A Critical Review of the Travel Cost, Hedonic Travel Cost, and Household Production Models for Measurement of Quality Changes in Recreational Experiences

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This paper compares three recreation valuation techniques—the travel cost (TC), the hedonic travel cost (HTC), and the household production (HP) techniques—on the basis of their theoretical underpinnings, econometric and data considerations, and policy considerations. The major focus is on how these techniques can be used to evaluate the benefits to recreationists of changes in the quality of recreation sites. Bockstael and McConnell's (1981) formulation of the HP model for sport fishing is used in the following discussion. Other variants, such as the model used by Smith et al. (1983), are only briefly mentioned.

The following section provides a discussion on the conceptual framework from which each technique is derived. The assumptions underlying each approach are outlined and benefit measurement procedures are described. Then, a third section provides a comparison of the three approaches on the basis of the data required, statistical problems encountered, and estimation techniques used. The fourth section then evaluates the three techniques in terms of the types of quality variables that can be included in each model, which suggests what types of policy questions each approach is capable of handling. The fifth and final section briefly summarizes the major points covered in this paper.

Theoretical Underpinnings

The three recreation valuation techniques which are considered in this paper are all classified as indirect market-based approaches. Each technique can be related to a behavioral model which describes individuals' decisions from which nonmarket values are inferred. The behavioral models are based on a common hypothesis of constrained utility maximization, where the utility function is defined on nonmarket goods, and the budget constraint is usually constructed by defining an implicit price for each nonmarket good. These implicit prices are derived on the basis of hypothesized relationships between each nonmarket good and some set of market goods. For example, the implicit price of a visit to a recreational site is determined primarily on the basis of the relationship between this commodity and market transportation goods that are purchased while traveling to and from the site. In some cases, implicit prices can be determined for commodities that describe the quality of a recreational experience. The conceptual basis of each of the three methodologies for deriving implicit prices and nonmarket values of recreation-related commodities is described below.

Conceptually, the three recreation valuation techniques differ mainly with respect to the relationships posited between recreational commodities and market goods. Also, the techniques assume different roles for the recreationist in determining implicit prices and in determining the quality of a recreational experience. In terms of the degree of flexibility the recreationist is viewed as being given, the basic single-site TC model can be regarded as the least flexible and the HP as the most flexible of the three techniques. In other words, the TC technique makes more restrictive assumptions regarding the recreationist's deci-

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sion-making process than do the HTC and HP techniques. The assumptions underlying the HTC technique appear more restrictive than those underlying the HP technique.

The TC method considers the number of visits made to a given site as the only recreation-related choice variable in the model. The underlying utility function is written as $U = U(v,z,y)$, where v denotes the number of visits to a given site, z denotes the quality characteristics of the site, and y represents all other commodities in the recreationist's choice set. It is assumed that purchased transportation goods (and in some cases travel time) are perfect complements to the recreational experience. Thus, transportation costs per trip can serve as a proxy for the nonexistent price of a visit.[1] Assuming that transportation costs are constant across visits, a demand equation for a single site is constructed by simply specifying the number of visits as a function of this fixed price and other demand determinants, including income and z. Conceptually speaking, the demand equation for visits is found by maximizing the utility function $U = U(v,z,y)$, subject to the budget constraint, $M = p_v v + y$, where M is total income and p_v is the fixed price of a visit. The price of y is assumed to be unity. In previous applications of the TC method, the demand equation for visits has not typically been related to a specific utility maximization problem. The estimated TC demand equation is normally used to determine the value of a recreational experience on the basis of the ordinary consumer surplus associated with changes in the travel cost variable p_v.

In a TC model, the quality of a recreational experience is assumed to be completely outside the control of the recreationist. Preferences over various quality characteristics are revealed only indirectly through the recreationist's decisions regarding which sites to visit or how many times to visit a particular site. Quality factors that are considered to influence the site choice decision or the level of participation at a given site may be included directly in TC demand equations. One can then evaluate the benefits of marginal changes in quality by calculating changes in consumer surplus associated with quality-induced shifts in the demand curve, but only under the condition that the quality factor is weakly complementary to the number of visits.[2] In cases where the weak complementarity condition does not hold, the benefits of quality changes could only be determined if the form of the underlying indirect utility function or, equivalently, the expenditure function, were known. As noted earlier, however, in empirical applications of the TC method it has not typically been the case that the demand equation has been derived from a specified utility function.

Like the TC method, the HTC method assumes that there is a fixed travel cost per trip to any given site. This method gives the recreationist more flexibility than does the former, however, by explicitly incorporating the fact that recreationists can directly influence the quality of recreational experiences by visiting sites with different quality attributes. In fact, the HTC method is based on the assumption that the only reason a recreationist would travel to a more distant site would be to consume a better quality experience. Given this assumption, the additional travel costs incurred on a trip to a more distant site can represent the implicit value of the additional quality characteristics obtained. In other words, the values to recreationists of differences in quality characteristics across sites are assumed to be fully reflected in the differences in the prices of a visit to each of these sites.

Given this assumption, variations in prices per visit across sites with different quality attributes can be used to infer implicit prices for those quality attributes. With the HTC technique, the implicit price of each characteristic is derived from an estimated hedonic price equation, which is written as $p_v = p_v(z_1,\ldots,z_m)$, where p_v denotes the price per visit and the z_i's represent m quality characteristics of a recreational experience at a given site. The partial derivative of the hedonic price equation with respect to any z_i yields the marginal hedonic price equation (or the implicit price equation) for that characteristic.

