

Differing values of time for non-market valuation:
A theoretical and empirical comparison*

by

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1. Introduction

Time may well be the ultimate scarce resource. As a result, choices about time allocation are especially important in signaling consumer preferences. They are also made continually and at numerous margins and timeframes over the course of a lifetime or throughout a single day. Many of these decisions have long-term consequences, such as labor market choices, retirement planning, and health-related resource allocations. Others are more mundane and include a multitude of everyday activities, such as running errands or taking a walk in a park. Over the past ten years there has been increasing recognition of the importance of time valuation to the measurement of the economic contribution of non-market activities in a revised set of national income and product accounts (see CBASSE [2000] and Landefeld and McCulla [2000]). Time valuation has also played an important role in the evaluation of the benefits derived from many public policies, including transportation programs and many environmental policies.

In environmental economics the methods used to value time generally rely on established labor market theories relating the value to labor market choices. These results are assumed to apply equally well to locational choices (Blomquist, et al. [1989]) and in the analysis of less consequential decisions, such as allocating time for a short recreation trip. While it stands to reason that these types of choices involve substantially different decision margins, little conceptual or empirical research exists that differentiates the two timeframes and analyzes the consequences for the shadow value of time. This paper explores a theoretical model that explicitly distinguishes the choice margins that reveal information about time tradeoffs. We propose and illustrate a new strategy for combining stated and

revealed preferences data to measure how the value of time for short term decisions can be different from the shadow values implicit in long term labor market choices.

Because of its importance in applied economics, including recreation demand, the value of time has received considerable attention over the years. Most existing work has concentrated on determining *the* value of time for an individual. In this paper we approach the topic from a somewhat different perspective. Our starting point is the observation that time is unlike many other resource endowments because the way total time is divided affects how it can be used. For example, one four-hour period of time conveys different consumption possibilities than four one-hour periods. This notion of the imperfect divisibility of time, particularly over a short planning horizon, is central to our analysis. More specifically, we highlight the fact that free time is usually available in non-contiguous blocks of time, and it is not possible to move time freely between blocks. There are a variety of activities that we do in these non-work blocks of time. Some can be easily reallocated between time periods, others can be partially shifted at a cost, and, finally, some cannot be moved between periods. Recreation is an activity that falls in the latter category for at least two reasons. The travel costs with outdoor recreation introduce indivisibility in time allocations. That is, it would be costly to replace a day-long recreation trip to a site with several shorter trips to the same site, even if the total time was the same. Moreover, the experience involved is different and the resulting satisfaction provided by the longer trip may be greater.

Finding a block of time for recreation in one period will require (potentially costly) shifting of competing activities to other periods. Some of these activities may be necessary but not especially enjoyable, such as cleaning the house or tending the yard. If there is diminishing marginal productivity of time in these alternative activities in a given period of

time, completing household tasks in one period in order to free another period for recreation implies that, as a greater amount of time is shifted, there is an increasing marginal opportunity cost of time for use in recreation.

In this paper we test the hypothesis that different sized blocks of recreation time have different marginal opportunity costs for the same person. To frame the problem we propose a conceptual model that explicitly accounts for the imperfect divisibility of time. With this structure we identify three different choice margins for time allocation and use them in a two-step estimation strategy that quantifies the degree to which time is costly to shift between periods. Our estimates allow the shadow values of different sized blocks of recreation time to be developed. We demonstrate our technique with an application using new data collected on a sample of homeowners in Wake County, North Carolina. We find that the marginal value of time can increase by several percentage points for each additional hour included in the time block.

Section two provides a short overview of previous research highlighting how the definition of choice margins and the contributions of time to well-being have influenced the logic used in each approach to measure the value of time. Section three outlines our model with four describing how it is implemented. Section five describes the survey we undertook to collect the data for the model, as part of a larger project. In section six we discuss our findings and the last section describes more general implications of the issues posed by our model.

2. Previous research

Applied economic research has questioned the use of the wage rate as the relevant opportunity cost of time for nearly forty years (see Becker [1965], Johnson [1966] as

examples). Nonetheless, we seem to be far from a consensus view on a workable method for estimating how individual circumstances and different types of decisions influence the relevant opportunity cost. The literature considering alternatives can be distinguished along several dimensions. For simplicity, we use three features of the characterization of the individual's choice process to describe the research. The first involves the description of how time enters preferences. The second considers the specification of the constraints to choice, that is, whether there are two or more resource related constraints and how they are specified in relation to each other. The last describes how time requirements are delineated in relation to the consumption of the goods and services that can contribute to well being.

