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Time, Weak Complementarity, and Nonuse Value

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Time, Weak Complementarity, and Nonuse Value

Introduction

Nonuse value has a long, interesting, and controversial history in environmental economics. Originally articulated by John Krutilla as a willingness to pay for preserving natural environments, it has been at the heart of debates about how to measure the value of nonmarketed amenities. In principle, the idea is simple enough: those who do not "use" a natural resource facility directly may nonetheless derive satisfaction from knowing of its existence and continued availability for members of society to enjoy. This, presumably, would be evidenced by a willingness to pay for preservation and protection of the resource.

It is in the measurement of nonuse value that controversy has ensued. A willingness to pay by *non*users of a natural resource facility must be very hard to detect from changes in market-related purchases, the usual yardstick by which economists measure value. Karl Goran-Mäler articulated the problem well with his analysis of weak complementarity between an exogenously-provided public good and a set of private market goods puchased by a consumer.[1] He decomposed the compensating variation measure of willingness to pay for a change in the public good into two parts, a change in the areas under the (Hicksian) demands for the weak complements (use value) and a change in expenditure when none of the weak complements are being consumed.

This latter change in willingness to pay has come to be known as nonuse, or passive use (Kenneth Arrow *et al.*) value. It is a change in willingness to pay for the public good that completely escapes detection by studying purchases of related private market goods. Mäler also showed that if a restriction on preferences, weak complementarity, holds, then nonuse value is zero, in which case the entire willingness to pay for the public good *can* be measured by studying market goods purchases. Under weak complementarity, a person not consuming the related private market goods experiences no change in value when the public good changes.

However, if weak complementarity does not hold, then an unknowable part of the value of a public good (i.e., nonuse value) is simply not measured by the revealed preference approach. Fundamentally, this means that revealed preference method measures only use value, not nonuse value.

The total value of a public good change can, in concept, be measured by stated preference approaches such as the contingent valuation method (CVM), conjoint analysis, or choice experiments. Originally popularized by Alan Randall and colleagues, stated preference approaches have been given a firm foundation in economic theory by Robert Mitchell and Richard Carson, among others. In principle, this approach can measure the full willingness to pay for a change in public goods, since it does not focus solely on market behavior. However, use of the CVM and other stated preference approaches have met with significant resistance in the economics profession at large (e.g., Peter Diamond and Jerry Hausman; Daniel McFadden) for a variety of reasons, perhaps most notably the fact that they are hypothetical.[2]

This has resulted in a rather unsatisfactory state of affairs for the determination of public goods values. The (revealed preference) approach preferred by most economists for determining the values peoples place on goods is incomplete, while the approach fully capable in principle of measuring public goods values is suspected of being biased in important public policy cases.

The purpose of this paper is to explore how recent developments in models of how people allocate their *time* as well as their money might provide a resolution to this problem. We now have both a better accounting for how people spend their time, and of models that describe peoples' actions when constrained both by time and by money. In light of this, it is appropriate to re-examine the use of the weak complementarity assumption in valuing nonmarket goods. In particular, it will be argued that weak complementarity is the appropriate, indeed the *only* appropriate, assumption when peoples' use of time is properly accounted for.

This has several saluatory effects. First, it resolves the ambiguity about preferences recovered from behavior (i.e., demand functions) because it uniquely identifies a single-quasi-preference function corresponding to any specific demand system.[5] Second, it puts nonuse value and use value on commensurate terms. Basically, it says that there is no value without behavior, i.e., without some change in a person's actions (use of time, spending of money) when environmental quality changes. This links the concept of nonuse value to an action that, in principle, can be measured and quantified. Finally, it offers the prospect that carefully-framed revealed preference and stated preference studies can measure *the same thing* (total value), not different things. This could accelerate the trend toward use of both RP and SP data collection on valuation problems, because they can be used and combined as complements in nonmarket value measurement.

These ideas are explored in a simple framework of choice subject to money and time constraints. The next section articulates the choice model and develops the analysis graphically, to fix ideas about what is to be measured, and how. The following section uses a common and convenient model of preferences, the linear expenditure system, that satisfies weak complementarity under time and money constraints. This allows one to obtain explicit expressions for both use value and nonuse value when environmental quality changes, and both are identifiable through activity demands. The final section concludes by noting some limitations of the present framework and suggesting areas for further work.