A hedonic technique can be used to determine implicit prices of the quality characteristics of any type of good, when there are different varieties of the good and when these va-

[1] This is the traditional explanation for the TC method. In the recent literature, however, it has been shown that the TC model can be derived from two different household production models. For example, Bockstael and McConnell (1981) show that the TC model is a special case of their more general HP model. In a more recent article, Smith et al. (1983) show that the TC model can be derived from a different formulation of the HP model. In their model, the number of visits to each site is treated as a nonmarket input in the production of recreational service flows. The TC demand equation is interpreted as the reduced form of the derived input demand equation for visits.

[2] A quality variable, z, is weakly complementary to v iff $\partial U/\partial z_{v=0} = 0$.

rieties differ only with respect to their prices and the quality characteristics they contain. The hedonic price function for a particular type of good relates the market price of any variety of the good to the characteristics possessed by that variety. In the HTC framework, each good class is made up of the recreational trips taken by individuals from a given origin zone, and the different varieties correspond to the different sites that provide services to that zone. These sites differ with respect to their distances from the zone (and hence the travel costs per visit) and with respect to the bundle of quality characteristics offered. The supply of a quality characteristc at any given site is assumed to be outside the control of the recreationist.

The decision framework for the recreationist is designed as if the site choice and participation rate decisions were made in two stages. In the first stage, the recreationist selects a bundle of characteristics, and in the second stage decides how many trips to take to the site that offers that bundle of characteristics. Assuming that the recreationist only visits one site, the utility function is specified as $U = U(v,z_1,\ldots,z_m,y)$.[3] In order to derive the ordinary demand equations for v and the z_i's, one would maximize this utility function subject to the budget constraint, $M = p_v(z)v + y$. The derived demand equations for the m + 1 choice variables are in the general case written as

$$z_i = g_i(p_1(z),\ldots,p_m(z),p_v(z),M) \qquad i = 1,\ldots,m$$

and

$$v = g_v(p_1(z),\ldots,p_m(z),p_v(z),M)$$

where $p_i(z) = \partial p_v(z)/\partial z_i$. Recreationists treat these implicit prices as parametric to their decisions. Even though these prices are not necessarily constant, they are considered to be exogenously determined in this framework, because consumers are unable to influence the hedonic price function. That is, the function $p_v(z)$ is the same for all consumers and is independent of v. This function and the corresponding marginal price functions are apparently regarded as being production cost determined in the HTC framework, as suggested by Rosen (1974).[4]

In the general case, Rosen (1974) argues that observed implicit prices of characteristics merely reflect equilibrium conditions, revealing little about the underlying structures of production technologies and consumer preferences. Rosen (1974) shows that the simultaneous estimation of supply and demand equations for characteristics, given the previously estimated hedonic price equation, is a feasible econometric procedure for identifying the underlying structures of producer technologies and consumer preferences. He further states that in cases where production conditions are identical across firms producing different varieties of the same good, the observed implicit price functions may be regarded as supply functions for the characteristics.

With regard to the HTC model, this means that if it can be assumed that there are no technological differences across the sites which provide services to a given zone, then the implicit price functions may be referred to as supply functions for the quality characteristics. One could think of the sites as representing different firms, each of which produces a different variety of the recreational experience. It follows from this assumption that the HTC method implicitly assumes that technological conditions are identical across the sites that provide services to a given zone. Hence, one can view the implicit price equations as identifying characteristic supply curves.

With the HTC technique, the structure of consumer preferences is identified through the estimation of demand equations for characteristics. In order to trace out characteristic demand equations, it is necessary to have a sufficiently large number of supply curves for each characteristic. Since it is assumed that a different hedonic price function describes the production technology for each different zone, the supply curves for characteristics will vary across zones. (A given site will be part of more than one supply curve for each characteristic

[3] Muellbauer (1974) notes that the choice of only one site "... is imposed as an extraneous assumption rather than as the outcome of the optimizing model." (p. 992). It should be pointed out here that a multiple site TC model would allow the recreationist to visit any number of sites with different quality characteristics. Although quality characteristics would not be treated as endogenous choice variables in such a model (as in the HTC model), the recreationist would be able to indirectly influence the quality of recreational experiences by visiting various sites. Since the multiple site TC model does not limit the recreationist to the choice of a single site, it is actually less restrictive than the HTC model.

[4] Rosen's viewpoint runs contrary to other theories, such as the theory of household production, that have also been used to justify the hedonic technique. These other theories are not consistent with Brown and Modelesohn's formulation of the HTC model, as is Rosen's interpretation. See Muellbauer (1974) and Deaton and Muellbauer (1980) for a comparison of the different theoretical approaches.

if that site supplies services to more than one zone.) The characteristic supply curves across zones are used to identify characteristic demand equations for a representative zone.

One can use estimated supply and demand equations for characteristics to obtain estimates of the benefits to recreationists of changes in implicit prices. Since the HTC method assumes that characteristic supplies are exogenously determined, one can also obtain estimates of the benefits to recreationists of marginal changes in the supply of characteristics. This is equivalent to evaluating the benefits of changes in implicit characteristic prices, because shifts in supply result in changes in equilibrium prices. For evaluating the effects of changes in characteristic supplies, it would necessarily be assumed that these changes would automatically lead to equivalent changes in the demand for characteristics.