Johnson [1966] observed in his early thoughtful paper on valuing travel time that:

“ . . . so long as work *and* leisure enter the utility function as separate variables, the value of leisure, travel time, or any use of time will be less than the money wage rate.” (p. 139)

His summary captures many aspects of the early literature and was directly related to estimating the value of travel time for recreation demand models by describing what was learned from the multiple constraint models for valuing time. If these constraints could be collapsed to a single restriction and leisure was the sole time argument in preferences, then we would not escape the conclusion that the money wage was the opportunity cost of time.

Ultimately each type of time was a perfect substitute for work time. For example, McConnell and Strand's [1981] proposal to include mileage-related travel costs and travel-time costs measured at the wage rate as separate arguments in a travel cost demand could be interpreted as a test of the Becker [1965] full price logic in costing trips to recreation sites. Viewed a different way, their results suggest that an individual is unable to perfectly exchange time units.¹

The conventional model can be amended in various ways to break the link between the market wage and the value of time: assuming different types of time contribute individually to well-being; introducing separate constraints on how much time could be allocated to activities; or limiting the exchangeability of the different types of time. Bockstael, Hanemann and Strand's [1987] analysis, for example, provides a situation where a model is based on whether individuals face limits on their ability to re-allocate time. In their case, time enters preferences as leisure but different opportunity costs arise because those working full time may not be able to adjust the hours worked. Moreover, when the amount of time spent working can be increased, the wage is often different from the full time (or regular) wage. Overall, their analysis suggests classifying individuals into different categories – flexible versus inflexible in their time decisions, and collecting information about wage rates for full-time and any additional part-time work.

Their model implies we must correctly specify each individual's margin for choice in order to recover measures of the opportunity cost of time. Their logic for describing time allocation among available work alternatives follows conventional labor economics and implies a piecewise linear budget constraint. Those individuals with no flexibility reveal very little (without additional information) from their actual choices. They are at the kink, so we do not know what they would do if they were able to adjust. By contrast, the choices of flexible individuals do reveal an opportunity cost for time as their wage. Finally, those with second jobs have revealed an excess demand for work and thus a reservation value for leisure less than the wage on their primary job.

An important limitation on our ability to use market choices arises from this logic. Many people in traditional full time jobs will have reasonably fixed hours and wages, with

little discretionary choice. In these cases, the only opportunity to use a revealed preference to recover information that could be used to value of time seemed to be through decisions about job changes. Feather and Shaw [1999, 2000] responded to this challenge by adapting Heckman's [1974] labor supply model to recover some information about shadow values of time for individuals who are unable to adjust their work time. They developed a simple stated preference question asking people about whether they would adjust their hours worked, if given the opportunity. Increased work would lead to increases in earnings and decreases to reductions. This question interpreted the existing wage as a lower or upper bound for these individuals' reservation wages. While an important insight, the analysis does not necessarily reveal the opportunity cost for the time these restricted individuals have available. Instead it reveals the long run shadow value if they could re-negotiate their employment conditions. In the short term, the work hours/wage tradeoff does not provide information on the shadow value of their available time. These allocation decisions relate to a different margin of choice.

Another line of research considers the implications of assuming time and money constraints cannot be linked. The two-constraint model was first proposed by De Serpa [1971]. He also assumed separate roles for various types of time in preferences. His formulation generalized Johnson's model, and highlighted the prospects for time used in specific consumption activities to exceed the efficient minimum. In De Serpa the work/leisure choice is also assumed pre-determined. Thus, the value of time can vary due to preference and resource constraints in relation to time requirements.

