter estimates) and plausibly signed effects for technical indexes of water quality as factors influencing site choice with freshwater lakes in Iowa. The model includes measures of lake size, facilities,

boat ramps, and regulations on boat wakes (that might disturb angling) as well as a large array of physical indexes for water quality. Estimates for travel cost and the other site characteristics are quite stable for two models that differ in the number of characteristics. However, the estimated parameters for income, gender, and age are not. While the author does consider how recreationists "learned about" the water quality features, his results imply this issue is definitely worthy of further consideration.

[33] This approach is analogous to the rationale we have argued accounts for weak complementarity's effectiveness in recovering Hicksian measures of quality change. The restriction allows quality changes to be represented as Hicksian equivalent price changes.

[34] The eco-tourism literature has considered this issue in developing countries, but there have been few attempts to apply travel cost models in this context. Most of this work has relied on contingent valuation. See Brown et al. [1994] as an example.

[35] Haab and McConnell [2002] provide a more complete overview of econometric models used in recreation demand analysis.

[36] Bockstael and Strand [1987] provide an intuitive discussion of this distinction in the context of single site demand models.

[37] Shonkwiler and Shaw [1996] provide an excellent overview of count models, zero inflated adaptations and hurdle specifications.

[38] See Morey et al. [1995] for an overview of multiple site demand models that allow interior and corner solutions.

[39] Thanks are due to J.R. DeShazo for discussing aspects of his unpublished research relevant to this strategy.

[40] Differential time costs are reflected in the expected cost of a trip through dummy variables for full employment, weekdays and length of workweek. However, they are not treated as choice variables.

[41] See McConnell, Strand, and Bockstael [1990] and Munley and Smith [1976] for early empirical analysis in simpler models.

[42] Provencher and Bishop also highlight this issue in their closing comments.

[43] The simple RUM framework yields a closed form solution for the willingness to pay. The non-parametric does not, and requires an approximation of the marginal utility of income. This is estimated as the negative of the derivative with respect to travel cost for each individual evaluated at the travel cost for the site to be maintained.

[44] Varian [1982] formalized the concept of a generalized axiom of revealed preference that allows for multi-valued demand functions.

[45] This is especially true when we contrast the findings between Adamowicz and Tomasi [1991] that find a small number of violations evaluating expenditures across trips for the same individual with the cross individual comparisons in Boxall et al. [1996].

[46] See Freeman [1993] and Bockstael and Freeman (this volume)

[47]Linear in income nested logit models have a similar closed form expression for choice occasion willingness to pay. See Morey [1999] for details.

Table 2.1 Summary Estimates of Price, Income Elasticities & Consumer Surplus Per Day

Type of Site Activity	"Early" Estimates		Recent Estimates		Consumer Surplus Per Day	
	Own Price	Income	Own Price	Income		
FRESHWATER SITES	-0.45[a]	--	--	--	--	
	-1.63 to -1.71	--	--	--	--	
Fishing	-0.27[b]	0.47	--	--	36.52[d]	
Coldwater	-0.38 to –0.97	--	-0.43[c]	--	--	
Warm water	-0.31 to -0.85	--	--	--	--	
Boating	--	0.34	--	--	39.25	
Sailing	-0.11	--	--	--	--	
Canoeing	-0.19	--	--	--	--	
Swimming	--	--	--	--	31.34	
SALTWATER SITES	--	--	-1.39[e]	0.24	--	
Sport Fishing	--	--	-0.80[f]	--	Salmon/River	13.69[g]
					Salmon/Lake	76.57
					Salmon/GL	114.78
					Bass/River	84.46
					Bass/Lake	34.11
					Bass/GL	27.84
Beach Recreation	-0.20	--	-0.33 to -0.50[h]	0.17	--	
LAND BASED SITES	--	--	--	--	--	
Camping	--	0.42	--	--	31.43	
Developed Camps	-0.15	--	--	--	--	
Remote Camps	-0.18	--	--	--	--	
Hunting	--	--	-1.76 to -2.40[i]	--	--	
Deer	-0.21 to -0.87	--	--	--	--	
Small-Game	-0.36 to -1.06	--	--	--	42.83	
Big-Game	-0.23 top -0.62	--	-1.03	--	45.41	
Waterfowl	--	--	--	--	30.73	
Hiking	-0.18	--	-3.38	--	40.47	
Wilderness	-1.59[j]	2.45	-1.10 to -6.28[k]	--	--	
Rock Climbing	--	--	--	--	Rocky Mtns.	42.04
Wildlife Viewing	-0.32	--	--	--	31.07	
Skiing	-0.70	0.50	--	--	--	
Downhill	--	--	--	--	27.91	
Cross Country	--	--	--	--	26.19	