In order to obtain an estimate of the value of a recreational experience, one may either use the demand equations for characteristics or the demand equation for visits. In the visits market, recreational benefit estimates would be calculated in the same manner as they would using the TC demand model discussed above. That is, the total area under the demand curve for visits and above the horizontal price line gives an estimate of total benefits for the recreationist. This total benefit measure would then be divided by the given number of visits to obtain an estimate of the average value of a recreational experience.

The above procedure is equivalent to estimating the benefits of sequentially increasing implicit characteristic prices from their current equilibrium levels to the points at which the quantity demanded of each characteristic just reaches zero.[5] The reason this is true is that an increase in the price of a visit (p_v) to the point at which the demand for visits just falls to zero would automatically cause the demand curve for each characteristic to shift to the left until the quantity demanded at the given equilibrium implicit price just reaches zero.

The existence of implicit markets for quality characteristics in the HTC model is what distinguishes this model from the traditional TC model. Implicit prices are derived for characteristics (which are treated as choice variables), but these prices are assumed to be either constant or to be dependent only on the supplies of characteristics, which are assumed to be fixed at each site. There are technological factors that influence the supply of characteristics at a given site, however, and these factors would in reality tend to vary from one site to another. For example, the technological factors that may influence the supply of a fishing success rate characteristic would include the stock of fish and the quality and quantity of fish habitat. Similarly, for a scenery characteristic, the technological factors might include the density of trees along the river, the geographic features of the surrounding area, and the number of acres of wilderness adjacent to the river (or the ratio of wilderness to developed acres). These technological factors at any given site may be fixed in the short run, but they could possibly be altered in the long run. Changes in technology would result in shifts in characteristic supply curves. Any such relationship between technological conditions and utility-yielding quality characteristics must be specified outside of the HTC model.[6]

The HP model is not necessarily restricted in this manner, because an explicit cost function is specified for those characteristics which are partially controllable by recreationists. If exogenous technological factors were included in the cost function, then the marginal cost (supply) equations for the endogenous characteristics would be dependent on these technological factors. Hence, the relationships between technological (i.e., environmental) conditions at a site and the supplies of endogenous characteristics may be specified directly within the model. This means that the HP framework could potentially be used to estimate the welfare impacts on recreationists

[5] A necessary condition for being able to measure the benefits of changes in p_v in characteristics' markets is that $\partial U/\partial v_{z_1,\ldots,z_m=0} = 0$. By the sequential procedure for evaluating the benefits of multiple price changes, one calculates the sum of changes in areas under the demand curves in all markets which experience price changes. In each market, the demand curve is conditioned on all previously considered price changes.

[6] Rosen (1974) shows that when firms are not identical, the cost function would be defined on attributes that vary from one plant to another, such as factor prices and technological conditions. In such cases, the structure of production could be identified through estimation of characteristic supply equations derived from the cost function. The implicit price equations in such a model would merely connect the points of intersection of supply and demand curves. To estimate the hedonic price equation, one would simply regress observed prices on characteristic quantities using the best fitting function form. This procedure does not seem to be applicable for estimating the HTC model, because there is no actual producer of characteristics for which a cost function could be defined. "Production costs" in this framework are actually borne by the consumer.

of exogenous changes in technology (or environmental quality).

In the HP framework, the recreationist is taken to be both a producer and a consumer of nonmarket goods (commodities). In Bockstael and McConnell's formulation of the model for sport fishing, for example, the sport angler is assumed to both produce and consume the fish catch rate (measured in terms of catch per trip or catch during a given time period). The angler is also assumed to both produce and consume the fishing trips taken during the given time period. Total fishing trips (v) are produced by combining purchased transportation goods and travel time. Technological factors that may influence the angler's productivity in taking fishing trips include the distance between the angler's residence and the site as well as the transportation mode used. The fish catch level (z_1) is produced by combining purchased fishing goods and fishing time given the environmental conditions at the site, the available fishing equipment, and the angler's level of experience.

Marginal costs are treated as implicit prices for commodities in this framework. They give the minimum costs for obtaining one more unit of a commodity, as they are derived by partially differentiating the cost function with respect to each commodity. As in the HTC model, in the HP model the optimal price-quantity combination in each commodity market is defined at the point of intersection of supply and demand curves. But unlike the HTC method, the HP method does not use the price of a fishing experience to infer an implicit price for an endogenous characteristic such as the fishing success rate. The HP method decomposes the fishing experience into two parts—the fishing trip itself and the sport-caught fish. A separate, but not necessarily unrelated, implicit price function is specified for each of these commodities.

Given the implicit price (supply) functions for fishing trips (v) and sport-caught fish (z_1), one can derive the commodity demand equations by maximizing utility, $U = U(v,z_1,\bar{z},y)$ subject to the "implicit" budget constraint, $I = p_v\, v + \pi_1 z_1 + y$, where p_v and π_1 are equilibrium implicit prices, and $\bar{z}$ denotes exogenous quality characteristics. The demand equations for fishing trips and fish catch at a given site during a given time period are written as

$$v = G_v(p_v(r_v,w,v,e_v),\ \pi_1(r_1,w,z_1,e_1),\bar{z},I)$$

and

$$z_1 = G_1(p_v(r_v,w,v,e_v),\ \pi_1(r_1,w,z_1,e_1),\bar{z},I)$$

where r_v and r_1 are market prices for the market transportation and fishing goods, respectively; w is the opportunity cost of both travel and fishing time; and e_v and e_1 denote technological conditions which would influence angler productivity in each commodity market. As noted above, environmental conditions at the site, such as fish density and water quality, may be included as exogenous technology variables in e_1. There are several different procedures one could use to estimate the welfare impacts on anglers of changes in exogenous quality variables that appear in the cost function. These procedures are described by Bockstael and McConnell (1983) and Strong (1983).

