PREDICTING RESOURCE MANAGEMENT BENEFITS BY SIMULATING ANGLER DEMAND AND SUPPLY RESPONSES

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ABSTRACT

The "product" travel cost model (PTC) improves supply and substitution specification in travel cost models (TCM), eliminating common biases in estimating welfare effects of qualitative changes at specific sites. Angling sites and participation are modeled as a system of product supplies and demands; changes in angling quality at specific sites are evaluated as changes in the supplies of relevant products. PTC assumes that each angler chooses from a selection of angling opportunities (i.e., products) based on access cost (i.e., travel cost) and the nature of each angling product. Key factors defining angling products (e.g., success rate, fish size) are derived from angler travel patterns: Anglers are assumed indifferent between sites providing identical angling products, so choose the lowest cost site. Therefore, the benefits of any management action not only differ from average welfare-change values, but are also site-specific. Changing angling attributes at a site changes its angling product: a unit of the existing product (potentially decreasing its supply) is lost while a unit of the newly created product is produced (potentially increasing its supply). Changes in supply at one site may alter angler participation patterns and the value of angling opportunities at the affected site plus at many other sites as well. Credit Valley Conservation contracted the application of the PTC examined here, namely angling in the Credit River watershed near Toronto, Canada. Average angler consumer surplus was estimated at $40 per angler day and varied according to angling product, location and season.

Keywords: angling, sport fishing, consumer surplus, travel cost model, TCM, AIDS, random utility model, RUM, product travel cost model, recreation supply, simulation model, benefit estimation

INTRODUCTION

Travel cost models (TCM) are generally used to estimate the non-market value of the use of publicly owned natural resources and to provide other useful information (e.g., forecasts of future use). However, many TCM poorly specify the supply of recreation opportunities, resulting in misspecification of the related demand equations. This misspecification leads to biased and potentially inaccurate estimates of economic values. Forecasts of the impacts of resource changes on the future values and uses of public natural resources should account for the simultaneous influences of both demand and supply, even if only reduced-form demand and supply equations are estimated. Yet TCM are commonly constructed to estimate non-market use values based on the premise that the primary challenge relates to demand estimation.

Single-site TCMs commonly assume a given site is unique (i.e., that there are no competing or substitute sites), rendering this class of TCM nearly useless for predicting the impacts of any changes to the site. The only change that can be modeled is the presence or absence of the existing site, and estimates of the value of that change are likely biased by the assumption of no substitutes. Single-site TCMs include no statistical basis for estimating the impacts of changes.

The most common TCM approach, the random utility model (RUM), models supply in a greatly reduced form. It assumes that the demand for any site is independent of the supply of other sites. In other words, RUM assumes zero substitution between sites. Failing to account for the impact of substitutes results in misspecification of demand and supply and can significantly bias value estimates.

The product travel cost (PTC) model is the only TCM that systematically both (1) defines site substitutability in terms of site attributes, and (2) models the simultaneous supply of relevant sites. The primary objectives of this paper are to describe the PTC model and to compare its advantages and disadvantages to RUM and other TCM. We show how PTC more accurately estimates the supply and demand for non-market goods by utilizing an approach analogous to the conventional specifications of demand and supply employed for market goods. The next section describes the generic structure of PTC, including the empirical foundation for defining recreation products based on site attributes and observed user site-selection patterns. Next it describes methods for simultaneously estimating demand and supply for each product using AIDS-like procedures. It also outlines key differences between the PTC and RUM and other TCMs. Finally, it describes a method for incorporating PTC-derived supply and demand functions in a dynamic simulation model and predicting changes in benefits and use at single or multiple sites. The third section presents a practical application of the PTC, defining and estimating the demand and supply of angling products in the Credit River watershed near Toronto, Canada. The resulting PTC estimates changes in consumer surplus attributable to changes in angling products (i.e., angling quality) at specific sites in the watershed. The final section summarizes our findings.

THE PRODUCT TRAVEL COST MODEL

Defining products

With conventional market goods, products are typically defined by the market; partly by producers through their efforts to differentiate their products to attract consumers. Consumers contribute to this definition through their purchasing patterns. The result is largely reflected in consumer loyalty, market shares, and differences in prices between products. With non-market publicly owned goods, we argue that product definition is operative and critical for many users, but the product types are much more difficult to observe and objectively define. Consumers of publicly owned goods differentiate among consumption opportunities (e.g., different angling sites), favor/are loyal to particular products, and allocate their expenditures and consumption shares according to their preferences. We argue that accurate definitions of product types and quality are as essential to demand and supply analysis of non-market goods as they are for the analysis of market goods. The PTC provides a systematic, theoretically sound and practical method for deriving the product types perceived by the consumers of these non-market goods.