In a series of articles Larson and Shaikh [e.g., 2001, 2004] have extended the two-constraint model in several directions. These time requirements are binding constraints since there is one good that only requires time but no income, and types of time do not enter

preferences. The structure is related to literature on rationing (Neary and Roberts [1980], Cornes [1992]) in that goods have fixed time and money prices. The value of time reflects the relative scarcity of time versus money in the task of maximizing utility. In their model each person has an opportunity cost of time that is the same regardless of how it is used (time is interchangeable), but it need not equal the wage. Indeed, like De Serpa it is not constrained to be less than the wage.²

A final strategy has been suggested in the past literature but has not proved promising. The most direct approach to developing different time values (e.g., ones that are different depending on how time is used) is to assume them. That is, different values can be assured when we introduce separate time uses as arguments in preferences, following De Serpa.³ While direct, this strategy is not informative without constraints that assure choices will reveal the relative importance of alternative allocations.⁴

We think that there are several important lessons from the literature to date. The models indirectly highlight different margins in which time choices are made. Overall labor/leisure commitments are associated with longer-term employment choices. These choices condition the short term decisions. For short run choices, it is important that we highlight different roles for time, but this specification does not necessarily imply that we must assume fixed time requirements per unit of consumption, or that the various types of time have intrinsic values (e.g. enter preferences directly). Rather we need to distinguish how time is used, allow for different (rather than fixed) production requirements in these uses, and focus on a margin of choice that assumes the overall work/leisure choice has been made.

3. Conceptual Model

We describe decision making in the face of discrete time blocks using a stylistic model of individual behavior. Employment and residential location are assumed to be decisions made as part of long run choices. For this analysis they are taken as fixed. Each individual's employment decision conveys a typical work week and corresponding blocks of time (e.g. weekends) that are not devoted to work. Assume the planning horizon for time allocation is J weeks. Let T^j represent the total amount of non-work (and non-sleep) time that is available in week j . This time is used in three ways: household chores, recreation, and other leisure.

Household chores include home production tasks such as preparing food, caring for children, cleaning the house, and caring for the yard. We label these tasks 'maintenance' and denote the output of maintenance in week j by M^j . The individual produces maintenance in week j using own time denoted t_m^j and purchased inputs. Define the maintenance production function by $M^j(t_m^j)$, where purchased inputs are suppressed for notional convenience. We assume the marginal product of own time is positive but diminishing. While there is a maintenance production function for each week, it is possible to shift maintenance effort between time periods, so total maintenance, M , in the planning horizon is the sum of maintenance in the individual periods. For simplicity we assume the individual has chosen a fixed level of maintenance for the planning period. In the absence of other considerations if the maintenance function (per week) were the same, then the person would spend equal amounts of time each week to minimize the total time costs of reaching the fixed level of total maintenance. To the extent the function differs by week time would be allocated to equalize implied marginal costs of producing the required level of total maintenance. Other uses of non-work time, however, imply the allocation is more complex.

The second use of time is for recreation, denoted R^j . Recreation is produced using time spent getting to a site, time spent on-site, complementary purchased goods such as travel and equipment, and the characteristics of the trip. Again suppressing the latter inputs for notional convenience we denote the recreation production function for week j by $R^j(t_r^j)$, where t_r^j includes both travel and on-site time. The marginal product of time for recreation is again positive, and the marginal productivity of time in recreation is increasing, at least over the relevant range for day trips.

Finally, the individual uses non-work time for leisure, denoted H^j . Since no purchased goods are involved H^j is the time numeraire, and leisure in different weeks can be combined linearly to yield leisure over the planning horizon, denoted H . Purchased goods are given by x , where price has been normalized to one, and income for the period is y .

The person gets satisfaction from recreation, leisure, and purchased goods. He allocates non-work time and income to maximize utility subject to income and time constraints and the maintenance requirement. Formally the individual solves the constrained maximization problem

$$\max_{t_m^j, t_r^j, H^j \forall j} U(R^1, \dots, R^J, x, H) \quad s.t. \quad T^j = t_m^j + t_r^j + H^j \quad \forall j, \quad y = x, \quad M = \sum_j M^j(t_m^j). \quad (1)$$

Notice that our model combines elements from several earlier treatments of time. Following Johnson, Becker and De Serpa, time can make different contributions to preference (e.g., through the R 's and separately through H). Implicitly there could be a contribution from work time, although it does not appear because it is assumed pre-determined. Finally following Larson and Shaikh, time makes contributions to activities important to the individual that do not contribute to well being (e.g., maintenance). By inverting the J time constraints and

substituting them into the maintenance function, the time and maintenance constraints can be combined as

$$M = \sum_j M^j (T^j - t_r^j - H^j). \quad (2)$$

With this substitution the $J+2$ constraint problem reduces to a more familiar two-constraint problem, although one constraint is for maintenance rather than time.

