Hedonic Travel Cost and Random Utility Models of Recreation^ψ

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Hedonic Travel Cost and Random Utility Models

Abstract

This paper demonstrates that hedonic and random utility models emanate from the same utility theoretic foundation, although they make different estimation assumptions. Using a theoretically consistent comparison, both approaches are applied to examine the quality of wilderness areas in the Southeastern United States. When consistently applied, both models lead to results with similar signs but different magnitudes. Because the two models are equally valid, recreation studies should continue to use both models to value site quality. Further, practitioners should be careful not to make simplifying a priori assumptions which limit the effectiveness of both techniques. (*JEL* C25, Q23, Q26)

Hedonic Travel Cost and Random Utility Models

Micro-economic theory began as an attempt to describe, predict and value the demand and supply of consumption goods. Quality was largely ignored in initial theoretical treatises; goods were assumed to be homogeneous. Over the last two decades, economists have started to address quality within the theory of demand and specifically the question of site quality, which is an important component of land management. Two distinct approaches for incorporating quality into recreational analysis have emerged: the hedonic travel cost method (HTC) and the discrete choice random utility methods (RUM). The hedonic method views site attributes as though they were individual goods which are bundled together in a single purchase. The random utility model treats quality through an index which is estimated by examining a discrete choice of alternative sites facing a consumer.

Because the mathematical derivations for the hedonic [21] and random utility models [15] are quite different, many practitioners do not recognize that both models are based on a common utility theoretic foundation. In the first section of this paper, we show how the hedonic and random utility methods are consistent with the same utility framework.

Curiously, practitioners of the two methods have often made different *a priori* assumptions about utility when applying the methods. Many studies using the RUM method have assumed linear utility functions (see Morey et al., for an exception) while studies using the hedonic method frequently rely on quadratic utility functions [5]. In section II of the paper, we examine linear and quadratic functional forms for utility in order to compare them for both the hedonic and RUM approaches.

Although both methods are based on the same utility theoretic framework, there is one important difference between the RUM and HTC methods. Each method makes very different

assumptions about the nature of the error terms in consumer decisions. Although this leads to the two methods having quite different predictions, it is difficult to judge which approach is better. There is little theoretical justification for either set of underlying assumptions. Of course, one could compare results. This is done in Section III in an application to wilderness areas in the Southeastern United States. However, it is difficult to judge the results since both sets of results are reasonable but not perfect.

1. The Utility Framework

It is well known that the quantity of goods purchased are arguments in the utility function of consumers. Although common utility theory glosses over quality, it is equally plausible that quality is also an argument in the utility function of consumers. After all, there are countless examples where consumers spend more for a unit of good with higher quality. Two approaches have emerged to characterize quality as a part of consumer choice. The hedonic approach treats quality as though it were simply another good. The random utility approach treats quality as an index to be attached to goods. In both cases, the techniques attempt to place values on these qualities by observing how consumers choose from amongst the package of available goods. In this section, we demonstrate that the underlying theoretical foundation for both methods is the same utility maximization subject to budget constraints. We argue that the theoretical foundations of both approaches are the same and consequently cannot be used to argue for one rather than the other approach.

1.1 The Hedonic Travel Cost Method

The theoretic derivation of the demand for goods from utility maximization subject to a budget constraint is a well established part of basic micro-economic theory. Without loss of

generality, we extend this derivation to include quality. We begin by considering a set of Hicksian demand functions for a vector of site attributes (qualities), $\mathbf{Z}$, described by a vector of attribute prices, $\mathbf{P}$, utility u , and an estimation error term, ϕ .

$$(1) \quad \mathbf{Z} = h(\mathbf{P}, u, \phi).$$

In the case of recreation demand, the price is not a market price, but an implicit price. This implicit price is found by estimating the hedonic price function. The hedonic price function is the empirical estimation of the hedonic price frontier across visited sites. The cost of accessing any site on the frontier is a function of the attributes of that site. Formally, the hedonic price function¹ is

$$(2) \quad C(\text{site } j) = \text{fn}(\mathbf{Z}_j)$$

and the vector of implicit prices for the site attributes is given by the gradient of (2)

$$(3) \quad \mathbf{P} = dC/d\mathbf{Z}.$$

Given (1), we can find a set of inverse demand functions:

$$(4) \quad \mathbf{P} = h^{-1}(\mathbf{Z}, u, \phi).$$

Here P reflects the marginal value that the consumer would pay for an incremental unit of quality. We derive the consumer surplus associated with the consumption of Z^* by taking a line integral of (4) from $Z=0$ to $Z=Z^*$ minus the costs of purchasing Z^* :