In this HP model, the angler derives utility from taking a fishing trip and from catching fish. Thus, the value of a fishing experience is equal to the combined value of the trip itself and of the sport-caught fish. The average value of a fishing experience would be estimated by first calculating the sequential sum of total benefits in both markets, and then by dividing this sum by the number of trips taken. Average values of a sport-caught fish could be estimated by calculating total benefits in the fish catch market alone, and then by dividing this benefit measure by the number of fish caught. Since the fish catch level is treated as an endogenous variable, the marginal value of a sport-caught fish cannot normally be determined in this framework as it can using the TC and HTC methods.

What primarily distinguishes the HP framework from the TC and HTC models for sport fishing is that it is not necessarily assumed that the shadow price per trip is fixed, nor is it assumed that the fish catch rate at any site is outside the control of anglers. As mentioned earlier, both the TC and HTC techniques assume that per visit prices for any site are constant. As for the fish catch rate, the TC method would treat it as an exogenous quality variable that would be weakly complementary to visits. The HTC method would treat is as a choice variable but the catch rate is fixed at any given site. Other types of quality characteristics which could be treated as choice variables in the HTC model may include scenery and congestion levels. These types of quality characteristics would be treated as exogenous quality variables rather than as endogenous choice variables in both the TC model and the HP model (as part of $\bar{z}$). If the fish catch rate (z_1) were treated as part of $\bar{z}$ (that is, as an exogenous but utility-yielding quality variable), and if the implicit price of a trip were constant, then the HP model would collapse to the TC model, as pointed out by Bockstael and McConnell (1981).

Econometric Considerations

In this section, the three techniques are compared on the basis of econometric considerations, including data needs, estimation techniques, and possible specifications biases. As pointed out in the previous section, the techniques can be ranked in terms of the degree of flexibility given the recreationist, with the TC being the least flexible and the HP the most flexible of the three techniques. With more flexibility, however, may come more extensive data requirements and greater analytical difficulty. Indeed, as is shown below, the TC method requires the least amount of basic data and is generally the easiest to apply. The HP technique seems to be at the other end of the scale, requiring considerably more data to obtain the best possible results. Also, analytical difficulties may arise in attempting to obtain solutions to highly nonlinear systems of equations. In terms of data requirements and the degree of analytical difficulty, the HTC method seems to lie somewhere in between the TC and HP methods.

In what follows three methods are compared as if each were applied to estimate a model for sport fishing. The common-choice variables in each model are defined as the number of fishing trips taken to a given site. Only one quality characteristic—the rate of fishing success—is considered to simplify the discussion. Two reasons for including a catch rate variable in the model would be to obtain estimates of the value of a sport-caught fish and to derive estimates of the welfare impacts of changes in either fish catch levels or in the implicit price of a sport-caught fish. It is assumed in this discussion that the utility function underlying each approach is weakly separable in sport fishing commodities, so that prices of other commodities may be omitted from the demand equations. It is also assumed that the TC and HP models are used to estimate a model for a representative site rather than one for multiple sites.

To apply the TC method to estimate a single site model, one simply specifies a single demand equation for fishing trips. If data are available over a number of sites, one can either estimate a separate demand equation for each site or pool the data across sites and estimate a demand equation for a typical site in the sample. For the basic model, data are required for constructing variables on the number of fishing trips taken to a given site, the fixed price of a visit, and the income level. The price variable may be defined as simply the multiple of round-trip distance and some fixed cost per mile for market transportation goods, or it may be constructed from actual data on reported per trip expenditures. The opportunity cost of round-trip travel time may also be included in the price variable.

If the price per visit is equal to the sum of expenditures on market transportation goods plus the opportunity cost of travel time, then it is necessarily assumed that marginal variations in money and time costs have the same effects on the demand for fishing trips. Since the TC model has been described as a special case of the HP model, this is equivalent to assuming that the marginal effects of purchased goods and travel time on the production of fishing trips are equivalent. It is also assumed that the cost function is linear in the trips variable, since the marginal cost equation for trips would be written as $MC_v = m_v + t_v$, where m_v denotes monetary travel costs and t_v is the time cost per trip. If time costs are included in p_v, then the budget constraint (and hence, the income variable) should include the value of available time in addition to the amount of available money income.