[a] The price elasticities are taken from Smith and Kaoru [1990a]'s Appendix summarizing the results they were able to compute from the primary sources. The sources are identified in their Appendix. Point estimates for specific sites or activities were selected here to fill in categories based on the objectives of the original studies compiled in Smith and Kaoru.

[b] These estimates are taken from Walsh [1985] Table 9.3, 9.4 and 9.6. In the case of the price elasticities he cites Adams, Lewis and Drake [1973] as his primary source for all but fishing, hunting and skiing. The hunting and fishing are taken from Gum and Martin [1975]. He does not cite his source for the skiing price elasticity. For the income elasticities he cites Kalter and Gosse [1979].

[c] Derived by combining demand model reported in Englin, Lambert and Shaw [1997] with summary statistics in Englin and Lambert [1995] for the same sample. Analysis involves coldwater trout fishery in New York State excluding New York City, New Hampshire, Vermont and Maine.

[d] The values per day in Rosenberger and Loomis [2000a] [2000b] are in 1996 dollars. They combine travel cost demand, random utility and contingent valuation estimates converted to a per day basis. When they were not summarized as overall averages, we computed the means from this table of disaggregate means.

[e] These results are for trips to the Albemarle-Pamlico Sounds in North Carolina and can involve swimming, fishing, camping, hunting, water skiing and a variety of water related activities. They are taken from Whitehead et al. [2000] from their revealed preference model with existing quality conditions. Using a stated preference question, joint estimates of trip participation and demand with 60% improvement in catch and 25% increase in shellfish beds lead to more inelastic demands, both in price and income. Income elasticity was not significantly different from zero. These estimates for the same area were -1.05 for price and 0.06 for income.

[f] These estimates are for Alaska and are taken fro the Hausman et al. [1995] linked RUM/count demand model. Smith [1996] has argued the price index proposed for their demand analysis does not meet the requirements for a consistent price index. Moreover, one of their estimated demand models used for these elasticity estimates has positive price effects (hiking). Given the estimation procedure the authors describe, the positive estimated parameter must be regarded as a type setting error. Otherwise, the elasticity would not be negative.

[g] The sport fishing unit values are in 1996 dollars on a per day basis. They also report per trip estimates. These means are based on the travel cost studies. This summary is from Boyle et al. [1999]. GL designates Great Lakes..

[h] These estimates are a composite of those developed by Leeworthy and Wiley [1993] and subsequent re-analysis of their data by Richard Dunford [1999].

[i] These estimates are from Herriges and Phaneuf [2002] for wetlands recreation in Iowa and are computed using the repeated mixed logit specification.

[j] Price and income elasticities are from Smith and Kopp [1980].

[k] Based on Lutz, Englin and Shonkwiler's [2000] comparison of disaggregate versus aggregate travel cost demand for backcountry and wilderness hiking. This range of estimates is across different sites including Hoover, Ansil Adams, John Muir, Lasser, Sequoia-Kings and Golden Trout in Inzo and Lasser National Forest Area. Their models include income but they do not report the means, so it was not possible to compute income elasticities.