Quality Change with Time- and Money-Constrained Choice: A Graphical Analysis

A fuller accounting for peoples' actions as they change when public goods of value to them change is becoming possible (though not necessarily here yet). On the one hand, a number of large time use studies in the United States and elsewhere (e.g., Robinson; Algers, Dillen, and Widlert; Ramjerdi, Rand, and Sælensminde) are providing unprecedented information on what people do with their time. On the other hand, we know more about how to develop models of how people *value* time that are consistent with utility-theoretic models of choice.[4]

To motivate a simple model of choice subject to time and money constraints that brings out the basic issues in measuring use and nonuse value, let the consumer's utility function be $U(\mathbf{x},q,\mathbf{s})$. The vector $\mathbf{x} = [x_1,...,x_4]$ is the set of activities the consumer chooses, q is an environmental quality variable valued by the consumer but chosen exogenously to him, and $\mathbf{s}$ is a vector describing his characteristics. Each activity, generally, has a money price and a time price; that is, consumption of the activity costs some money and takes some time. Activities needn't have both a money price and a time price;[5] in fact, many of the activities we enjoy most do not cost money, such as taking a walk or sleeping. For our purposes, x_1 will be a good with a money price p_1 and no time price ($t_1 = 0$); x_2 is a good with a time price t_2 and no money price ($p_2 = 0$); and x_3 and x_4 are numeraire goods in the money and time constraints, respectively, so that $p_3 = 1$, $t_3 = 0$, $p_4 = 0$, and $t_4 = 1$.

With these goods, the budget constraints facing the consumer are

$$M = p_1 \cdot x_1 + x_3 \tag{1}$$

and

$$T = t_2 \cdot x_2 + x_4, \tag{2}$$

for money and time, respectively. The constrained optimization problem is given by the Lagrangian

$$\mathcal{L} = \max_{\mathbf{x}} \mathrm{U}(\mathbf{x},\mathrm{q},\mathbf{s}) + \lambda(\mathrm{M} - \mathrm{p}_1 \cdot \mathrm{x}_1 - \mathrm{x}_3] + \mu[\mathrm{T} - \mathrm{t}_2 \cdot \mathrm{x}_2 - \mathrm{x}_4], \tag{3}$$

where μ and λ are the marginal utilities of time and money, respectively, and their ratio, $\rho \equiv \mu/\lambda$, is the consumer's marginal value of time. It serves as the opportunity cost of time for specfic activity choice, since time not spent in the activity would have this monetary value. The structure of this problem in the recretation context has been analyzed by Bockstael, Hanemann, and Strand, and more recently by Larson and Shaikh (2001). The latter paper showed that Marshallian demands of the "full price, full budget form" $\mathbf{x}(\mathbf{p} + \rho \cdot \mathbf{t},\mathrm{M} + \rho \cdot \mathrm{T},\mathrm{q},\mathbf{c})$ satisfy the maintained hypothesis that both constraints are continuously binding (i.e., that time has a strictly positive value). Given the price vectors $\mathbf{p} = [\mathrm{p}_1,0,1,0]$ and $\mathbf{t} = [0,\mathrm{t}_2,0,1]$ in our analysis, the Marshallian demands of interest that solve this problem are $\mathrm{x}_1(\mathrm{p}_1, \rho \cdot \mathrm{t}_2,\mathrm{M} + \rho \cdot \mathrm{T},\mathrm{q},\mathbf{c})$ and $\mathrm{x}_2(\mathrm{p}_1, \rho \cdot \mathrm{t}_2,\mathrm{M} + \rho \cdot \mathrm{T},\mathrm{q},\mathbf{c})$.[6]

The Marshallian good x_1 is like the goods analyzed in the standard money-constrained consumer choice problem, since it has a money price but takes no time in consumption. Good x_2, however, is the opposite: it requires no money in consumption, so it essentially is a time use. This is the type of activity that would be ignored by the standard, single-constraint analysis of the value of environmental quality change, which is what the problem in (3) reduces to if the researcher assumes that time does not play a role in choice and that, therefore, $\mu = 0$. For our purposes, x_2 might be volunteering, engaging in activism, consuming print or TV news, or simply worrying. To the extent that x_2 changes when q changes, a willingness to pay money (wtp) will arise. This wtp would be treated as nonuse value in the standard analysis, since it is a wtp that remains even when consumption of the market good x_1 is zero.