In the preceding section, it was shown that quality characteristics of a fishing experience (such as the fishing success rate) may be included as exogenous variables in the TC demand equation. For a fish catch rate variable, however, there is a problem with using this approach. That is, there is likely to be a correlation between the error term of the estimated demand equation and the catch rate variable, which would arise from a correlation between errors of measurement in this variable and in the dependent variable (Brown and Sorhus, 1981). This correlation would tend to result in biased parameter estimates. One way to correct for these potential biases is through the use of an instrumental variables technique.[7]

[7] If the price variable for visits is calculated using data on reported expenditures, then the same kind of correlation may also

An alternative approach to including the catch rate variable directly in the demand equation has been proposed by Brown and Sorhus (1981). This approach requires a two-stage estimation procedure. In the first stage, the values of selected sites are determined on the basis of total consumer surplus estimates obtained from a TC demand model. In the second stage, these consumer surplus estimates for each site are regressed on the total number of fish caught at each site. This second stage regression provides an estimate of the marginal value of a sport-caught fish. The marginal value estimate obtained from a linear model would represent the fixed marginal value of a sport-caught fish at a typical site in the sample. In order to apply this technique, one needs to have both fish catch data and data on fishing activities across a sufficiently large number of sites. The fish catch data by site need not be obtained from the same source as the data on fishing activities which are used to estimate the TC demand model. Given the assumption of weak complementarity between fishing trips and fish catch, it is valid to use changes in the area under the demand curve for fishing trips to estimate the marginal value of a sport-caught fish, which is what this procedure does indirectly.

As discussed earlier, the HTC technique provides estimates of the marginal value of a quality characteristic, such as the fish catch rate, by identifying an implicit market for the characteristic. Although the marginal value of a given quality characteristic is not necessarily measured in the market for visits, as with the TC method, the implicit price of the characteristic is defined on the basis of changes in the price of a visit. Thus, although a close relationship is posited between fishing trips and the fish catch rate, they are not necessarily assumed to be weak complements.

A two-stage procedure is used to empirically estimate an HTC model. In the first stage, the hedonic price equation for a given zone is specified by expressing the price of a visit to each site as a function of the fixed catch rate at the site and as a function of unknown parameters which can be viewed as describing the production technology for the hypothetical owner of the sites. This first-stage equation is estimated with data on per visit prices and catch rates across various sites visited by anglers from the zone. These data may be obtained from a survey of a sample of anglers from the zone. The estimated hedonic price equation is then used in the second stage to specify a demand equation for visits and one for the catch rate as well.

The same definition for the fixed price of a visit may be used here as would be used in a TC model. As with the TC model, it is important to obtain sufficient variability in observed prices across the sample. This means that the various sites visited by the anglers from the given zone must span a broad enough geographic area. For the TC model, on the other hand, this means that the residences of visitors to a given site must span a broad enough geographic area. Thus, the sampling methods used for each technique may differ.

Rosen (1974) states that the hedonic price function identifies the offer function in the case where firms are identical.[8] Since the offer function is derived from a cost function, there is apparently a theoretical form for the hedonic price equation. In empirical applications of the hedonic technique, however, one typically selects a functional form that fits the data well. If a linear function is used, then the estimated implicit characteristic price will be constant across the anglers from the zone. Variability in implicit prices across the sample is required for estimating a demand equation for the characteristic. In the case of a linear hedonic price equation, the only way to obtain different values for an implicit price is to estimate different hedonic price equations for various zones.

The demand equation for the characteristic, along with the demand equation for visits, may be derived from an explicit functional form for the utility function, $U = U(v_1, z_1, y, \gamma)$. As before, v denotes the number of visits to a particular site and z_1 denotes the fixed catch per trip at that site. The symbol γ represents unknown taste parameters. In general, both the demand for v and the demand for z_1 will be dependent on the price of v, the estimated implicit price of z_1, fixed income (M) and taste parameters (γ). Since the budget constraint is written as $M = p_v(z_1,\beta)v + y$, where $p_v(z_1,\beta)$ denotes the estimated hedonic price function

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occur between measurement errors in the dependent variable and in the price variable. Using distance traveled and a constant travel cost per mile to compute travel expenditures is one possible way to avoid this specification bias. A different approach is discussed later in this section.

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[8] An offer function defines the unit prices a firm is willing to accept on various designs of a product for a fixed profit level, given that the optimal quantities of each model are produced (Rosen, 1974).

and β denotes the estimated "technology" parameters, it follows that the estimated values of p_v rather than the actual values should be used in the demand equations. Estimated values of p_v are determined by using the observed quantities supplied of z_1 in the formula $p_v = p_v(z_1,\beta)$. If the implicit price of z_1 is not constant for a given zone (i.e., the hedonic price equation is not linear in z_1), then estimates of implicit prices are obtained by using the observations on characteristic supplies in the implicit price equation, $p_1 = p_1(z_1,\beta)$.[9]

With the HP method, as with the HTC method, demand equations for fishing trips (v) and the fish catch rate (z_1) are derived from a utility function specified as $U = U(v_1,z_1,y,\gamma)$. In the HP model, however, the implicit price of z_1 is used directly in the budget constraint, $M = p_v(r_v,w,v,\beta_v)v + \pi_1(r_1,w,z_1,\beta_1)z_1 + y$, where z_1 is defined as total catch rather than as catch per trip, and β_v and β_1 denote unknown technology parameters in each market. The implicit price functions for v and z_1 are derived from a cost function for the angler, who is taken to be both the producer and the consumer of these commodities.

The need to specify a cost function for the angler makes the basic HP model more data dependent than the other two types of models. Also, analytical difficulties may arise in cases where both the cost function and the utility function are highly nonlinear. Since quantities of outputs (i.e., commodities) as well as inputs (i.e., market goods and time) are assumed to be endogenous in this framework, the complete system of equations consists of demand equations for v and z_1 as well as demand equations for all of the inputs used to produce both of these commodities. Demand equations for inputs are derived from the cost function, which will in general be defined on fixed input prices, commodity quantities, fixed technological conditions, and unknown technology parameters.