Table 3.1 Evaluations of Choice Set Specification in Recreation Context

Authors	Structure of Choice Set	Total # of Alternatives	Type of Recreation	Model	Environmental Quality Measures	Policy Considered	Welfare Computation	Findings For Benefit Measures
Parsons and Kealy [1992]	3, 6, 12 and 24 lakes randomly drawn from within 180 miles of person's home	1,133	fresh water recreation at Wisconsin lakes	nested logit two levels; North and South Wisconsin, then lakes in each group	dissolved oxygen (DO) and secchi disk discrete readings; site attributes	improve all lakes to a low DO standard; improve all lakes to high DO standard	uses all sites in 180 miles and all visited by at least one person and within 180 miles	large variation in per trip Hicksian welfare measure; larger number of sites generally but not always smaller benefit measure; difference as large as 9 times across models
Feather [1994]	6, 12, 24 simple and importance sampling	286	fresh water at Minnesota lakes	simple RUM	water quality measured using secchi disk	10 % increase in lake size	all alternatives	importance sampling close to model based on full choice set yields differences in welfare measures under 20% over range of models; simple random sampling of site alternatives understates full model's benefit measure, has more instability at a given sample size of choice alternatives; its difference with full model declines with number of sites
Kling and Thompson [1996]	five new shore site aggregates supporting each of four modes (beach, pier, charter boat, private boat) and three off shore supporting two modes (charter	26	sport-fishing in California	nested logit two levels	average catch rate for all species	eliminate site alter-natives in various combinations	all alternatives	evaluate sensitivity to restrictions on catch coefficient and to nesting structure; welfare estimates for all policy scenarios sensitive to nesting structures and restrictions on catch coefficient; values differ by 3 to 4 times from lowest to highest per trip for all policy scenarios; test favors model with largest welfare measures

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	and private boat); four site/mode nesting structures							
Parsons and Hauber [1998]	choice set defined by distance pre-measured in terms of travel time 0.8 to 4.0 hours	1,899	recreational fishing Maine	nested logit three levels; site type of fish	water quality fish species presence and abundance; level of toxic pollution	clean to EPA attainment; clean toxins; salmon absent	choice set defined by distance boundary	outside 1.6 hours travel time little change in per trip benefit measures across all three scenarios; dramatic differences inside this boundary; on average benefit measure 6 to 7 times larger for smallest to largest choice set
Shaw and Ozog [1999]	examined two nesting structures A – participation, stay overnight, the site choice (8 alternatives) B – participation, site choice first day and stay overnight	sites aggregated from 13 rivers to 8 river group defined as site alternatives; Atlantic salmon fishing	five sites in Maine, three in Nova Scotia, New Brunswick, and Quebec, Canada	nested logit three levels; nonlinear income effect	catch rates	double salmon catch rates at Penobscot River	all alternatives	use quadratic loss function to solve for per trip consumer surplus; only model A could be solved for benefit measure; B could not be solved; per period Hicksian consumer surplus lower for those users with one day trips than those staying overnight; no conclusion on alternative nests based on welfare measures; model A preferred on consistency conditions of dissimilarity parameters
Parsons, Plantinga and Boyle [2000]	combination of aggregation and distance based definitions -- regional aggregate, popular sites, policy region, composite commodity for all	814	fishing lakes in Maine	nested logit in study area and outside	measure of expected cold water fish catch rate and qualitative variable indicating importance of site for cold water species	loss of five sites in China Lakes region	compares nested with random sample of all sites to different "surgical" aggregates: regional aggregate of alternatives,	definition of alternatives impacts substitution effect and extent of market; latter arises because expansion of sites considered as substitutes has number of individuals "unaffected" by loss increased when more substitutes; treatment of substitutes included in model affects

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	outside sites						alternatives as popular sites and no consideration of outside alterna-tives – simple RUM focused on region	per recreationist benefits; substi-tution works as expected -- less substitutes, measures for loss larger; extent of market tends to reduce discrimination between alternatives
Jones and Lupi [1997]	examine eight different nesting structures to de-scribe choice sets that include species-site and site species combinations in 2, 3 and 4 level nests	2,029 fishing sites and up to four fish species at each site	recreational fishing in Maine	nested logit	qualitative variables for elevated toxics and fish consumption advisories, nonattainment of EPA water quality standards due to nonpoint source pollution and for species abundance (salmon, trout bass and other)	three scenarios: cleanup of non-attainment sites based on water quality; cleanup based on toxics; eliminate salmon as available species	median estimate of 20 random draws from each model – using average across all sample individ-uals of per trip consumer surplus	
Parsons, Massey, and Tomasi [2000]	compares simple RUM with full choice set to: nested with familiar and unfamiliar; simple RUM with only "favorite" sites; simple RUM with only familiar	beach recreation in Delaware, New Jersey, Maryland, and Virginia	62 beach sites from Sandy Hook, NJ, to Assateague Island, VA.	nested logit two levels; simple RUM with full and variety of smaller choice sets; over number of site familiar = 11.5 sites, favorite =	length of beach, dummy variables for: width of beach, boardwalk, amusements, park inside, presence of surfing	beach closures and loss in beach width	uses choice set relevant to each model	full choice set has smallest Hicksian welfare measure per trip for most beach closures; full choice set welfare measure in the middle of the range of values across models; variation in estimated per trip consumer surplus can be large