Maximizing utility subject to (2) and the income constraint leads to solutions for the optimal time allocation and the indirect utility function $V(y, T^1, \dots, T^J, M)$. Denoting the Lagrange multipliers for the money and maintenance constraints by λ and μ , respectively, the Envelope Theorem implies $V_y = \lambda$ and $V_M = \mu$. More importantly it is also the case that

$$V_{T_j} = \mu \frac{\partial M^j}{\partial T^j} = \mu \frac{\partial M^j}{\partial t_m^j}.$$

This means that the marginal utility of time depends on the marginal product of time in maintenance, and the marginal opportunity cost of time is given by

$$\rho^j = \frac{V_{T_j}}{V_y} = \frac{\mu}{\lambda} \frac{\partial M^j}{\partial t_m^j}. \quad (3)$$

Equation (3) implies the marginal value of time is larger when the marginal product of time in maintenance is larger. Since the marginal product is diminishing for maintenance, the marginal value of time is higher when little time is devoted to maintenance. Intuitively, if little time is spent on maintenance, the marginal productivity of maintenance effort is high, and the opportunity cost of spending that time in recreation or leisure is also high. This result has implications for the shadow value of different sized blocks of recreation time. While leisure time is divisible and utility from leisure fungible across time periods, utility from recreation is dependent on the amount of time available to produce the experience. In a short

term decision horizon it may be optimal to reallocate maintenance across periods. This change would be in addition to shifting leisure to recreation within periods, to make more time available for longer recreation trips. For a given individual these choices can result in differing marginal values of time for trips of different lengths, as well as shadow costs of time that increase at an increasing rate for longer trips. That is, for trips requiring a shift in maintenance time we would expect that the marginal value of time is greater than the average value of time. This result is important to our strategy for measuring how the value of time changes with the activity as well as the individual and differs from most of the literature as noted in the section 2.

4. Empirical Strategy

It is reasonable to assume that an individual's marginal value of time varies according to his circumstances. Numerous long and short term constraints will play a role in determining the shadow value for time reallocation. Implementing a structural empirical model to reflect this reality in applied analysis is, however, a daunting task. Observation of time allocation choices at several margins over multiple timeframes for a sample of people would be needed. In our model, 'maintenance' is an aggregate, unobserved commodity with unspecified units. Fortunately to estimate a version of equation (3) we can identify enough information about the production function from information about personal time allocations and a strategic choice question. While it is not possible to do this within a structural model that integrates long and short run time horizons, we can use a combination of choices (and their respective models) to estimate the maintenance production function. This function provides the basis for describing how the marginal value of time varies over different sized blocks of time.

Our strategy relies on a recursive decision process that assumes separability between decisions made at three different time horizons. We take advantage of this logic and use estimates from models describing tradeoffs from two choice margins. As noted earlier we distinguish a long horizon in which individuals or families make decisions about jobs and residential location, an intermediate horizon over which decisions on maintenance levels and maintenance inputs are made, and a short horizon in which recreation decisions are made and the shadow costs of the associated input, time, are borne. By separately estimating the time tradeoffs implied by choices involving long and intermediate time horizon decisions, it is possible to combine these results to draw inferences about the shadow costs of the short horizon (recreation) decisions.

Most of the research on the value of time has exploited the long horizon choice between leisure and income. As discussed in section 2 early approaches primarily used the wage rate to provide information about a person's willingness to trade time for money. Recent approaches (e.g. Bockstael et al. [1987], Feather and Shaw [1999]) have explicitly recognized that people might not be able to freely choose their work hours, and as such have allowed the shadow value of time to deviate from the wage rate. Our strategy first uses the Feather and Shaw [1999] approach to estimate what we will think of as the long run, labor market-based shadow value of time. We denote this shadow value by ρ^s and assume it is fixed in the intermediate and short horizon decisions.