The situation is illustrated in Figure 1. Here the utility-constant (Hicksian) versions of the activity demands x_1 and x_2 are presented.[7] Baseline prices are p_1^0 and t_2^0, and both panels have quantity axes measured in units of the activity and price axes measured in dollars.[8] The left panel is what would be picked up in the standard money-constrained analysis, and panel 2 depicts what would be missed. The measurement of use value, following Mäler's 3-step logic,[9] results in measurement of area a.

While q changes and x_1 is not consumed during the second step of Mäler's analysis, a shift in x_2 also occurs, and is illustrated in panel (ii). If x_2 and q are complements, the change in q will also shift the demand for x_2, from $x_2(\pi_1^0, \rho \cdot t_2, q_0, u)$ to $x_2(\pi_1^1, \rho \cdot t_2, q_1, u)$.[10] The partial net value traced out by this shift, area b, is a wtp missed in the standard analysis.[11] It shows up in the standard analysis as a violation of weak complementarity of x_1 with q, since $\partial x_1(\pi_1(q,u), \rho \cdot t_2^0, q, u)/\partial q \neq 0$.

If, in addition, x_1 and x_2 are *jointly* weakly complementary to quality (Bockstael and Kling)[12], areas a and b represent the total value of the quality change. Area a would be identified as use value under the standard analysis [which would not include panel (ii)]; area b would be identified as nonuse value, and would show up as a wtp that could be measured by SP methods only.

In the expanded analysis that includes uses of time, both a and b are areas that represent shifts of activity demands. Thus they are both measurable by demand (RP) analysis. While their sum (a + b) could be termed use value, we will continue the current naming conventions and call "a" use value and "b" nonuse value. Given the joint weak complementarity of x_1 and x_2 with quality, a + b is the total value of the quality change.

Table 1 compares the measurement of the value of a quality change from q_0 to q_1 using the Standard versus the Expanded analyses. The difference is that with a more detailed accounting of activities that may signal value when quality changes, all value is found as areas under activity demands. This puts SP and RP methods on an equal footing with respect to measuring value: both methods can, in principle, measure the total value of a quality change.

This is not a panacea, by any means: the activity demand system must be correctly specified for the resulting value estimates to be accurate.[13] Nor is it simply a redefinition of terms to assume nonuse value away. Instead, it is a reflection of what nonuse in the standard value must be: changes in peoples' uses of time when an important environmental quality change occurs, above and beyond any changes that occur in market purchases. Once these activities are brought into the analytical framework, their demands can be estimated and nonuse value is capable of measurement using revealed preference methods. The reason is the joint weak complementarity restriction, which is a sensible, and arguably the only appropriate, assumption to make about the preferences underlying the behavior observed when both time uses and market purchases are accounted for.

Joint Weak Complementarity in Models of Time and Money Allocation

Weak complementarity was originally devised by Mäler as a means to judge what one misses, as well as what one obtains, by identifying nonmarket values for quality changes as areas under demand curves. In the standard money-constrained analysis, the idea that weak complementarity holds only as a special case is well-rooted in empirical practice. Its use is an assertion by researchers that the resource being valued (i.e., whose quality changes) appeals only to those who use it, and that the welfare of nonusers is unaffected. Thus it is usually judged most appropriate for local resources with plentiful substitutes and limited markets. In contrast, resources with international appeal and unique features (a Lake Tahoe, Mount Rushmore, or Prince William Sound, for example) are much more likely to be valued by nonusers (e.g., nonvisitors), who would be affected if the quality of these resources deteriorated. Such value by nonusers would clearly be missed by an analysis that focused only on the consumer's money expenditures, such as expenses for trips to the area in question (even if the time involved in those trips were accounted for). Thus the idea that weak complementarity *does not* hold for some important resources is eminently sensible, within the limited reach of the standard analysis.

Consider now the implications of weak complementarity, and in particular its *failure* to hold, in a consumer choice model that accounts for both money expenditure and time uses. Assume for the moment that this accounting is complete and accurate—i.e., the model is correctly specified. If, in such a model, joint weak complementarity between the activities in the model and quality *did not* hold, this would be saying that as quality changes, the consumer is affected even though she changes no activity, no monetary purchase nor any way in which she spends her time. Such a possibility strains credulity: how can value change in the complete absence of behavior? It seems there is no other answer than "it cannot." If this were possible, the link between preferences and value which runs throughout all economic analysis would be rather strongly undermined, to say the least.