$$(5) \quad CS = \int_0^{Z^*} h^{-1}(Z, u) dZ - C(Z^*) + g(\phi)$$

Generally, practitioners take the expectation of $g(\phi)$ to be zero, but the exact structure of the error term in (5) depends on the nature of the error (e.g. omitted variables or measurement error, see [2]). Note that the definition of (5) allows for nonlinearity in the price schedule of Z . Since $h(Z, u, \phi)$ is a Hicksian demand, the consumer surplus measure in (5) is an exact measure of the welfare associated with Z^* ; it is also a money metric utility function, U^m ,

$$(6) \quad U^m = \int_0^{Z^*} h^{-1}(Z, u) dZ - C(Z^*) + g(\phi).$$

One criticism of the hedonic method is that it estimates Marshallian demand, not Hicksian demand. Using a Marshallian demand function for (1) yields an inexact measure of consumer welfare in (5). However, Hausman [11] shows that an exact welfare measure can be recovered directly from the Marshallian demand function. Alternatively, when the assumed utility function is linear in income, the Marshallian demand is identical to the Hicksian compensated demand. Finally, in most circumstances which pertain to recreation, policy measures affect only a small fraction of user's potential incomes. Consequently, it is reasonable to assume that the Marshallian measure is a good approximation of true welfare (see [22]).

Given the above construct, one can evaluate the welfare effects of changing from one level of site quality Z^0 to another, Z^1 . The demand relations (1) and (4) determine a unique welfare measure:²

$$(7) \quad CV = U(Z^0) - U(Z^1)$$

where U is the money metric utility in (6). If the individual stays at the site he originally visited, (7) simplifies to:

$$(8) \quad CS = \int_{Z_a^0}^{Z_a^1} h^{-1}(z, u) dz,$$

because there is no change in travel costs associated with visiting the original site a .

1.2 The Random Utility Method

The random utility method envisions that site qualities form an index to be associated with each good (a visit to a site). The method focuses examines how a consumer chooses from a set of discrete sites each of which embodies a vector of attributes (qualities). Following McFadden [15], the consumer chooses a site to maximize their conditional utility:

$$(9) \quad \text{Prob}(\text{choose site } j) = \text{Prob}[U(Z_j, X) + \varepsilon_j] \geq \text{Prob}[U(Z_{ij}, X) + \varepsilon_{ij}]$$

such that $Y = [HX + C(Z_j)]$.

The conditional utility of the RUM may have the same functional form as U^m from the hedonic approach. The random utility function consists of a deterministic core, $U(Z_j, X)$, and a random component, ε_j . This random utility is a function of the attributes, Z_j , of the site chosen, j , and all the remaining goods, X , that can be consumed. H is the price of other goods X , ε is a random variable and Y is income. Unlike the hedonic approach, the random term is rarely assumed to have a normal distribution since this distribution makes econometric estimation cumbersome. Instead, practitioners usually assume a generalized extreme value distribution for the error term. The deterministic component of the RUM method corresponds to the underlying utility function in HTC. The theoretical foundations of both approaches are identical since they rely on the same underlying framework. What makes the two approaches so different is that they make different assumptions about the error structure. However, the assumptions made about the error structures in both approaches do not follow from theory, so one must be cautious arguing for theoretical superiority.

If we assume, without loss of generality, that the price, H , of other goods X is 1, then we can substitute $HX = Y - C(Z_j)$ into the utility function in equation (9) in which case the consumer chooses a site to maximize their random utility:

$$(10) \quad U(Z_j, Y - C(Z_j)) + \varepsilon_j$$

Note that (10) is a conditional random utility, conditional upon choosing to visit a site. As we showed with the hedonic method, any functional form for the deterministic portion of the random utility, U , implies a Hicksian demand function for Z .

We now need a measure of welfare change that demonstrates the compensation or payment required to maintain utility with and without an environmental change. In the RUM

model, utility is random so we must calculate expected utility. Formally, the expected utility of a representative consumer is

$$(11) \quad E[U] = \sum_{j=1}^n \text{Prob}(\text{site } j) * U_j$$

where the probability of choosing any one of the n sites is given by

$$(12) \quad \text{Prob}(\text{site } j) = \int_{-\infty}^{\infty} \prod_{j \neq i} F(\epsilon_j + U_j - U_i) / f(\epsilon_j) d\epsilon_j$$