In order to estimate the complete system of equations, one should have data on input prices and quantities, commodity quantities, income and indicators of technological conditions. Input prices include both market prices of goods as well as opportunity costs of time inputs. Price data and quantity data for all of the inputs used to produce both of the commodities are needed. Thus, the additional data that are required for an HP model as compared with the data required for a TC or an HTC model include market prices and total input quantities (rather than just average per trip expenditures), and data for constructing technology variables. Cross-section data would usually provide a sufficient amount of variability in input quantities and in technological factors that vary across anglers. Obtaining sufficient variability in market prices using cross-section data could be difficult, especially if the survey covers a relatively small geographic area.

As noted earlier, water quality indicators, both physical and biological, may be included in the model as technology variables. Data would be needed across a number of different sites in order to obtain variability in these quality factors. Using cross-section data across various sites, one could estimate an HP model for a representative site.

A problem that one would likely encounter in gathering data for constructing an HP model is the difficulty involved in obtaining independent data on input quantities used by anglers during a given time period. Since both the TC and HTC methods assume a constant price per visit, only data on average expenditures per visit are required for estimating these models. For estimating an HP model, on the other hand, it would be helpful for anglers to keep a record of their expenditures on each and every trip, so that total input usage variables could be constructed independently of the total number of trips variable. Also, if catch per trip is not assumed to be constant across trips, it would be important to obtain data on fish catch across all of the trips taken during the given period of time.

An issue that has received some attention in the literature is the problem of how to define the price of a visit in empirical studies of recreation demand. In other words, what types of expenditures should be included in the price variable?[10] In cases where the analyst is con-

[9] It would seem that a specification bias may result from using the estimated values of prices as exogenous variables in the model, because the dependent variable z_1 is used to calculate these prices. An alternative procedure would be to specify the characteristic demand equation in its reduced form by solving $z_1 = g_1(p(z_1,\beta), p_v(z_1,\beta),M)$ for z_1 in terms of β and M. Ideally, one would want to estimate the complete system of equations simultaneously, where the complete system would consist of the demand equations for z_1 and v as the hedonic price equation for p_v and the implicit price equation for p_1. This method is not applicable, however, because observations on p_1 are not available until the hedonic price equation has been estimated.

[10] The price variable in both TC and HTC models is defined as the sum of expenditures. Even though this is not the case with HP models, one still has to decide what types of input prices to include in the implicit price equations.

cerned with determining the value of a recreational experience, it would seem that the price variable should reflect the price that a hypothetical producer could charge for a recreational experience. That is, it should represent the recreationist's marginal willingness to pay value for a recreational experience.[11] Assuming that a person's actual expenditures on any visit adequately reflect the marginal willingness to pay value, it seems reasonable to include in the price variable any expenditures that are made over and above what the person would have spent otherwise (i.e., what would have been spent in the absence of recreating). Any goods purchased in addition to what would normally be consumed would presumably provide the recreationist with additional utility. This additional utility—in monetary terms—provides a measure of the benefits derived by the recreationist from the experience.

The utility-yielding components of a fishing experience include the trip itself, the sport-caught fish, and the aesthetic attributes of the site (e.g., scenery and congestion). It follows that the price variable in TC and HTC models should include the expenditures made for the purpose of consuming these commodities. Expenditures made for the purpose of consuming the trip itself would include costs of operating the vehicle (including time costs), food and lodging costs, and on-site costs (excluding costs associated with fishing activities). The latter two types of purchases are discretionary in nature; so only those costs over and above what would normally be spent in lieu of recreating should be considered. Aesthetic attributes of a site are consumed through the process of taking the trip so no additional expenditures are associated with these attributes. The expenditures made to consume the fish catch on a trip would include costs of fishing time, rental equipment, guide service, bait, etc.

In both TC and HTC models, the fishing experience is composed of the trip itself plus the quality characteristics of the site visited (which are assumed to be fixed). Thus, all of the expenditures described above should be included in the price variable. The fixed on-site costs associated with consuming additional quality characteristics may be treated as quasi-entry fees, as suggested by Gardner Brown. These "entry fees" would be expected to vary across sites as quality levels vary. The HTC method assumes that recreationists would be willing to pay additional "entry fees" as well as travel longer distances (and hence make more travel expenditures) to obtain better quality recreational experiences. This assumption is implicitly made in the TC methodology because, given the assumption of weak complementarity, an improvement in quality would shift the demand curve for visits to the right, thereby increasing the price recreationists are willing to pay per visit.

As mentioned earlier, the HP method decomposes the recreational experience into two commodities: the trip itself and the sport-caught fish. Thus, the price of a visit would be based on all expenditures except those that are made for the purpose of catching fish. These latter expenditures would be allocated to the fish catch commodity. In this framework, all types of expenditures, including travel costs, are assumed to be endogenously determined. That is, the quantities of market goods and time used are dependent on fixed prices and technological conditions. Similarly, implicit price variables for visits and sport-caught fish are functions of these same variables. In TC and HTC models, on the other hand, the price of a visit is usually defined as the sum of actual expenditures on market goods and time. Ward has shown that this procedure may lead to biased parameter estimates when discretionary costs (such as on-site expenditures and on-site time) are included in the price variable, because of the endogenous nature of these types of expenditures and their likely dependence on distance. Since the HP method treats all market goods and time inputs as endogenous variables, there is no reason to believe that these biases would appear in an estimated HP model.