It is one thing to recognize, rightly, that incomplete accounting for actions may give rise to value that is not captured by the incomplete framework, as nonuse value can be interpreted to be within the standard analysis. But it is quite another thing to argue that even when all uses of time (including money expenditures that derive from time spent in labor, for most people) connected to environmental quality are correctly accounted for, that value can exist apart from, and unrelated to, those actions.

It is very reasonable to rule out this possibility. Thus it is appropriate to assert that

Joint Weak Complementarity is an integral part of correctly-specified models of money expenditure, time use, and environmental quality change

And what if the model were incorrectly specified? In particular, what if an important time use related to environmental quality were omitted from the activity demand system? This seems a likely possibility in many situations involving nonusers. How does one measure time use changes for households in Michigan when an oil spill occurs in Prince William Sound? It seems all too likely that measurement errors and omissions could occur in setting up an activity demand system to measure household time use changes by nonusers that are attributable to environmental quality changes.

In these cases, one would not expect the results of SP wtp analysis and RP demand analysis to give the same results. But this is a useful diagnostic: until all the value obtained in an SP analysis can be explained by areas under activity demands, the model of preferences is under-specified. Until such point that a correct specification is arrived at, hypothesis tests for significant differences between SP and RP would be rejected.

So a comprehensive, integrated framework of value deriving from preferences that can be measured with multiple analytical techniques can serve a couple of useful purposes. It can serve as a guide for the use and evaluation of the different SP and RP analytical methods within a coherent underlying model of preferences. Such combined analyses are conducted fairly routinely today, within the standard money-constrained framework. Clearly one requirement for this, under both the standard and expanded framework, is that the functional forms for RP data (typically a compensating variation or other wtp measure) be compatible with the functional forms for SP data (typically demands). However, the expanded framework also provides an explanation for why systematic differences between SP and RP occur, and offers guidance about how to reduce or eliminate those differences: by increasing the number of activities, particularly those related to uses of time, in the activity demand system.

Since functional forms, and their compatibility, are an important issue for empirical work, the next section explores the use of joint weak complementarity within a model of time- and money-constrained choices and preferences from the Linear Expenditure System (LES) model. Formulas are derived for use value, nonuse value, and the total value of an environmental amenity change within this model.

Joint Weak Complementarity and Amenity Values in the Linear Expenditure System

What do expressions for use value and nonuse value look like using the expanded framework for analysis? To obtain these, the money expenditure function is needed, both when x_1 and x_2 are being consumed (for total value), and when just x_2 is being consumed (for nonuse value). The difference between the two is use value.

In the LES model, the jointly weakly complementary direct utility function from equation (3) is

$$U(x,q) = b_1(q) \cdot \ln(x_1 + 1) + b_2(q) \cdot \ln(x_2 + 1) + b_3 \cdot \ln(x_3 - c_3) + b_4 \cdot \ln(x_4 - c_4), \qquad (4)$$

where $b_i(q)$, $i = 1,2$ are functions of quality, and b_i, $i = 3,4$, are parameters.[14] The quantities c_i, $i = 1,...4$, are subsistence parameters, and $c_1 = c_2 = -1$. Setting $c_1 = c_2 = -1$ for the principal goods of interest, x_1 and x_2, makes them jointly weakly complementary with q. This can be seen by noting that when both are zero,

$$U(0,0,x_3,x_4,q) = b_3 \cdot \ln(x_3 - c_3) + b_4 \cdot \ln(x_4 - c_4)$$

and

$$\left.\frac{\partial U(x,q)}{\partial q}\right|_{\substack{x_1=0,\\ x_2=0}} = 0. \qquad (5)$$

which is the definition of weak complementarity of a set of goods with a quality characteristic. However, neither x_1 nor x_2 individually are weakly complementary with quality, since

$$U(0,x_2,x_3,x_4,q) = b_2(q) \cdot \ln(x_2 + 1) + b_3 \cdot \ln(x_3 - c_3) + b_4 \cdot \ln(x_4 - c_4)$$

$$U(x_1,0,x_3,x_4,q) = b_1(q) \cdot \ln(x_1 + 1) + b_3 \cdot \ln(x_3 - c_3) + b_4 \cdot \ln(x_4 - c_4)$$

and

$$\left.\frac{\partial U(\mathbf{x},q)}{\partial q}\right|_{\substack{x_1=0,\\ x_2\neq 0}} \neq 0, \; \left.\frac{\partial U(\mathbf{x},q)}{\partial q}\right|_{\substack{x_1\neq 0,\\ x_2=0}} \neq 0. \tag{6}$$

Equations (5) and (6) are the conditions required for joint weak complementarity with two goods.