where $F(\bullet)$ is a cumulative and $f(\bullet)$ is a density probability function. A change in quality at one or more sites causes a change in expected utility not only because the deterministic portion of utility, U , changes at the affected site(s) but also because the probability of choosing each site changes. Traditionally, RUM practitioners assume a generalized extreme value distribution for ϵ and thus the change in expected utility can be found by

$$(13) \quad E[\Delta U] = \left\{ \ln \left[\sum_j \exp \{U(Z_j^1)\} \right] - \ln \left[\sum_j \exp \{U(Z_j^0)\} \right] \right\},$$

where the superscripts represent states of the world in terms of site quality. It is unclear how different assumptions about the distribution of the random term would affect the expected welfare measure. When the marginal utility of income is assumed to be constant (usually the case in RUM applications) the change in expected utility is converted to a money metric numeraire by dividing through by the marginal utility of income, λ , giving an expression for

the expected change in welfare. In this case, since the marginal utility of income is constant, the welfare measure is equal to compensating variation which is equal to equivalent variation which is equal to change in consumer surplus. Formally the expression for change in welfare is

$$(14) \quad E[\Delta CV] = \frac{1}{\lambda} \left\{ \ln \left[\sum_j \exp\{U(Z_j^1)\} \right] - \ln \left[\sum_j \exp\{U(Z_j^0)\} \right] \right\}.$$

Note that the expected welfare measure used in RUM is not the same as the deterministic calculation in HTC. The expected welfare approach suggests that the consumer obtains utility not only for the site that he actually visits but also for the sites that he chooses not to visit. The deterministic welfare measure derived for the HTC method, however, would only estimate welfare values for visited sites. These two alternative ways of estimating welfare likely lead to different results. One way to overcome this discrepancy in welfare measures is to calculate expected welfare for HTC. Visitation could be viewed in terms of probabilities and an expected measure of welfare could be calculated. The welfare function, in this case, would be [6] but otherwise the calculation would resemble the RUM approach. An alternative approach is to use the deterministic component of RUM and measure welfare only at visited sites. In this study, we follow the traditional assumptions of each approach and use deterministic calculations for HTC and expected calculations for RUM.

2. Utility Functional Form

Although practitioners have conducted RUM and HTC studies on the same data sets, no study has yet made theoretically consistent comparisons. All the empirical comparisons made to date have made different assumptions about the nature of the utility function in their HTC versus their RUM models. The studies have assumed that utility is linear in their RUM models and quadratic in their HTC models. These are a priori assumptions made by the authors, not theoretical properties of each technique. Assuming that utility is linear is equivalent to assuming that demand is perfectly elastic in prices. That is, the marginal value of quality would be the same no matter how much quality is provided. Although there are some examples where quality appears to be somewhat price elastic, this is a strong a priori assumption to make and a general failing of applications of RUM in the literature (see [22] for a thorough discussion of this point). In this section, we examine both linear and quadratic utility functions for both the RUM and HTC models.

2.1 Linear Utility

Utility functions that are linear in both attributes and income (cost) are used commonly in applications of the RUM to recreational quality (e.g. [3], [18], [19], and [13], and [12]).

The standard deterministic core of the linear utility function is

$$(15) \quad U_j = \gamma Z_j + X \text{ subject to } Y = HX + C(Z_j),$$

where subscript j refers to site j , Z_j is the vector of quality attributes that describe site j , $C(Z_j)$ is the cost of accessing site j with attributes Z_j , and Y , H , and X are as before. If we assume

that utility (15) is linear in income (all other goods), and that H is fixed and can be set arbitrarily to unity, then we can use the income constraint to substitute $Y - C(Z_j)$ for X giving us:

$$(16) \quad U_j = \gamma Z_j + \lambda [Y - C(Z_j)],$$

where λ can be interpreted as the (constant) marginal utility of income. Equation (16) forms the deterministic core of the RUM in which the conditional random utility derived from choosing site j is

$$(17a) \quad v_j = U_j + \varepsilon_j$$

$$(17b) \quad v_j = \gamma Z_j + \lambda [Y - C(Z_j)] + \varepsilon_j,$$

where ε_j is a random term. Most frequently, the RUM is estimated assuming a logistic or extreme value distribution for ε_j . The estimation of the RUM proceeds by a differences in utility specification in which the differences in utilities between sites also has the same distribution as the difference in random terms. In the differences in utilities approach, λY disappears from the utility function because income does not vary across sites and the marginal income of utility is assumed to be constant. In the econometric application of the RUM, the conditional random utility function becomes

$$(18) \quad v_j = \gamma Z_j - \lambda C(Z_j) + \varepsilon_j.$$

Note that (18) also is a conditional indirect utility function in price $C(Z)$ and quality, Z_j .