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	and favorite (labeled Peters et al.); and simple RUM with only familiar (labeled Hicks and Strand).			9.4 sites and visited = 4.1 sites				
Peters, Adamowicz, and Boxall [1995]	compares full choice set, random selection with 5 alternatives, and individually defined consideration based choice set.	67	freshwater fishing in Southern Alberta, Canada	simple RUM	general catch rate, trout catch rate, index of effort for large fish; qualitative variables for pristine lake, trees stocking; measures of stability of water flow and length of stream	site closures (four alter-natives) in-crease tree cover at a site, introduce trout stocking	appears to be all sites for full model and random selection and indi-vidually de-fined choice set for consideration based choice set	full and random choice set very close estimates of per trip Hicksian surplus measures; individual consideration set large differences; relationship depends on policy considered; always agrees in direction of effect; magnitude of estimates varies from 4 times larger to 1/10 as larger.
Hicks and Strand [2000]	compares full choice set with distance based choice set (6 different alternatives) and set de-fined as familiar to individual	10	publicly accessible recreation beaches along the western shore of Chesapeake Bay in Maryland	simple RUM	measure of bacterial contamination (fecal coliform in water), measure of presence of both facilities, boat docks, and pools	reduction in fecal coliform, closure of sites (including well-known site)	uses all sites for full site model, distance (or time) based and familiarity based definitions	distance based measures of choice set stabilize to approximate the full choice set for all Hicksian welfare computations (based on mean for per trip values) at approximately 2.5 hours (set ranges from 1 to 3.5 hours); full set is about 4 hours travel time; familiar set very different for all three welfare scenarios; estimates especially different for loss of familiar site (five times larger then conventional

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								estimates); otherwise smaller than full site and distance based measures (60 to 84 percent of their values)

Table 7.1 Alternative Perspectives on the Research Challenges for the Travel Cost Method

Author	Research Issues
Ward and Loomis [1986]	**Valuation of travel time** Need continued research to evaluate effects of assumptions and establish greater consensus on best practices. **Treatment of on-site time** Develop consistent framework for role of on-site time in trip demand models. **Research issues in matching variant of travel cost model to management issue to be addressed**.
Smith [1989]	**What is a site?** Aggregations and disaggregations of land-based sites have been developed without regard to attachment of site characteristics, travel cost measurement; etc.; we do not understand implications in RUM for choice set in estimation and welfare measurement. **Supply and demand** Modeling of congestion, measures of scarcity of recreation resources, resource management of existing sites require we begin to model sorting of recreationists among sites and define what supply means in this context. **Perceptions versus technical measures of quality** Most site demands include technical measures of quality or warnings (fish consumption advisories); we know little about how people form perceptions about the quality of recreation sites at any point in time or with changing quality over time. **Demand for recreation activities** Classification of studies and results at beginning mixed site demand with activity demand; issue of whether we can consistently interpret and measure them; can we move the modeling of activities for stories to identifiable analytical models capable of empirical implementation?
Fletcher, Adamowicz and Graham-Tomasi [1990]	**Primary data collection** On-site, intercept, and user group surveys with limited information on perceptions, time allocation and choices among activities for using time; limit ability to address fundamental issues in travel cost models; need more primary data. **Evaluation of modeling performance, especially benefit measures and transfer** Recommend comparison of estimates for comparable activities across geographic areas and evaluate sources of differences. **Aggregation** More attention to aggregation over time, quality conditions for trips, individuals and sites. **Welfare measurement** Selection of functional forms for demand/preference models and welfare measures.