Given the money and time constraints from (1) and (2), the Lagrangian for the consumer choice problem is

$$\mathcal{L} \equiv U(\mathbf{x},q) + \lambda[M - p_1x_1 - x_3] + \mu[T - t_2x_2 - x_4]$$

and using the LES direct utility function of (4), the first order conditions for optimal choice of $x_1 - x_4$ are

$$x_1: \quad \frac{b_1(q)}{x_1+1} = \lambda p_1 \tag{7}$$

$$x_2: \quad \frac{b_2(q)}{x_2+1} = \mu t_2 \tag{8}$$

$$x_3: \quad \frac{b_3}{x_3-c_3} = \lambda \tag{9}$$

$$x_4: \quad \frac{b_4}{x_4-c_4} = \mu. \tag{10}$$

Solving (7) for $p_1x_1 = b_1/\lambda - p_1$ and (9) for $x_3 = b_3/\lambda + c_3$ and adding the two[15],

$$p_1x_1 + x_3 = (b_1 + b_3)/\lambda - p_1 + c_3 = M, \tag{11}$$

from (1). The last two terms of equation (11) can be solved for the marginal utility of money, λ, as

$$\lambda = \frac{b_1+b_3}{M+p_1-c_3}. \tag{12}$$

Similarly, solving (8) for $t_2x_2 = b_2/\mu - t_2$ and (10) for $x_4 = b_4/\mu + c_4$ and adding these two,

$$t_2x_2 + x_4 = (b_2 + b_4)/\mu - t_2 + c_4 = T, \tag{13}$$

from (2). The last two terms of equation (13) can be solved for the marginal utility of time, μ, as

$$\mu = \frac{b_2+b_4}{T+t_2-c_4}, \tag{14}$$

and the Marshallian marginal value of time in this model,[16] $\rho \equiv \mu/\lambda$, can be determined from (12) and (14) as

$$\rho(\mathbf{p},\mathbf{t},q,M,T) = \frac{b_2(q)+b_4}{b_1(q)+b_3} \cdot \frac{M+p_1-c_3}{T+t_2-c_4}.$$

Using equations (7) and (12), the Marshallian demand for activity 1 can be obtained as

$$x_1 = \frac{b_1}{b_1+b_3} \cdot \frac{M+p_1-c_3}{p_1} - 1.$$

Similarly, using (8)-(10) and (12)-(13), the Marshallian demand for the time use x_2 is

$$x_2 = \frac{b_2}{b_2+b_4} \cdot \frac{T+t_2-c_4}{t_2} - 1$$

while the demands for the numeraire goods are

$$x_3 = \frac{b_3}{b_1+b_3} \cdot (M + p_1 - c_3) + c_3$$

and

$$x_4 = \frac{b_4}{b_2+b_4} \cdot (T + t_2 - c_4) + c_4.$$

These can be written more simply by noting that discretionary budgets after purchasing subsistence consumption are $M^* \equiv M + p_1 - c_3$ and $T^* \equiv T + t_2 - c_4$. Also, define $f_1 \equiv \frac{b_1}{b_1+b_3}$ and $f_3 \equiv \frac{b_3}{b_1+b_3}$ as fractions or weights that describe how the discretionary money budget is spent between goods; similarly, define as well as $f_2 \equiv \frac{b_2}{b_2+b_4}$ and $f_4 \equiv \frac{b_4}{b_2+b_4}$ for the discretionary time budget. With these simplifications to the notation, the Marshallian demands are

$$x_1 = f_1 \cdot \frac{M^*}{p_1} - 1. \qquad (15)$$

$$x_2 = f_2 \cdot \frac{T^*}{t_2} - 1 \qquad (16)$$

$$x_3 = f_3 \cdot M^* + c_3 \qquad (17)$$

and $$x_4 = f_4 \cdot T^* + c_4. \qquad (18)$$

Note that since the f_i vary with quality, so too do all four Marshallian demands. This makes sense, as it maintains binding budget constraints when the quantities of the activities directly affected by quality (x_1 and x_2) change.