The deterministic portion of the linear utility function is not strictly "well-behaved" in the sense that it is not strictly concave. The linearity of the utility function means that the marginal value of any attribute remains the same for all levels of quality (i.e. the marginal value is constant).

$$(19) \quad \frac{\partial U}{\partial \mathbf{Z}} = \gamma,$$

where $\frac{\partial U}{\partial \mathbf{Z}}$ is a column vector of marginal utilities and γ is a column vector of coefficients. If a single linear utility function is thought to apply to all consumers, then we assume that all consumers place the same marginal values on attributes, $\mathbf{Z}$, regardless of how much is purchased (experienced).

The linear utility function can be estimated by the hedonic method by estimating a single linear hedonic price function for all markets (origins). The hedonic price function must be the same for all markets since by assumption the marginal utility of another unit is equal to a constant.

2.2 Quadratic Utility

Many applications of the hedonic method to recreational quality implicitly assume a utility function that is quadratic in its non-income arguments ([16], [22], [23]). More sophisticated applications of the HTC assume quadratic utilities that also contain cross-price terms (e.g. [7], [4]). The functional form for the deterministic core of the quadratic utility function is:

$$(20) \quad U_j = \frac{1}{2}(\mathbf{Z}_j - \boldsymbol{\alpha})' \boldsymbol{\beta}^{-1} (\mathbf{Z}_j - \boldsymbol{\alpha}) + \lambda X, \text{ subject to } Y = HX + C(\mathbf{Z}_j),$$

where $\mathbf{Z}$ is a vector of site attributes, $\boldsymbol{\alpha}$ is a vector of constants, and $\boldsymbol{\beta}$ is a matrix to be estimated. A well-behaved quadratic utility function requires that all elements of the vector $\boldsymbol{\alpha}$ are positive and that the matrix $\boldsymbol{\beta}$ is negative semi-definite. The cross-price terms allow attributes to act as substitutes or complements.

With the quadratic utility function, it is theoretically possible to have oversatiation if a consumer faces a cheap (nearby) and over-abundant supply of a specific attribute. For some economists, the potential for negative prices (decreasing utility with increasing attributes) is sufficient reason to reject a quadratic utility functional form [8]. There are, however, two cases in which a quadratic utility function might be appropriate for the analysis of recreational quality. The first case is where the feasible consumption set is one in which all or most consumers have a utility that lies within the increasing range of the utility function. The second case is when consumers do not enjoy free disposal [6] and may be forced to consume some attributes at a level that exceeds complete satiation. For example a skier may happen to live near a ski area which has exceedingly large amounts of a normally desirable attribute such as deep snow. The consumer cannot sell off this overabundance and may be observed to occasionally travel further (pay more) to go to a site with less snow. The negative prices often found in applications of the HTC can reflect oversatiation. Results using the same data that follow in Section 3 and published in another paper [20] show that for hiking in the Southeastern United States, negative implicit prices are associated with attribute levels that are significantly higher than attribute levels where prices are positive.

The hedonic method estimates the parameters of the quadratic utility function by first estimating a hedonic price function for each origin in which $C(\mathbf{Z})$ is regressed upon $\mathbf{Z}$. Any

functional form can be used in the regression. Using these hedonic prices, a system of seemingly unrelated demand functions is estimated

$$(21) \quad \mathbf{Z} = \alpha + \beta \mathbf{C}_z + \phi.$$

where $\mathbf{Z}$, α , $\mathbf{C}_z$ are the same vectors as before, ϕ is a vector of error terms, and β is a matrix. In order to integrate the inverse of (21) back to (20) and to ensure that integration is path independent, it is necessary to constrain the cross-diagonal elements of β to be symmetric (the Slutsky conditions).

The RUM analysis can estimate the coefficients of the quadratic random utility function after expanding the vector notation of (20) (see [22]). A simplified form of the expanded utility would follow:

$$(22) \quad U = \left[\beta_1^{\text{rum}} z_1 + \frac{1}{2} \beta_2^{\text{rum}} z_1^2 + \dots + \beta_n^{\text{rum}} z_n + \frac{1}{2} \beta_{n-1}^{\text{rum}} z_n^2 + \beta_{n+1}^{\text{rum}} z_1 z_2 \right] + \alpha^{\text{rum}} \dots + \lambda(Y - C(\mathbf{z})) + \varepsilon$$

where the coefficients, α^{rum} and β^{rum} represent collected terms (i.e. the complex coefficients that result from the matrix multiplication in (20)). The income constraint is substituted in for all other goods X in (20). Unlike the hedonic estimation, there is no need to restrict cross-price terms since only one coefficient is estimated for each cross-attribute pairing. The constant, α^{rum} , cannot be estimated using the RUM and is irrelevant for welfare and utility calculations. As with the linear utility function the income term, Y , is dropped in the standard RUM estimation.