A key underlying concept of PTC is the assumption that users reveal their definitions of “products” by their collective use patterns: Users are expected to be indifferent between sites that users perceive to offer the same “product”. Users are assumed to behave as rational consumers and to choose the desired product at the lowest available cost. Demand and supply analyses of market products adopt the same assumptions. Therefore, users have few reasons not to primarily use the least expensive site offering each given product (i.e., a user is not likely to travel past one site to reach another site with essentially the same attributes). If users primarily choose the least cost option for a particular product, user behaviour can reveal 1) which attributes at different sites are important to them, 2) the relative value of the bundle of attributes offered by different sites and 3) those sites that are sufficiently similar to be defined as the same “product”.

Market and non-market products can be defined with various degrees of precision depending on the purposes of the analysis. For instance, many people differentiate between red wine and white wine. Some differentiate between sweet and dry red wines. Avid wine drinkers differentiate between a merlot and a pinot noir or a cabernet. Wine connoisseurs differentiate between a pinot noir of a particular vintage produced in a particular region and even a particular vineyard. This differentiation is reflected through wine prices and other purchasing patterns. A coarse-level demand and supply analysis of red wine might lump all red wines as a single product reducing the information and analytical demands of the analysis. The disadvantage would be that little information would be revealed about the attributes that are important to consumers in differentiating among red wines or the contribution of these attributes to the market price. A similar dilemma arises with defining non-market products.

Non-market products can be defined in various ways, including various market segmentation methods, such as cluster analysis (Talhelm and Mahoney, 1997) and discriminant analysis. Talhelm (1972, 1973, 1982; Talhelm, et al., 1987) developed a discriminant analysis method specifically for use in PTC. This method is based on the assumption that the degree of correspondence between proposed product definitions and users' implicit definitions is revealed by the extent to which users select only the least-cost site among multiple sites offering a given product. The calculated "excess travel cost" indicates the degree of apparent irrationality in user behaviour (i.e., lack of correspondence with product definitions). Excess travel is calculated as follows:

$$E = \sum\sum (TC_{ij} - MC_{ij}) \tag{1}$$

Where: E is the aggregate excess travel across all visits j and all products i,

TC is the estimated travel cost[1] incurred for visit j to a given site offering product i,

MC is the estimated minimum travel cost for visit j if it had taken place at the least-cost site offering product i,

i is one of n products found in the system of m recreation sites, as defined in a given proposed product classification key, and

j is one of q recorded visits in the system of m recreation sites.

The objective of the discriminant function is to find the product definition that minimizes E (i.e., minimizes the lack of correspondence within product categories) for the smallest "reasonable" n (the smallest realistic number of products). Note that excess travel can be minimized to zero (eliminated) by defining each product/site as unique; doing so however yields little information about user preferences. As a result, an important part of the discriminant objective is to find the smallest number of products while also minimizing excess travel. As n increases, E decreases by reducing the possibility of excess travel (i.e., "possible" E). Thus, a simpler way of expressing the same discriminant objective is to find the product definition that maximizes the difference between possible E and observed E. In either case, minimizing within-category lack of correspondence effectively maximizes the differences between categories (i.e., the differences between products). Thus, sites offering the same product are uniform but differ from sites offering other products.

This discriminant analysis involves a recursive process in which alternative hypotheses are proposed for classifying products; the resulting E and n are used to select the best definition. At the outset, the system of sites is defined and key attributes of each site that are expected to be significant for the users and relevant to the purposes of the research are identified and quantified. Cluster analysis or other techniques for finding similarities and differences can help in this process. A set of products (i.e., the initial hypothesis) is defined by lumping sites with similar attributes into defined product categories. For example in the case of angling sites, key attributes might include species present (e.g., trout, salmon, warm-water species), expected catch rate (e.g., high, medium or low), expected crowding (e.g., high or low), and other potentially significant site attributes. In this example, 18 products (combinations of species, catch rate and crowding) are possible, although all 18 may not actually be present in the system. Once the tentative list of products is defined, the amount of excess travel cost, E, is estimated using Equation 1. Users observed using the least cost site offering a given product contribute no excess travel cost. Similarly, no excess travel is incurred for unique sites. This process is repeated recursively, hypothesizing alternate definitions of product sets based on different combinations of site attributes until a reasonable hypothesis (product definition) is found with acceptably low E and n.