The welfare measures of interest are defined as changes in willingness to pay money when environmental quality changes; this change is represented by a change from initial quality level q^0 to the subsequent level q^1. To obtain the money expenditure function, the Marshallian demands in (15)-(18) are substituted into the direct utility function (4), obtaining the indirect utility function; this is then inverted with respect to the money budget argument to obtain the money expenditure function (Larson and Shaikh 2004).

Substituting the Marshallian demands into the direct utility function (4), the indirect utility function is

$$\begin{aligned} \mathrm{V}(\mathbf{p},\mathbf{t},\mathrm{q},\mathrm{M},\mathrm{T}) = \sum_{i=1}^{4} \mathrm{b}_i \ln(f_i) - b_1 \ln(\mathrm{p}_1) - b_2 \ln(\mathrm{t}_2) + (b_1 + \mathrm{b}_3) \cdot \ln(\mathrm{M}^*) \\ + (b_2 + \mathrm{b}_4) \cdot \ln(\mathrm{T}^*). \end{aligned} \tag{19}$$

Inverting (19) with respect to money income M, the log-money expenditure function is

$$\ln(e^*) = [u - \sum_{i=1}^{4} \mathrm{b}_i \ln(f_i) + b_1 \ln(\mathrm{p}_1) + b_2 \ln(\mathrm{t}_2) + (b_2 + \mathrm{b}_4) \cdot \ln(\mathrm{T}^*)]/(b_1 + \mathrm{b}_3),$$

where $e^* \equiv e(\mathbf{p},\mathbf{t},\mathrm{q},\mathrm{T},\mathrm{u}) - \mathrm{c}_3 + \mathrm{p}_1$. (The log-expenditure function proves a little easier to work with in deriving the algebra for the model.)

To make this operational for empirical work, the utility index u must be initialized. This can be obtained from (19) for initial quality level q^0, where the quality functions are $b_i^0 \equiv b_i(\mathrm{q}^0)$, for $\mathrm{i} = 1,2$. Substituting the initialized level of utility obtained in this way into (20), the empirical log-money expenditure function is

$$\ln(e^*) = [\sum_{i=1}^{4} \mathrm{b}_i^0 \ln(f_i^0) - \sum_{i=1}^{4} \mathrm{b}_i \ln(f_i) + \triangle b_1 \ln(\mathrm{p}_1) + \triangle b_2 \ln(\mathrm{t}_2/\mathrm{T}^*)$$

$$+ (b_1^0 + b_3) \cdot \ln(M^*)]/(b_1 + b_3). \tag{20}$$

where $\triangle b_i \equiv b_i^1 - b_i^0$, i = 1,2, is the change in the quality parameters induced by the change in quality $q^1 - q^0$. The last step is to recognize that the total value of the quality change is simply

$$TV = M^* - e^* = M^* \cdot (1 - e^*/M^*)$$

$$= M^* \cdot (1 - \exp[\ln(e^*) - \ln(M^*)]) \tag{21}$$

Using (20) in (21), the expression for total value of the quality change from q^0 to q^1 is

$$TV = M^* \cdot \left[1 - \left(\frac{\prod_{i=1}^{4} f_i^{0\,b_i^0}}{\prod_{i=1}^{4} f_i^{b_i}} \cdot \left(\frac{p_1}{M^*}\right)^{\triangle b_1} \cdot \left(\frac{t_2}{T^*}\right)^{\triangle b_2}\right)^{\frac{1}{b_1+b_3}}\right] \tag{22}$$

Use and Nonuse Value in the LES Expanded Analysis

To evaluate "nonuse" value, we need the utility function when x_1 is not being consumed, which is

$$U_{-1}(\mathbf{x},q) = b_2(q) \cdot \ln(x_2 + 1) + b_3 \cdot \ln(x_3 - c_3) + b_4 \cdot \ln(x_4 - c_4), \tag{4'}$$