Author	Research Issues
Bockstael, McConnell and Strand [1991]	**Modeling range of recreation decisions** Consider the relative strengths and weaknesses in discrete choice and continuous demand models. Integrate models of participation decisions. **Dealing with multiple price/quality changes** Evaluate how effects of price and quality changes on demand and welfare measures can be consistently aggregated over different sites and activities. **Dynamic behavior and welfare measurement** Repeated visits reduce site attribute uncertainty and lead to increased skills. Develop models for the effects of these changes over time in a consistent framework. **Aggregate welfare measurement** Reconciling needs for individual welfare measures, consistent aggregation, and evaluation of distributional effects implied by heterogeneity in preferences and income.
Parsons [2001]	**Measuring trip cost** Consider how we measure travel and time costs, access fees, equipment costs, lodging, time on site in integrated model. **Perceived versus objective quality measures** Perceived measures are preferred to describe behavior, but may be able to short circuit the need to know them if objective measures are a consistent proxy across people. **Multiple destination trips** Cost allocation is key issue when trip has multiple objectives; portfolio of sites used as a choice alternative needs to be investigated in RUM framework. **Site and choice set definitions** Need to evaluate approaches to defining sites and choice sets in a RUM framework; evaluate sensitivity to their definition; potential in considering choice set formation as an endogenous process. **Time interdependence** The role of experience and habitats in some types of recreation potentially important; also RUM often assumes independence across choice occasions; influence of season and timing of use important.
Herriges and Kling [2003]	**Opportunity cost of time** Multiple influences on the full opportunity costs of time; despite extensive research empirically tractable, theoretically consistent encompassing solutions remain to be developed. **Dynamic aspects of recreation choices** Potential for individuals to substitute intertemporally between current and future trips has significant implications for welfare measurement. Experience with discrete dynamic optimization models is limited and needs to expand. **Multiple site trips** Consider evaluation of multiple objective trips as portfolios or trip combinations. Limited research using this strategy – it is worthy of further study. **General modeling issues** Continuing need to evaluate selection criteria to discriminate among alternative functional forms for demand and indirect utility functions; issues with site aggregation and extent of the market lack clear-cut resolution; scope for using combined revealed/stated preference data in recreation as a validity gauge for each method, especially if stated preference includes nonuse values.