3. An Empirical Comparison

Past comparisons between hedonic and RUM methods have made no attempt to make consistent assumptions about the underlying form of the utility function (e.g. [3] and [5]). In this section we estimate both linear and quadratic utility functions for the HTC and RUM methods. Note that comparing a linear RUM and a quadratic HTC is not an appropriate methodology for comparing the two techniques.

3.1 Data

Data were collected on 4778 visits to 46 trails in 20 different forest areas near the Smoky Mountains (see [20]). Visitor data came from permits collected by the USDA Forest Service (USFS) and an independent survey. We limit the data set to visitors from within 300 miles of the North Carolina and Tennessee border in order to focus the analysis on single purpose trips. The data were collected between 1992 and 1994. Trails were surveyed in wilderness areas, non-wilderness areas, the State Park system, and the Great Smoky Mountain National Park.

Important trail attributes were identified by interviewing hikers and reading popular trail guides. Standard ecological techniques were used to measure these attributes along each of the 46 trails in the study. The set of trail attributes includes "basal area" (a measure of the size of trees and tree density), "elevation" (the maximum elevation of each trail), "riparian" (percent of trail along a creek), and "isolation" (measured as miles from the paved road to the trail head). Appendix A gives summary statistics for the trail attributes. In addition, the distance from each origin to a trailhead was calculated using the program ZIPFIP (USDA 1993). All distances are in one way miles.

3.2 The Methods

Both the RUM and HTC methods are estimated according to standard practice. We give a brief review of the estimation methods here.

The Hedonic Cost Function

We estimate the implicit price of trail attributes by regressing the total travel costs to sites visited, $C(Z)$, on levels of environmental attributes at these sites. Because the geographic configuration of sites differs for every origin, a different hedonic price function is estimated for each origin. Using OLS, we estimate the hedonic price function only for those sites actually visited by residents of a given origin. It is assumed that sites that are not visited are not on the hedonic price frontier (i.e. these sites are inferior). We assume that the hedonic price function is linear:

$$(23) \quad C(Z) = c_0 + C_1(\text{basal}) + C_2(\text{elevation}) + C_3(\text{riparian area}) + C_4(\text{isolation}) + \psi$$

where Z is a vector of quantities for the selected attributes (basal, elevation, riparian, isolation) and ψ is the estimation error. The coefficients, C_i , represent the implicit prices for the attributes. Because we run a different regression for each origin, a different vector of implicit prices, C_z , exists for each origin.

Some critics argue that the hedonic price function cannot be estimated since the cost of obtaining the recreational good is exogenous. As described earlier, consumers choose only the sites that lie along the hedonic price frontier. Arguea and Hsiao [1] show that if attributes are independent, then consumers will make choices that are best represented by a linear in attributes price function. The linearity depends on the production function only to the degree

that the attributes are independent. The linearity of this function is not dependent on the actual offer function and thus does not require any knowledge of the functional form of the offer function. To the degree that attributes are not independent in production, a linear in attributes hedonic price function may represent a mis-specification of the true hedonic price function. Mis-specification in the hedonic methods is not qualitatively different than mis-specification in other types of estimation (e.g. the RUM) and can be tested using standard techniques.

The coefficients of the hedonic cost function represent the implicit prices of attributes. These implicit prices represent the marginal value of any attribute. The linear in attributes utility function implies a constant marginal value for each attribute, regardless of the level of attributes consumed. Therefore, a single hedonic cost function also was estimated for all origins simultaneously. The coefficients of this "universal" linear hedonic cost function are consistent with the marginal values that would be derived from the linear utility function.