Performing the same steps as above to obtain the indirect utility given x_1 not consumed, one obtains

$$V_{-1}(\mathbf{p},\mathbf{t},q,M,T) = b_2 \cdot \ln(f_2) + b_4 \cdot \ln(f_4) + b_3 \cdot \ln(M^{**}) + b_2 \cdot \ln(T^*/t_2)$$

$$+ \mathrm{b}_4 \cdot \ln(\mathrm{T}^*). \tag{19$'$}$$

where $\mathrm{M}^{**} \equiv \mathrm{M} - \mathrm{c}_3$ and T^* is as defined before. Inverting this to obtain the log-money expenditure function, as before, and initializing the utility index gives the empirical log-expenditure function given that x_1 is not consumed:

$$\ln(e^{**}_{-1}) = \Big[b_2^0 \cdot \ln(f_2^0) - b_2 \cdot \ln(f_2) + \mathrm{b}_4 \cdot [\ln(f_4^0) - \ln(f_4)] + \triangle b_2 \ln(\mathrm{t}_2/\mathrm{T}^*)\Big]/\mathrm{b}_3$$

$$+ \ln(\mathrm{M}^{**}), \tag{20$'$}$$

where $e^{**}_{-1} \equiv e(\mathbf{p},\mathbf{t},\mathrm{q},\mathrm{T},\mathrm{u}) - \mathrm{c}_3$, analogously to M^{**}. Since x_1 is not consumed, the change in log-expenditure with quality is the area under the Hicksian demand for x_2, so that, as in (21),

$$\mathrm{NUV} = \mathrm{M}^{**} \cdot (1 - \exp[\ln(e^{**}) - \ln(\mathrm{M}^{**})])$$

$$= \mathrm{M}^{**} \cdot \left[1 - \left(\frac{f_2^{0^{b_2^0}}}{f_2^{f_2}} \cdot \left(\frac{f_4^0}{f_4}\right)^{\mathrm{b}_4} \cdot \left(\frac{\mathrm{t}_2}{\mathrm{T}^*}\right)^{\triangle b_2}\right)^{\frac{1}{\mathrm{b}_3}}\right] \tag{22$'$}$$

Use value can be obtained as the difference between the total value in (22) and the nonuse value in (22′).

There are a couple of important purposes behind the nonuse value expression in (22′). First, it provides an explicit formula for nonuse value corresponding to a particular maintained hypothesis about the form of consumer preferences, which can be used with SP data to provide an estimate of nonuse value. Most work that estimates nonuse value from SP data does not maintain this tie between what is estimated and the underlying preferences. The other important thing about (22′) is that its parameters can be estimated from the demand for a time use (jointly with market purchases and other behavior). As such, it is a revealed preference estimate, since data on the quantity of time spent in different activities can be collected (and is, in time use surveys), along with time prices[17] for the activities, in recreation surveys. Thus there are two avenues for estimating nonuse value in the expanded framework of consumer choice, which should permit better estimates and more flexibility in obtaining those estimates.

Concluding Remarks

This paper argues that an expanded view of consumer choice, with a fuller consideration of the use of time, helps resolve differences in the conceptual basis for measuring use and nonuse value from SP and RP methods. The reason is that in a fuller accounting of the consumer's actions that includes how they spend their time, and how that time spent changes with environmental quality, the assumption of joint weak complementarity is an appropriate, indeed a necessary, part of the description of preferences. This restriction helps fully identify the quasi-preferences underlying observed choices and behavior, and means that what is now termed nonuse value can be thought of as changes in consumer's surplus from uses of time. With preferences that satisfy joint weak complementarity, there is no value remaining when none of the weak complements are consumed, meaning that the total value of an environmental quality change can be measured as changes in areas behind demands for market goods and for uses of time. This expanded view of consumer choice involving the environment offers two strategies for identifying nonuse value, the usual stated preference approach and a revealed preference approach.

Clearly there are important issues and problems involved in specifying which sets of activities comprise the weak complements to quality. But when preferences are identified using both SP and RP data, any systematic differences in the nonuse value estimates from the two types of data can be interpreted as a specification error that can be reduced by expanding the set of weakly complementary activities. The reason is that the two types of data should produce the same nonuse value estimate with a correctly specified model in the expanded framework. In other words, SP and RP data should measure the same thing in the expanded framework, whereas in the standard money-constrained choice model they measure different things.