Product definitions do not precisely explain all site-selection decisions; users sometimes select more expensive sites apparently offering a given product. Possible exceptions include (1) exploration (users may select sites in part to learn about their attributes rather than because of their attributes), (2) misinformation or lack of information about the attributes of sites infrequently visited, (3) product misspecification (individual users may act on attributes not included in the selected product definitions, and/or may not include some of the attributes that were included), (4) price misspecification (user origins are usually defined as cities, postal code zones or other areas, so the cost is not precisely equal for all users from a given origin to a given destination; the lowest cost site for some users from a given origin may differ from that of other users from the same origin), and (5) multiple purpose trips (i.e., fishing is not the primary objective of the trip). For these reasons, some residual excess travel is common.

Similar issues are commonly encountered in conventional market analyses. Prices for non-homogeneous market product are typically aggregated into price indexes. Similar price indexes could be constructed for non-market products, but determining appropriate weights for sites offering the same product would be difficult. Further, a price index approach would be inconsistent with our definitions of supply, demand and products. For purposes of the PTC approach, we recommend that (1) use at same-product sites for which user costs are only slightly higher than the minimum cost be aggregated in Q as though this use had occurred at the minimum-cost site, and (2) use at same-product sites for which user costs are clearly higher than the minimum for that product not be included in Q, but estimated separately as a function of the price differential and assumed to have the same value as use at the minimum-price site.

Supply of recreation products

A supply function is the schedule of minimum prices at which given quantities of a product will be offered to consumers over a given time period, *ceteris paribus*. For outdoor recreation and some other non-market goods, users are both producers and consumers from a household production function perspective. Users convert "opportunities" into actual visits (i.e., user trips and days). Users also consume these visits and hence gain welfare from doing so. The marginal costs of production are dominated by travel time and monetary travel costs; their fixed costs of production are dominated by automobile ownership costs and the costs of equipment needed to enjoy a particular opportunity. In the short term, the minimum price at which relevant quantities of a given product will be produced is equal to the average marginal costs incurred per visit by potential users from a given origin at the least-expensive site offering that product. This marginal cost can be estimated using average travel costs and the travel distance and time from the user origin to the least expensive site. Graphically, the supply of any individual product for potential users from a given origin is a horizontal line depicting a constant price for all relevant quantities of use at the least expensive site offering that product[2]. The travel costs associated with all other sites offering the same product are irrelevant because their prices are higher. In the above example relating to angling sites, users from each origin would face up to 18 simultaneous supply schedules, one for each available product. Even so, the total number of angling sites in the study area may greatly exceed 18.

Demand for recreation products

Demand is usually defined as the schedule of maximum quantities of a product which would be purchased at each given price over a given time period, *ceteris paribus*. In our example, up to 18 demand schedules could be estimated. Each schedule would include the quantity per capita of site visits (i.e., units of a specific product consumed) from each origin expressed as a function of the supply price for that product (i.e., at the least expensive site offering a given product), the supply prices of the other competing products, and other demand factors (e.g., demographics, average income). A set of n demand equations including cross-price elasticities may be estimated in an AIDS equation set (see Green and Alston, 1990). The generic form of these demand equations is as follows:

(2)
$$Q_{i,o} = f\left(\sum_{i=1}^{n} P_{i,o}, I_o\right) + \varepsilon_{i,o}$$

Where: $Q_{i,o}$ is the per capita quantity of site visits for product i from origin o,

$P_{i,o}$ is the price (i.e., estimated travel cost) incurred for each visit from origin o to the least-cost site offering product i,

I_o is the socio-economic factors for origin o affecting demand, and

$\varepsilon_{i,o}$ is the error term for origin o for product i.

Two issues should be considered in specifying and estimating these functions: First, income compensated demand equations will be needed to estimate Hicksian consumer surplus and compensating variation. Statistical demand equations estimate Marshallian measures (see Desvouges and Smith, 1984.). Second, adjustments are necessary to compensate for price-limited dependent variables caused by frequent observation of zero use at high prices (corner solution issues) (see Phaneuf, 1999, for a possible solution). However, PTC eliminates many zero observations at high prices by specifying product prices rather than site prices, eliminating observations at all sites more expensive than the least-cost site for each product.