The Demand for Site Attributes

The second step in the hedonic travel cost analysis is to estimate the demand for site attributes based on the implicit prices faced by each visitor and the level of attributes chosen by each visitor. In this study, we estimate a system of demand functions that are linear in site attributes and socio-economic shift variables. Using data on all visitors, we estimate the following system of demand functions:

$$(24) \quad Z = \alpha + \beta C_z + \delta S + \phi$$

where Z is a vector of quantities for the selected attributes (basal area, elevation, riparian, isolation), C_z is a vector of hedonic prices from the first stage regressions, S is a vector of

socio-economic variables, ϕ is a vector of estimation errors and α , β and δ are respectively a vector and two matrices of coefficients to be estimated. The socio-economic shift variables are characteristics of each origin and are derived from U.S. 1990 census data. Interestingly, we could not identify any socio-economic variables that significantly affected the demand for site attributes and so S was dropped from (24). Because the coefficient on income (an element of S) was not significantly different from zero, we conclude that the income elasticity of demand for forest attributes is zero and thus compensating variation, equivalent variation, and consumer surplus are equivalent.

The prices from the first stage and the quantities of site attributes chosen by hikers allows us to estimate the demand functions of equation (24). Because hikers from different origins face different prices, we treat each origin as a separate market. The existence of multiple markets allows the estimation to be specified and avoids the pitfalls common to single market hedonic applications (see [14]). We estimate equation (24) using a generalized least squares, seemingly unrelated regression procedure. We constrain the cross-prices of β to be symmetric in order to ensure that welfare measures are path independent.

The Random Utility Models

We estimate the RUM models using standard non-nested multinomial logit methods. All trails are included in the choice sets of individuals. We estimate a linear in attributes conditional random utility function

$$(25) \quad v_j = \beta^{\text{linear rum}} Z_j + \lambda[Y - C(Z_j)] + \varepsilon_j,$$

where Z_i is defined as before (i.e. $Z_i = \{\text{basal area, elevation, riparian, isolation}\}$). We also estimate a quadratic in attributes random utility function

$$(26) \quad v_j = \beta_1(\text{basal area}) + \beta_2(\text{basal area})^2 + \beta_3(\text{elevation}) + \beta_4(\text{elevation})^2 + \beta_5(\text{riparian}) + \beta_6(\text{riparian})^2 + \beta_7(\text{isolation}) + \beta_8(\text{isolation})^2 + \varepsilon_i$$

where all of the coefficients, of course, refer only to the quadratic specification.

3.3 Econometric Results

The linear utility parameters for the HTC model suggest that basal area and elevation are both goods whereas isolation is an economic bad and creek is not relevant. (Note that a single linear in attributes hedonic price function for all origins is an inappropriate application of the HTC. We include this estimation solely for comparison. The results from the linear RUM analysis suggest that both elevation and creek are undesirable whereas basal area and isolation are good. Although the basal area and isolation results are consistent with prior expectations, the remaining results from the RUM analysis seem inconsistent with the description of trail attributes in hiking books.

In general, the results of the quadratic utility function are superior to the linear utility model. More coefficients are significant and have the expected sign and the models explain a greater fraction of the observed behavior. The quadratic utility parameters for the HTC model imply negative own price elasticities (downward sloping demand functions) for all four attributes. The cross price elasticities between basal area and both creek and isolation are positive implying these attributes are substitutes. Elevation also has a positive cross price elasticity with respect to isolation. The quadratic utility parameters for the RUM model yield

similar results. The linear and quadratic coefficients for both basal area and creek have the expected sign. All interaction terms between attributes suggest that the attributes are substitutes. Neither model, however, performs exactly as expected. If the estimated coefficients are taken at face value, the HTC model implies that creek is a bad not a good. However, it should be noted that the coefficient on the interaction term between creek and elevation is not significantly different from zero. If we set this term equal to zero, then the hedonic method depicts creek as a normal good. In contrast, the RUM model suggests that the more isolation and the more elevation, the better the site becomes at an increasing rate.

Seventeen of the 20 common coefficients between the HTC and RUM models are of the same sign. All of the coefficients, however, differ by at least one order of magnitude. All but one of the coefficients which were significantly different between the RUM and HTC models involved creek.

3.4 Welfare Estimates

For perspective, welfare estimates are given for changes in the levels of attributes at all trails and changes in the levels of attributes at a single trail (the Pleasant Garden Overlook in the Unaka Wilderness Area of Tennessee). Attribute changes are calculated for a change in the level of each attribute equal to 10% of the mean across all sites. All of the results are given as mean welfare changes, in dollars assuming that it costs \$0.25 per mile traveled. The welfare results are proportional to the assumed travel cost so that the reader can easily adjust these figures for different travel cost per mile estimates.

We make two different welfare measurements using the HTC empirical estimates. In the analysis labeled HTC, we assume that people stay at the same site before and after the

quality change. The welfare measure is (6). With the RUM analysis, an expected welfare measure is used (16).