Policy Considerations

In this section, the three techniques are evaluated on the basis of the kinds of policy questions they are each capable of handling. In

[11] The traditional explanation for the TC method as described by Bowes and Loomis (1980) would suggest that only travel costs should be included in the price variable. There is some question as to whether this definition would be adequate for a study designed to determine the benefits of quality changes at a site rather than to simply determine the benefits associated with the site's accessibility. That is, the use of travel costs as a proxy for an entry fee would reflect only the price that a hypothetical owner could charge for access to the site—not for the complete recreational experience. In this discussion, we view the hypothetical owner as both producing a recreational experience and transporting it to the "market place." Thus, we are trying to determine the marginal willingness to pay value at the "market place."

particular, the usefulness of each model is judged on the basis of the types of quality variables that may be included in the model. This then suggests what types of policy-induced quality changes each model can be used to evaluate and the data that are needed to apply each model in this manner.

Both the TC and HTC models are restricted to the evaluation of quality changes that are perceived by recreationists. Quality variables only enter these models through the utility function, and it is assumed that these quality factors directly influence recreationists' behavior regarding the choice of which site to visit and/or the level of participation at any given site. Thus, quality variables should be defined in terms of the recreationist's subjective evaluation of quality levels.

The main advantage the HTC technique has over the TC technique is that an implicit market is defined for each quality characteristic. This means that it is not necessary to assume that a weakly complementary relationship exists between each quality characteristic and the visits variable in order to evaluate the benefits of quality changes. Thus, it would seem that the scope of the HTC model in evaluating the effects of policy-induced quality changes is somewhat broader than that of the TC model. Another advantage of the HTC model for sport fishing is that a fish catch rate variable can be included directly in the model since it would be treated as an endogenous choice variable across sites. It was mentioned earlier that in a TC model the inclusion of a catch rate variable could lead to biased parameter estimates. By employing Brown and Sorhus' two-stage procedure, however, one may determine the marginal value of a sport-caught fish using fish catch data by site that need not come from the same source as the data on fishing trips.

Estimates of the marginal value of a sport-caught fish from either a TC or an HTC model may be useful for evaluating the benefits of exogenous changes in factors affecting fish catch levels. For example, one could determine the recreation benefits associated with an increase in fish stocks or an improvement in either habitat quality or water quality. Of course, it would be necessary to have prior knowledge of the effects of changes in fish stocks or of changes in habitat or water quality conditions on fish catch levels.

It was shown earlier that the effects of changes in fish stocks and in habitat or water quality on fish catch levels can be specified directly in the HP model. That is, exogenous (objective) quality variables may be included in the fish catch production function. Thus, without needing any additional information than would be provided by an empirical HP model for sport fishing, one could evaluate the benefits of increases in fish stocks or of improvements in habitat or water quality. The HP model provides estimates of marginal values for any exogenous quality factors that are included as technology variables in the model. In constructing a model for the purpose of evaluating policy changes, one would want to use policy-related variables in the model.

Marginal values can also be determined for any exogenous quality characteristics that are included as arguments of the utility function in the HP model as in the TC model. Since the fish catch level is treated as an endogenous variable in this model, the model does not provide estimates of the marginal value of a sport-caught fish, but it does give an estimate of the average value. It is not always appropriate to use average values for determining the effects of marginal changes in quantities of a commodity. Therefore, the HP model may not be useful for evaluating the effects of changes in fish catch levels induced by changes in quality factors that are not included in the model as technology variables. In cases where the relevant policy-related variables are included in the model, however, the HP technique has definite advantages over both the TC and HTC techniques in the evaluation of policy-induced and quality changes.

Summary

This paper has attempted to describe the theoretical foundations for three recreation valuation techniques. It was shown that all three techniques can be related to a constrained utility maximization problem, and that nonmarket values for recreational commodities are inferred from hypothesized relationships between these commodities and various groups of market goods. The three techniques were found to differ primarily on the basis of the decision making process used to describe recreationists' behavior, and on the basis of the recreationist's role in determining the quality of a recreational experience. These distinguishing factors have implications for how each technique can be used to obtain measures of the benefits to recreationists of quality changes.

The single-site TC model assumes that the recreationist only decides how often to visit the given site (or a representative site when multiple-site data are used). Although the recreationist may take into consideration the quality attributes of the site, those attributes are assumed to be completely exogenous to the decision making process. By assuming a weakly complementary relationship between a quality attribute and the recreationist's level of participation at a site, one can determine the nonmarket value of the attribute in terms of benefits derived from the recreational experience.

The HTC technique permits the recreationist to select a bundle of quality characteristics, and thus to determine the quality of a recreational experience. Given this decision, the recreationist then decides how many times to visit the site that offers that bundle of characteristics. Since each type of quality characteristic is treated as an endogenous choice variable in the HTC model, an implicit market is defined for each characteristic. One can thus determine the nonmarket value of a characteristic by measuring benefits in the market for that characteristic. The implicit price of a characteristic is defined on the basis of additional expenditures a recreationist is willing to make while visiting a site which offers one more unit of the characteristic. It is assumed that the bundle of characteristics provided at each site are fixed.