Simulation modeling to estimate values

Users from each origin face a unique set of prices ($P_{i,o}$) for a given set of products n. Product i may be available at multiple sites, but only the site with the lowest travel cost defines $P_{i,o}$; the other sites at which product i is available are not competitive. Since the demand equation for each product (Equation 2) is a function of all n products as well as population characteristics (i.e., I_o) of that origin, each demand equation is unique for each origin. Figures 1 and 2 illustrate hypothetical demand curves representing the demand for two products (i.e., D_2 and D_5 for products 2 and 5 respectively) for origin O. P_2 initially is \$25 per visit representing the travel cost to site X (the nearest site offering product 2). P_5 initially is \$30; this product is available at site Y. The two products are partial substitutes for each other. These hypothetical equations are based on actual equations based on observed angling behaviour in the Credit River watershed. Product 2 is defined as angling for resident brook trout and brown trout with a moderate catch rate[3]; whereas product 5 is defined as angling for Lake Ontario steelhead (i.e., rainbow trout that run into the river to spawn) with a moderate catch rate; steelhead are much larger than resident trout.

Now assume that the species composition at site X changes from brook/brown trout to steelhead, but the catch rate does not change. The product available at site X would change from 2 to 5, changing the prices

Figure 1. Demand for Product 2 when P5=30

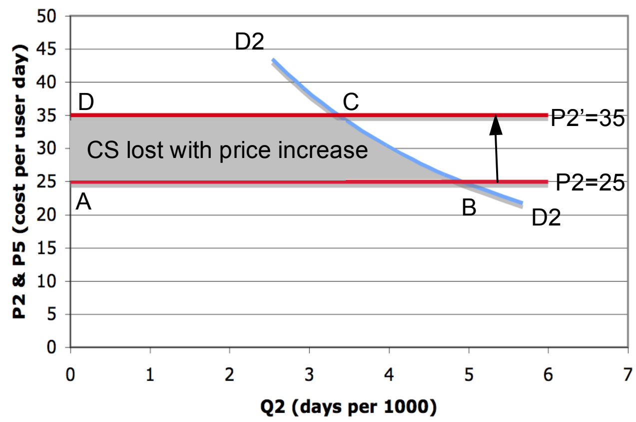
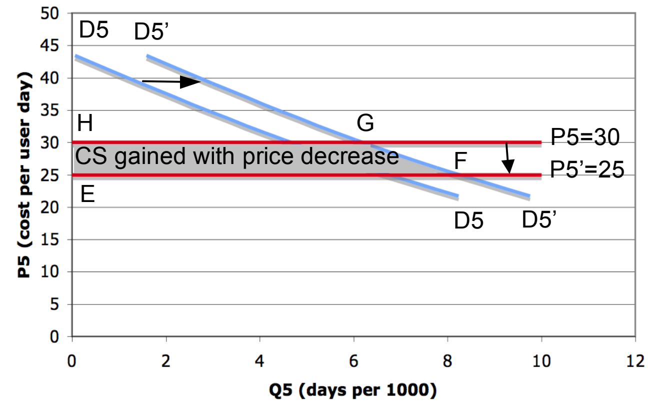


Figure 2. Demand for Product 5 shifts when P2 increases



of both products for anglers from origin *O*. Site *Z* would now be the new lowest-price site for product 2, so P_2 would increase to \$35 given the greater travel cost to access this site. Conversely, product 5 would now be available at site *X* at a price of \$25. Because the price for each product appears in each demand equation, all of the demand equations for origin *O* would be affected as well[4].

In this case, D_2 shifts to the left as the price of its substitute decreases (not illustrated), and D_5 shifts to the right as the price of its substitute increases (Figure 2). The resulting change in Marshallian consumer surplus[5] (CS) could be estimated using demand equations before they shift or after they shift or some hybrid of the two. We recommend that the overall change in CS be estimated by subtracting the maximum CS lost (i.e., ABCD in Figure 1 calculated before D_2 shifts to the left) from the maximum CS gained (i.e., EFGH in Figure 2 calculated after D_5 shifts to the right). The resulting change in the pattern of angling use from origin *O* at sites *X, Y* and *Z* can also be estimated from the two equations. Note that if P_2 had been \$30 or higher (i.e., equal to or higher than the price of angling at site *Y*), P_5 would be unchanged because site *Y* would still offer the lowest price for product 5. In this case, anglers fishing at site *Y* would not benefit from the change at site *X*[6], and D_2 would not shift. However, D_5 would still shift to D_5' and total CS for product 5 (the area under D_5 above \$30) would increase. Note that a shift in D_5 does not necessarily imply a welfare change: The shift in D_5 simply implies that any future change in P_5 would now result in a larger change in welfare.