Figure 3.1

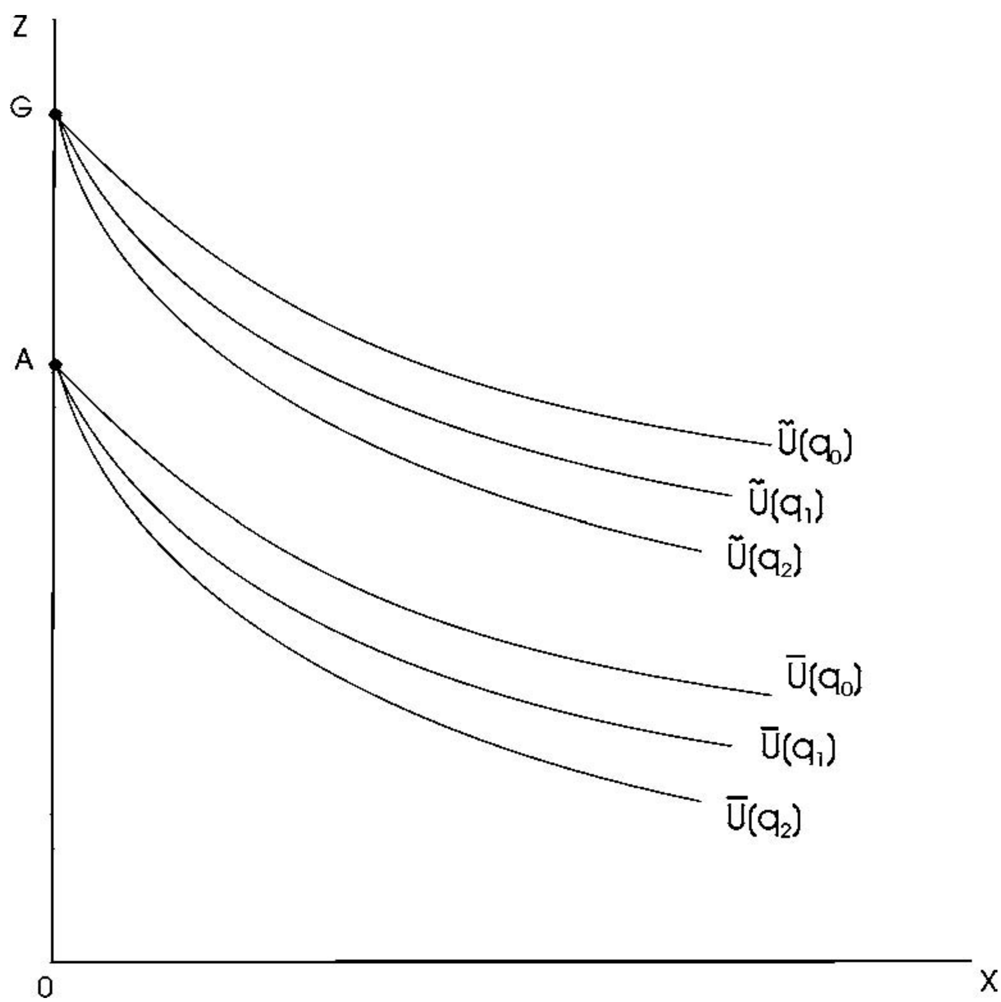

Figure 3.2