Additionally, there are currently limitations in the data available to implement the expanded model of consumer choice, and little current guidance in the literature about specification and estimation of systems of time use and market goods demands. But the basic tools are in place, from an increased understanding of how to estimate shadow prices of time to routine data collection (e.g., in time use surveys) on how people spend their time. What is needed, in part, is collection of auxiliary information on time uses as part of recreation and other nonmarket valuation surveys, in order to develop more empirical experience with the expanded consumer choice framework.

The model used to develop the basic insights of this paper is a simple one, with each good having either a time price or a money price, but not both. Clearly many activities have both, and a useful next step is to characterize nonuse value in the expanded consumer choice model for these types of goods.

Footnotes

1. The prototypical example of this complementarity is between water quality at a lake, and the private goods required to travel to it. Not consuming the related private goods means the person is not a "user" of the lake (i.e., does not travel to experience directly its services).
2. The drawback in empirical practice is that, at root, the scenarios evaluated by respondents are hypothetical, which may lead to systematic divergences between what people state and what they actually do (e.g., Ronald Cummings *et al.* JPE; Cummings, Harrison, and Rütstrom AER). For a more optimistic view about how to reduce the hypothetical bias in stated preference methods, see Cummings and Laura Taylor.
3. Since nonuse value is expected to be an *additional* source of value beyond use value, something else must be at work. The difference in value estimates may also reflect any of a number of empirical biases in implementing one or the other method empirically, and seemingly the net effect of these biases dominates the nonuse value (since the sign of the value difference is opposite of what one would expect).
4. A fairly large stock of value of time estimates has accumulated over the 40 years since the influential papers by Becker and DeSerpa. One major area of emphasis empirically is the value of travel time, both in the transportation literature (e.g., Truong and Hensher, Algers, Dillen, and Widlert;) and the recreation demand literature (Cesario; Smith, Desvousges, and McGivney; McConnell and Strand; Bockstael, Hanemann and Strand; Feather and Shaw; Larson and Shaikh 2004).
5. Each good must have either a time price or a money price, though, to conform to the assumption that all valued activities are costly.
6. The numeraire goods x_3 and $x_4$determined by x_1, x_2, and their respective budget constraints.
7. These are obtained from the money expenditure minimization problem dual to (1), which is not shown for brevity.
8. For activity 2, the marginal dollar value of time, ρ, converts the time price t_2 into dollars.
9. This involves first raising price to the choke level π_1^0 that sets x_1 to zero; then raising quality from q_0 to q_1 while simultaneously raising price to π_1^1, maintaining $x_1 \equiv 0$ throughout; and finally reducing price to its original level p_1^0.
10. If x_2 and q are substitutes, the shift in x_2 will be inward rather than outward.

11. Unlike the case of price changes, areas a and b are not alternative representations of the same wtp. Each is an effect of the quality change on a separate activity, and the sum of all such changes in areas under activity demands must be summed to obtain the full wtp for the (or other non-price parameter) change.
12. Joint weak complementarity of x_1 and x_2 with q means that when *neither* are consumed, there is no change in wtp when q changes.
13. Of course, correct specification is required for any economic model to be valid, not just nonmarket valuation models.
14. The vector of individual characteristics **s** does not play a central role here, so is suppressed in the notation for simplicity.
15. To reduce the volume of notation, the dependence of the b_i on q is suppressed except where needed for clarity.
16. This is one of three values of time in the two-constraint choice model, and is the one estimated in practice as it depends only on observable variables, not on unobservable utility like its two Hicksian counterparts (Larson and Shaikh 2004).
17. Time prices are the amount of time required for the activity. In many cases, for activities naturally denominated in hours, they are 1 (an hour of the activity requires an hour of time), though they can be greater than 1 in some cases. Other activities, such as travel from home to recreation destinations, are denominated in units other than hours (e.g., trips) and have time prices that reflect the time required in travel.

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***Table 1. A Comparison of Value Measurements Using the Standard and Expanded* Analyses of Consumer Activities**

Type of Value	Standard Analysis	Expanded Analysis
Total value	a+b	a+b
(Measured by)	*(RP only)*	*(SP and RP)*
Use value	a	a
(Measured by)	*(SP and RP)*	*(SP and RP)*
Nonuse value	b	b
(Measured by)	*(SP only)*	*(SP and RP)*

Figure 1. Effects of a Quality Change on a Money purchase and a Use of Time