Yet another possibility is that site *X* is not the lowest-price site offering product 2 for users from some other origin, implying no change in P_2 for those users. This does not necessarily imply however no welfare change. After the species change at site *X*, the site could become the lowest-price site for product 5 for some other origins, benefiting those anglers consuming product 5 from these origins. Further, lowering P_5 would shift D_2 to the left, but, would not necessarily change the welfare of anglers from that origin consuming product 2. Finally, for some origins the change at site *X* would not change the price of either product. In this case, no welfare impacts would occur.

A simulation model can simultaneously estimate changes in welfare for multiple products and origins and forecast the redistributed use across all origins and angling sites. This type of analytical tool is essential for using PTC results for practical management decisions, particularly where multiple management actions at multiple sites are being evaluated on a regular basis. As well, if negative feedback is present as a result of crowding at popular sites, a dynamic simulation model would be required to arrive at a stable redistribution of use.

Comparing the product model with other travel cost models

Simple TCMs estimate the demand for use of a single site using a "zonal" model to estimate demand and supply. Two problems plague these estimates: They assume that: (1) the site is unique and (2) there are no substitutes or complements. The first assumption greatly reduces the value of the analysis for most practical management purposes. The results are only applicable to one site in its current state. The results cannot be used to predict how demand, supply and welfare would change if important site attributes were changed or changing the number of sites available. The second assumption biases the estimated demand schedule by ignoring partial substitutes and complements. This source of bias is thoroughly examined in the literature and need not be elaborated here. With the PTC, perfect substitutes and partial substitutes are empirically defined and play key roles in supply, demand and welfare valuation of non-market goods as illustrated above. Most notably, defining and evaluating perfect substitutes (i.e., product categories) enables analysts to estimate without bias the impacts of adding, subtracting or changing site attributes within a system of sites. In the above example, if site *X* (i.e., product 2) had no perfect substitutes, the welfare loss for origin *O* resulting from the assumed change in fish species would have been equal to the entire area under the demand curve above P_2=\$25, rather than the truncated area shown (i.e., ABCD).

Other TCMs, including RUMs and hedonic models, address the first problem by generalizing their estimation across sites, but their estimates are biased since not all impacts of substitutes and complements are captured. Burt and Brewer (1971) estimated a multi-site TCM, but without procedures for defining products or for evaluating changes in site quality within the system. Several researchers have regressed estimated consumer surplus for various individual sites against site attributes in attempts to estimate the marginal values of the attributes (some early examples: Flick, 1975; Brown, 1981; Samples and Bishop, 1985). However, this approach assumes that the CS estimates are independent of each other and of the sites' relationships to the distribution of population; assumptions that have little basis in fact.

Hedonic TCMs estimate the demand for attributes in two stages (Freeman, 1979; Brown and Mendelsohn, 1982). First, the "implicit price" of each attribute is estimated by observing how much more users must pay to find sites offering higher levels of the attributes. For example, one could estimate the marginal travel cost incurred per fish caught per angling hour as a function of fish caught per angling hour. Anglers generally have to travel farther to reach angling sites they consider better. Second, the demand for each attribute is estimated as a relationship between the level of the attribute consumed and its implicit price. This approach overcomes the problem of having to define "lumpy" products by directly estimating the demand for individual site attributes. This is an advantage if one wishes to estimate the marginal value of, say, increasing the numbers of fish available to anglers. However as shown in the example in Figures 1 and 2, the marginal value of increasing the number of fish available depends upon where the increase occurs. The hedonic approach sacrifices the ability to specify supply and to consider simultaneously the supply of multiple sites with different attributes. As well, the effects of substitutes on site-specific values are excluded, permitting only estimates of the average value of the attributes of a given site.