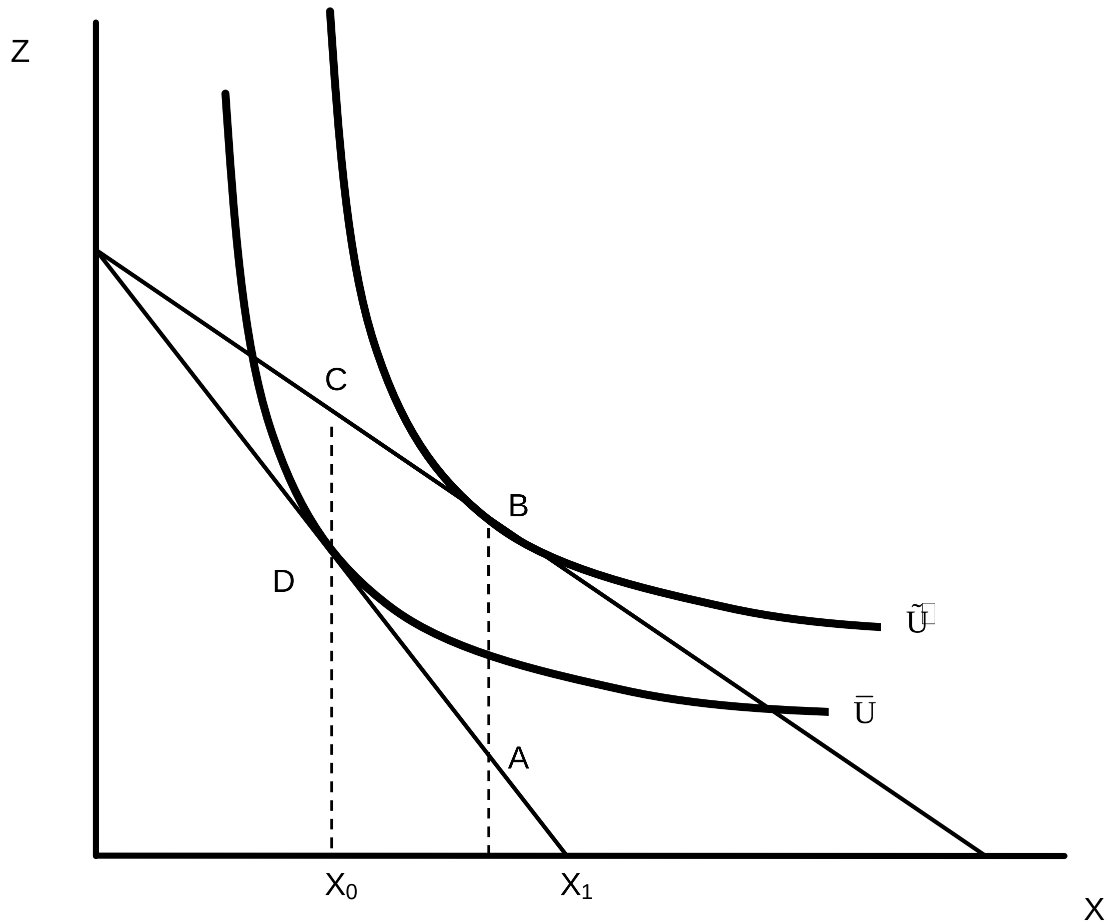

Figure 3.3

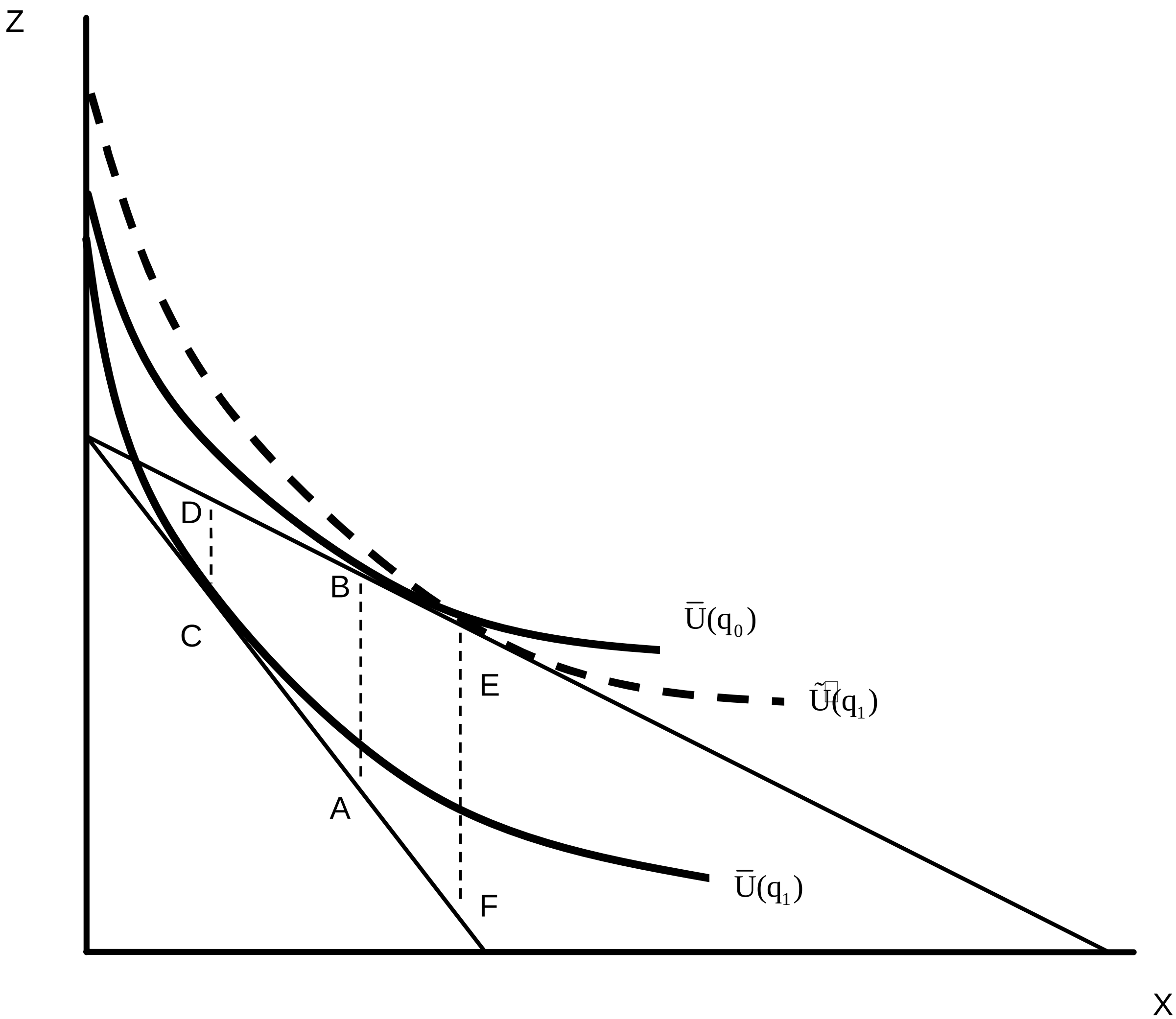

Figure 6.1