The HP technique drops this assumption for certain types of quality characteristics, such as the fishing success rate. That is, for certain recreational commodities, including the level of participation at a site, the recreationist is viewed as both a producer and a consumer of each commodity. Implicit prices are defined on the basis of the minimum costs that must be incurred to produce one more unit of a commodity. Included in these costs are expenditures on market goods and the opportunity costs of time used in the production process. Nonmarket values of an endogenous quality characteristic may be measured in the market for that characteristic, which is represented by an endogenous supply and demand at each site. With this technique, nonmarket values may also be determined for exogenous quality factors that influence the supply of an endogenous characteristic at a given site.

The TC method, while making the most restrictive assumptions regarding the recreationist's decision making process, has the advantage of being less data dependent than the other two methods. Also, this method usually involves the simple estimation of a single demand equation for the recreational activity. Exogenous quality variables may be included in this demand equation. Variability in quality levels could be found in data obtained over a number of different sites. Variability in the price of a recreational experience could normally be obtained with data over recreationists that traveled different distances to visit each site.

The estimation of an HTC model requires that the given geographic area in which different sites are located be divided into a number of different zones. The recreationists living in each zone must visit a number of different sites at varying distances from the zone and with varying quality attributes. Estimation of the hedonic price equation for each zone requires that the distance traveled to each site be significantly correlated with the quality attributes of each site. The estimated hedonic price equation for a given zone provides a set of implicit prices for the quality characteristics. With implicit price data across a number of different zones, one can estimate a demand equation for each characteristic.

The HP method has the most extensive data requirements of the three methods. Input price as well as quantity data on both inputs and commodities may be required to estimate the complete system of input and commodity demand equations. Quantities and implicit prices of commodities, including endogenous quality characteristics, would typically vary across individual recreationists. If exogenous quality variables were included in the model, then data across multiple sites would be required, because these data would not vary across recreationists for a given site. Objective quality data may be used to define these exogenous quality variables.

To include any quality variables in either the TC or HTC model, on the other hand, one should have data on the recreationists' subjective evaluations of quality attributes at various sites. The same would be true of exogenous quality variables that are included in the utility function of an HP model. These quality variables are assumed to directly influence the recreationist's participation decision. Recreationists would most likely base their decisions on how they personally perceive the quality of a site.

To use the TC and HTC models in policy evaluation, one must first specify the relationships between policy-related variables and the subjective quality variables that are included in the models. The HP model would thus have a definite advantage over these other two models in cases where policy-related variables could be included in the model as determinants of the supply of commodities. Therefore, in certain circumstances, it would be worth the extra effort to construct an empirical HP model. In terms of the scope of each model in evaluating the benefits of quality changes, the HTC technique seems to have an advantage over the TC technique. That is, it is not necessary to assume weak complementarity with the HTC technique.

The availability of data and the types of quality variables that are to be included in a model are two factors that would influence the decision on which of the three techniques to use in a given situation. The assumptions underlying each approach should be given careful consideration, especially those regarding the recreationist's role in determining the quality of a recreational experience. Not only would the types of quality characteristics considered influence the model selection decision, but they would also have implications for the definitions for price variables used in the model.

References

Bockstael, Nancy E. and Kenneth E. McConnell. "Theory and Estimation of the Household Production Function for Wildlife Recreation." *Journal of Environmental Economics and Management* 8(1981):199–214.

———. "Welfare Measurement in the Household Production Framework." *American Economic Review* 73(1983):806–814.

Bowes, Michael D. and John B. Loomis. "A Note on the Use of Travel Cost Models with Unequal Zonal Populations." *Land Economics* 56(1980):465–470.

Brown, William G. and Farid Nawas. "Impact of Aggregation on the Estimation of Outdoor Recreation Demand Equations." *American Journal of Agricultural Economics* 55(1973):246–249.

Brown, William G., Colin Sorhus, Bih-lian Chou-Yang, and Jack A. Richards. "Using Individual Observations to Estimate Recreation Demand Functions: A Caution." *American Journal of Agricultural Economics* 65(1983):154–157.

Brown, William G. and Colin Sorhus. "On Estimating Values of Sport-caught Fish with Application to Oregon Salmon and Steelhead." Unpublished manuscript, 1981.

Deaton, Agnus and John Muellbauer. *Economics and Consumer Behavior.* London: Cambridge University press, 1980.

Gum, Russell L. and William E. Martin. "Problems and Solutions in Estimating the Demand for and Value of Rural Outdoor Recreation." *American Journal of Agricultural Economics* 57(1975):558–566.

Muellbauer, John. "Household Production Theory, Quality, and the 'Hedonic Technique'." *American Economic Review* 64(1974):977–994.

Rosen, Sherwin. "Hedonic Prices and Implicit Markets: Product Differentiation in Pure Competition." *Journal of Political Economy* 82(1974):34–55.

Smith, V. Kerry, William H. Desvousges, and Matthew P. McGivney. "Estimating Water Quality Benefits: An Econometric Analysis." *Southern Economic Journal* 50(1983):422–437.

Strong, Elizabeth J. "Measuring Benefits of Outdoor Recreation Services: An Application of the Household Production Function Approach to the Oregon Steelhead Sport Fisher." Unpublished thesis. Oregon State University, Corvallis, 1983.

Ward, Frank A. "Some Considerations in the Specification of the Price Variable in Travel Cost Demand Models for Outdoor Recreation." Unpublished manuscript.