RUM directly estimates a utility function for a representative user, in which the total CS per trip for the recreation activity is a function of site attributes. A second equation (or component of the first equation) is usually also estimated in which the number of trips is a function of the predicted value per trip and user characteristics. Total CS is the CS per trip times the number of trips. As with the hedonic model, RUM assumes that utility increases as users incur higher costs to obtain preferred site attributes. RUM assumes that the representative user chooses from among mutually exclusive sites based on site attributes, ignoring the possible impacts of substitutability between sites (Haab, et al, 2000, Freeman, 2003). These assumptions contrast sharply with those of the PTC: that users might find preferred attributes at less-expensive (i.e., closer) sites but may sometimes incur greater costs to use sites that have different (not necessarily "higher") attributes, and that the amount of use at any given site is impacted by the prices of competing sites. All of the above models except possibly the hedonic model also focus on estimating total welfare change between having existing recreation at given sites and the complete loss of recreation at the sites; the value of the choice between all or none of the good (i.e., the all-or-none value). RUMs, for example, estimate average all-or-none values per angler, so the value of a site is the change in the total number of days with and without the site times the average all-or-none value per angler. Values obtained in this manner differ sharply from those estimated with PTC considering perfect and partial substitutes.

VALUATION OF ANGLING OPPORTUNITIES IN THE CREDIT RIVER

The Credit Valley Conservation (CVC) authority is a partnership of the municipalities within the Credit River watershed dedicated to conserving, restoring, developing and managing natural resources on a watershed basis. The watershed is located on the western edge of the Toronto metropolitan area, Ontario, Canada. Management decisions/actions by the CVC affect the quality and quantity of natural resources available in the Credit River watershed. The analysis reported here is part of a longer-term initiative by CVC to develop a comprehensive understanding of the value of ecological goods and services provided by the Credit River watershed. The purpose of this study (Hanna, et al, 2008) was to estimate the economic value of the angling opportunities supplied by the Credit River watershed.

Total angling effort in the watershed for 2006 was estimated at 30,154 angler days from 28 origins (defined by postal codes) distributed among 18 destinations by season (spring, summer, fall, winter). Angler effort from each origin to each destination was estimated primarily with a self-administered on-line survey that asked anglers to report their angling activities at all identifiable angling sites throughout the watershed by month over the preceding year. The survey was advertised to the angling community through angling organizations, via local angling supply outlets, through signage at popular entry points for anglers along the river, by direct contact with individual anglers and on the CVC website. The survey received 494 responses from August 3, 2006 to January 31, 2007. This information was supplemented with a streamside angler intercept survey of 154 anglers from August 28, 2006 to October 7, 2006 which asked about angling-related behaviour on the day encountered. All anglers encountered on site were also asked to visit the CVC website and to fill out the online survey. These samples were expanded to totals in proportion to creel census findings from the mid-1990s for five of the same destination sites (ranging in length from 1.9 to 5.2 kilometers of river shoreline). While this sampling methodology was cost-effective, the error rate may be high. Sources of error included (1) self-selection and non-randomness in the on-line survey, probably resulting in avidity bias, and (2) averaging over different time periods used to expand the samples, involving comparing average 2006 survey findings to average mid-1990s census findings. However, the demographics of the Credit angler population sample were similar in many respects to results reported elsewhere for the province as a whole, other than some expected exceptions.

Travel costs were estimated as a function of travel distance, based on (1) origin to destination road distance and travel time, (2) standard vehicle travel cost, (3) travel time based on household income, assumed 1.56 wage-earners per household, and 75% of the calculated average hourly wage rate (after Shaw, 1992 and Smith, 1997), and (4) 30 minutes extra travel time allowed per trip for preparing, packing and unpacking. Other costs were not included. Almost all trips were day trips. We estimated only one cost function because we assumed costs were uniform across all activity types. If boating-based angling, for example, followed a different cost pattern, separate cost functions might be justified but virtually all of the angling was shore-based.

The discriminant process described above was used to define angling products. Table 1 illustrates three product definitions hypothesized to describe spring angling products. Fishing opportunities vary by season due to regulations and seasonal migration patterns of some species (e.g., steelhead, salmon). Based on discussions with fishery managers and angler responses to the survey, species presence and success rate were known to be key site attributes. Fish size was implicitly included through the combination of season, species and river section used to define products. Salmon and steelhead are invariably large given they are mature fish entering the river to spawn. Resident rainbow in the upper sections are much smaller.