The welfare estimates, per visit, for a 10% decrease in each attribute for all trails is presented in Table III. The results from the RUM linear utility model do not appear consistent with intuition. The RUM model predicts that decreases in elevation and creeks would improve the value of a trail. The linear HTC model also predicts one strange result -- decreases in access to creeks would improve trip value. The quadratic results for the RUM are more problematic than the linear results. Decreases in three attributes considered goods (basal area, elevation, and creek) are predicted to increase site value. The anomalous welfare results from the quadratic RUM are the result of the interaction terms, the coefficients of which are all negative. The HTC model, in contrast, predicts that a decrease in basal area, elevation, creek, and isolation would all reduce site value.

In Table IV, we examine the welfare impact of a quality change at only a single site. A decrease in the level of attributes at one site should have only a marginal impact on visitor welfare because visitors can readily move to substitute sites. The RUM which allows this substitution should predict smaller welfare effects from quality reductions at a single site. As predicted, the results in Table IV for the RUM models are substantially smaller than the results reported in Table III where every site underwent a change. For the quadratic RUM, the greatest welfare loss (-\$0.14) occurs for a 10% loss in the level of basal area at the Pleasant Garden Overlook Trail. The results for the quadratic HTC are much larger. The maximum welfare loss for the HTC (-\$3.70) for basal area is considerably larger than the results using the other methods. Our standing assumption that visitors would stay at a site when its quality declines may explain this much larger estimate of welfare damage.

5. Conclusion

Unlike other studies that compare the hedonic and RUM methods (e.g. [5], [3]), this study compares the models under identical utility theoretic assumptions. This study shows that neither the hedonic nor the RUM models can be selected *a priori* simply because they are based on a better theoretical foundation. The hedonic and RUM models are consistent with the same utility framework. The two methods simply estimate parameters using different estimation procedures or assumptions. It is difficult to argue that either set of estimation assumptions is superior. They are simply alternative perspectives on the nature of choice and error.

The empirical comparison of linear and quadratic utility functions for both the HTC and RUM models indicates that practitioners need to be more careful before using linear utility functions for quality. The results from both techniques are heavily influenced by this assumption. Unless a practitioner has *a priori* evidence that the demand for a specific quality is perfectly price elastic, it is important to use quadratic utility functions.

Comparisons between RUM and HTC must assume consistent utility functional forms for both techniques. Comparing a linear RUM and a quadratic HTC is inappropriate. This paper provides the first theoretically consistent comparison of the two methods. Unfortunately, the evidence cannot discern which of the two methods does a better job of estimating the welfare impacts of environmental change. Conventional wisdom suggests that the hedonic methods are well-suited to choices where there are abundant alternatives whereas the random utility method lends itself to limited discrete choice sets. Our study shows only that the welfare estimates of the two methods differ greatly and that the source of these differences cannot be found in the utility-theoretic foundations of the models. Further research is needed to

determine when to expect one model to be superior to the other. In the meantime, both models should continue to be used in the difficult task of valuing site qualities..

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Table Ia: The Estimated Parameters of the HTC and RUM: Linear Utility

HTC Results		Constant	basal area	elevation.	riparian	isolation
$C(z) =$		66.2	0.199	5.81×10^{-3}	-1.96	-2.12
(t-statistics)		(3.90)	(1.57)	(3.27)	(-0.216)	(-6.04)
observations = 4778			corrected $r^2 = .0201$			
RUM Results		basal area	elevation	riparian	isolation	travel cost
$v(z, C) =$		2.57×10^{-2}	-4.99×10^{-5}	-0.513	0.103	-2.97×10^{-2}
(t-statistics)		(21.6)	(-25.6)	(-6.64)	(24.0)	(-46.0)
observations = 4778			percent sites correctly predicted	31.65		log likelihood = -13197

Table Ib: The Parameters of the Inverse Demand Functions: Uniform Linear Utility

HTC	$C_{\text{basal area}}$	$C_{\text{elevation}}$	C_{riparian}	$C_{\text{isolation}}$
	0.199	5.81×10^{-3}	-1.96	-2.12
RUM	0.866	-1.68×10^{-2}	-17.3	3.45

Table IIa: The Estimated Parameters of the HTC and RUM: Quadratic Utility
(t-statistics in parentheses)

HTC		basal area	elevation	riparian	isolation
constant		79.2 (215)	2990 (143)	0.284 (65.6)	5.73 (100)
$C_{\text{basal area}}$		-7.18 (-11.8)	22.8 (0.689)	0.502×10^{-1} (8.95)	0.652 (16.1)
$C_{\text{elevation}}$		22.8 (0.689)	-8610 (-3.12)	-0.154×10^{-1} (-0.049)	22.7 (8.56)
C_{riparian}		0.502×10^{-1} (8.95)	-0.154×10^{-1} (-0.049)	-0.434×10^{-3} (-5.13)	-0.911×10^{-3} (-1.83)
$C_{\text{isolation}}$		0.652 (16.1)	22.7 (8.56)	-0.911×10^{-3} (-1.83)	-0.43 (-60.8)
observations		4778			
corrected r^2		0.135	0.054	0.242	0.505
Wald Test on linear restrictions				264	
RUM		basal area	elevation	riparian	isolation
$v =$					
coefficient		0.567 (28.0)	2.43×10^{-3} (7.93)	42.0 (31.1)	1.62 (25.3)
		(basal area) ²	(elevation) ²	(riparian) ²	(isolation) ²
coefficient		-1.95×10^{-3} (-19.6)	2.08×10^{-7} (7.63)	-13.5 (-27.4)	1.69×10^{-2} (9.30)
		isol. *riparian	elev. *riparian	elevation *basal	basal area *riparian
Coefficient		-0.882 (-29.1)	-1.31×10^{-3} (-10.4)	-3.55×10^{-5} (-18.7)	-0.346 (-31.1)
				elevation *isol.	basal area *isol.
observations = 4778			percent sites correctly predicted		-1.34×10^{-2} (-23.2)
					31.94
					travel cost -2.94×10^{-2} (-43.5)

Table IIb: The Parameters of the Inverse Demand Functions: Quadratic Utility

constant		$C_{\text{basal area}}$	$C_{\text{elevation}}$	C_{riparian}	$C_{\text{isolation}}$
$\beta_{\text{basal area}}$	HTC	850	6.19	96700	1430
	RUM	19.3	8.26×10^{-2}	1430	55.0
$\beta_{\text{elevation}}$	HTC	-3.53	-2.39×10^{-2}	-399	-5.77
	RUM	-0.133	-1.21×10^{-3}	-11.8	-0.454
β_{riparian}	HTC	-2.39×10^{-2}	-2.96×10^{-4}	-2.68	-4.62×10^{-2}
	RUM	-1.21×10^{-3}	1.41×10^{-5}	-4.46×10^{-2}	-5.96×10^{-3}
$\beta_{\text{isolation}}$	HTC	-399	-2.68	-47500	-647
	RUM	-11.8	-4.46×10^{-2}	-920	-30.0
	HTC	-5.77	-4.62×10^{-2}	-647	-12.2
	RUM	-0.454	-5.96×10^{-3}	-30.0	1.15

Table III: Welfare Estimates for A Change in Each Attribute for All Trails (US\$/trip)						
	Linear Utility			10% Decrease in Each Trail Attribute		
	basal area	elevation	riparian	isolation	basal area	Quadratic Utility
RUM	-2.82	2.80	0.30	-0.77	2.72	isolation -0.16
HTC	-0.65	-0.97	0.03	0.47	-33.50	riparian 1.13 elevation 4.13 isolation -1.10

Table IV: Welfare Estimates for A Change in Each Attribute of One Trail (Pleasant Garden Overlook Trail, Unaka Wilderness Area, TN), (\$/trip)								
	Linear Utility			<i>Decrease in Each Trail Attribute of 10%</i>			Quadratic Utility	
	basal area	elevation	riparian	isolation	basal area	elevation	riparian	isolation
RUM	-0.07	0.08	-0.01	-0.02	-0.14	0.01	-0.01	0.07
HTC	-0.01	-0.01	-0.00	-0.00	-3.69	-0.95	-2.20	-0.36

Appendix A
Summary Statistics

Attribute	Description	Sample Mean (standard deviation)
Basal area	Square feet of trees/acre	65.1 (21.0)
Riparian	% of trail along riparian	34.4 (34.0)
Elevation	Maximum elevation of trail	3330 (1090)
Isolation	Miles from paved road to trailhead	4.45 (4.65)

List of Symbols

ϕ	phi, script in equations 1, 4, 5, 6, and in the text of section 1.1
$\boldsymbol{\phi}$	vector (bold) in rest of text
ε	epsilon, script
f	probability distribution
F	cumulative distribution
∞	infinity, script
λ	lambda, script
α	alpha, script
ψ	psi, script

Footnotes:

¹ In this section, we assume that the true functional form of the hedonic price function is known. We address questions of estimation in later sections.

² If we are dealing with n attributes per bundle, the calculation requires a line integral.