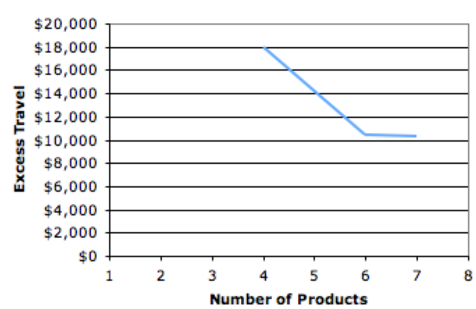
Table 1. Three alternative hypotheses for defining Spring angling products.

Product Hypotheses								
H1			H2			H3		
Name	Fish Type	CPUE	Name	Fish Type	CPUE	Name	Fish Type	CPUE
SPc1	coldwater	1	SPb1	brook/brown	1	SPb1	brook/brown	1
SPc2	coldwater	2	SPb2	brook/brown	2	SPb2	brook/brown	2
SPc3	coldwater	3	SPb3	brook/brown	3	SPb3	brook/brown	3
SPw2	warmwater	2	SPr1	rainbow	1	SPr2	rainbow	2
			SPr2	rainbow	2	SPw1	warmwater	1
			SPw1	warmwater	1	SPt1	all 3 trout spp.	1
						SPt2	all 3 trout spp.	2

In this example, hypothesis 1 included four products described by whether the fish available at a given site were coldwater species (trout) or warmwater species (species other than trout) and by two catch rates (i.e., catch-per-unit-effort, CPUE). Different CPUE thresholds were tested to determine their influence on angler travel behaviour. Three CPUE categories (i.e., 1.0<, 1.0< to <2.75, >2.75 fish/trip) were found to provide adequate resolution to predict angler behaviour. Subsequently hypothesis 2 which includes six products and hypothesis 3 includes seven products were developed and analysed.

For each hypothesis, the dollar value of excess travel was estimated using equation 1. As the number of products increased, the amount of excess travel decreased. However, the decrease in excess travel was not directly proportional to the number of products (Figure 3). Indeed, the angling product set with seven products resulted in essentially the same excess travel as the product set with six types (i.e., $10,435 for six products vs. $10,332 for seven products). On the other hand, increasing from four products to six products reduced the excess travel by almost 50%.

Figure 3. Excess travel analysis for three spring angling hypotheses.



On the basis of these results, the six-product hypothesis (i.e., Product Set H2 in Table 1) was selected to characterize the spring fishery. A similar process was used to define products for the other seasons. Using this product set for the spring fishery, 68% of the total travel cost was accurately predicted. The remaining 32% of the travel costs were spent by anglers traveling to sites farther than the least-cost site, representing choices not fully explained by the product hypothesis. Much of this excess travel was attributable to the relatively minor differences in travel costs between proximal competing destinations. Given the relatively small difference in product "price" among some destinations, the likelihood increases that other less significant factors (e.g., suitability for wading or shore fishing, crowding, shoreline access) not included in the product definition will affect angler choices.

Demand functions similar to equation 3 were estimated by season for all products defined in the season.

(3) $$Q_i = a_i - b_{i,}P_{i,} + b_{i'}/P_i + \sum (b_jP_j, j\neq \mathrm{i})$$

Where: P_i is the price (estimated travel cost) for visits to the least-cost site offering product *i*, and

a,b are regression constants.

This form of the demand equation allows the price to lie near the price axis at high prices. Some demand equations were unstable due to small sample size, so $b_{i'}$ was allowed to be negative when dropping the $b_{i'}/P_i$ term would have caused b_i to be positive. Cross-price variables were included only where the coefficients were positive and significant. The data were too limited to estimate a full AIDS model.

The above demand and supply equations and related information form a simulation model capable of estimating the changes in consumer welfare illustrated in Figures 1 and 2: Changes in Marshallian consumer surplus and the amount of angling at relevant sites attributable to specific proposed angling quality changes at given sites. In this case, the CVC requested estimates of the value of all angling by product, by user origin, and by location fished. Therefore we estimated total Marshallian consumer surplus per capita for each origin as the area under each demand curve above the initial (current) price and below P_{max} (the demand equation intercept with the price axis, where $Q_i = 0$). Prices of substitutes were assumed to be constant at their initial levels.

These value estimates are measures of non-income-compensated willingness to pay or willingness to accept compensation per capita for the choice of maintaining current consumption or being permitted no use of the product (i.e., the all-or-nothing value per capita of each product). They assume the prices of other products remain unchanged. The all-or-nothing value per capita of the entire Credit watershed fishery was estimated by summing consumer surplus values for each product multiplied by the population of each origin. This estimated total was $1,167,529, or $38.72 per angler day. Total consumer surplus could also have been estimated for each origin as the simultaneous increase in the prices of all products, with each price capped at its P_{max}. In this case the total consumer surplus for each product[7] would be higher because each change in the prices of substitutes would shift the demand curves to the right.

Average consumer surplus per angler day varied greatly by product, ranging from a low of $9/day to $148/day. These results are sensitive to data limitations, model specification and variable measurement. Angling sites with higher pressure had higher values per trip. Among sites with identical or similar products or similar levels of angler pressure, those closer to larger angler populations generally had higher values. By origin, average consumer surplus per day ranged from under $1 to $87. Generally, origins closer to high-valued sites and with fewer outdoor recreation opportunities outside the watershed (i.e., fewer competing substitutes) had higher values per day. Simple average values per angler day such as these may be misleading. For this reason, these types of values should only be used as broad indicators; when specific management decisions are being made, actual changes in angler consumer surplus at all affected sites should be forecast using these supply and demand functions and associated methodology.

CONCLUSIONS

Product travel cost models reduce the statistical and analytical bias found in other TCMs in estimating the demand and supply of non-market use of publicly-owned natural resources. Using a method more analogous to that commonly used to estimate the demand and supply of market goods, PTC includes the impacts of perfect and partial substitutes and prices. Most TCMs focus on demand, and provide limited insight into product definition, changes in supply and cross-price elasticities. PTCs more precisely estimate the benefits of resource management options at specific sites and across a system of sites by including the potential for perfect substitution between “identical” sites, and partial substitution between other sites. For this reason PTCs are well suited for accurately assessing both local resource management actions and for assessing system-wide resource management plans. The demand and supply equations and other information upon which PTCs are based can be used to construct comprehensive dynamic simulation models that can forecast changes in value (i.e., consumer surplus) as well as to forecast how users will respond to changes in site attributes at specific sites.

Products can be defined in several ways. The discriminant analysis approach uses observed site-choice behavior to define products, based on the assumption that if users consider two or more sites as identical in quality, they will primarily choose the lowest-cost site. Invariably product classification systems including those involving market products, imperfectly describe the choice structure of all users. As the definition of products become more refined, the choices of the most discerning consumers will be more closely approximated. Practically however, a balance between precision in product definition and data and analytical demands must be struck. In any event, analysis of supply and demand cannot proceed without first defining the products to be analyzed. The PTC method provides a systematic and theoretically sound basis for defining non-market products.

A disadvantage of the PTC method is that it requires more data than RUM and some other TCMs if its strength in capturing the effects of perfect and partial substitutions is to be fully realized. More data are required to estimate more parameters; to more completely and accurately model a system of sites and their complex inter-relationships. PTC models can be successfully developed with reduced datasets, as we did in our CVC study, but some sacrificing of robustness is necessary.

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ENDNOTES

[1] Predicted user expenditure based on a "user cost function" is estimated from user data in which cost per unit of effort is a function of monetary outlays plus the value of time, spent for recreation at the site.

[2] This assumes that crowding is not a critical site attribute defining a product. Where crowding is a significant attribute, recursive simulation is required until forecast use patterns are reconciled with the crowding attribute limits.

[3] "Catch rate" throughout this paper refers to fish caught and kept, except for catch-and-release fishing, in which case all fish caught are included.

[4] This example is hypothetical but realistic. Consideration is being given to removing dams in the midsections of the river that would allow steelhead to migrate further upstream into sections currently inhabited exclusively by resident brown and brook trout.

[5] "Consumer surplus" in this paper generally refers to "Marshallian consumer surplus", as estimated from statistical demand equations, which is not adjusted for income effects. Though we have not done so, it is possible to estimate indifference equations from Marshallian demand equations, from which one may estimate compensating variation or other exact measures of consumer surplus (Hausman, 1981). The amount of error associated with the demand equations we estimated does not justify the additional precision that would be gained by estimating these exact measures.

[6] If, after site X becomes product 5, its price is approximately the same as that of site Y, angling use from C could be split between the two sites, and this could impact the CPUE at each site, depending upon the portion of anglers at the sites who come from C, and the price changes for anglers from other origins.

[7] Consumer surplus estimates for demand equations not including any cross price coefficients would not differ between the two different assumptions.