The intermediate time horizon model concerns decisions about maintenance and maintenance inputs. We assume an individual allocates his own time to produce maintenance. We introduce a new opportunity to this choice. We offer the possibility of purchasing (at a fixed hourly price) regularly scheduled hours of weekly maintenance (i.e., lawn services,

cleaning services, and a variety of other time saving market services). With the availability of purchased maintenance, the household or individual must decide how much maintenance they will do themselves and how much they will contract for each week. By comparing the market price of purchased maintenance to ρ^s , the pre-determined shadow value of time determined by labor market choices, the individual determines how many hours per week, if any, of maintenance service will be hired.⁵ Observing and modeling this decision conditional on ρ^s (obtained from the Feather and Shaw model) constitutes the second step in our strategy.

To derive an estimating equation for the intermediate horizon decision we consider a simplified version of the model in section 3. Define utility for a representative week by $U(x,H,M)$ where weekly maintenance M is now a choice variable and H represents leisure of all types, including recreation time. Denote own labor devoted to household maintenance production by L and purchased hours of maintenance labor by L^s .⁶ We define $f(L)$ to be the contribution to total maintenance from own labor, where $f'(L) > 0$ and $f''(L) < 0$, and we normalize the units for maintenance so that one hour of professional service provides one unit of maintenance. Maintenance is therefore the total of own and purchased production, given by

$$M = f(L) + L^s. \quad (4)$$

Utility is maximized subject the money constraint $y = x + w_s L^s$, where w_s is the price per hour of purchased maintenance, and time constraint $T = H + L$. Substituting the time constraint and the maintenance function in (4) into the budget constraint yields

$$y = x + w_s [M - f(T - H)]. \quad (5)$$

There are two types of solutions to the utility maximization problem. First consider individuals who purchase a positive amount of service at the offer price, so there is an interior

solution. Maximizing utility subject to equation (5) yields first order conditions $U_x = \lambda$, $U_H = \lambda w_s f'(T-H)$, and $U_M = \lambda w_s$, where λ is the Lagrange multiplier for the budget constraint. From these first-order conditions, the value of time at the intermediate horizon for these individuals is

$$\rho^s = \frac{U_H}{U_x} = w_s f'(T-H).^7 \quad (6)$$

For people who do not purchase service at the offered price, it is not possible to collapse the maintenance and time constraints into the budget constraint. The value of time for these individuals is given by a corner solution in the purchased service market:

$$\rho^s = \frac{U_H}{U_x} = \frac{\mu}{\lambda} f'(T-H) < w_s f'(T-H), \quad (7)$$

where μ is the Lagrange multiplier for the maintenance constraint.

Estimating equations are derived from (6) and (7). Using censored regression and a specification for f one can estimate a transformation of the weak inequality

$$\frac{\rho^s}{w_s} \leq f'(L), \quad (8)$$

where L is the amount of own maintenance labor when the service is available at a price w_s and ρ^s is the value of time from the employment information. Our survey instrument provides information on behavior in a hypothetical market for personal maintenance services that allows estimation of (8). The specific form of the hypothetical market is described below.

Once the marginal product function has been estimated it is possible to calculate the value of the marginal product for each individual's own maintenance labor in the absence of the hypothetical purchased personal service. This is the marginal product evaluated at the

observed allocation of personal labor to maintenance in the baseline, designated here as L^* .

With the baseline marginal product and the long term value of the shadow wage ρ^s it is possible to calculate μ/λ , the marginal value of maintenance as

$$\frac{\mu}{\lambda} = \frac{\rho^s}{f'(L^*)}. \quad (9)$$

During the short time horizon when recreation decisions are made the marginal utility of income and the marginal utility of maintenance are unlikely to vary. Therefore, the short horizon marginal value of time from equation (3) will vary with changes in maintenance time because of the changing marginal productivity. Those changes result from the indivisibility of recreation trips. Since the marginal value of time varies with trip length, the total time cost for a trip must be calculated as the integral of the marginal time cost, rather than a simple product. Given estimates for the marginal product of maintenance and the long horizon shadow wage our strategy provides all the information needed to empirically identify the total time cost of recreation trips of varying lengths.

5. Data

The data used for this paper were collected as part of a larger research effort on water quality that integrates residential housing sales information, survey data on homeowners' recreation visits and their household characteristics, as well as spatially delineated data on the quality of the recreation sites. This paper uses the components of the survey that were focused on household time allocation decisions and time saving activities. Between May and September 2003 a mail survey was sent to a sample of homeowners in Wake County, North Carolina. The target population was residents of owner-occupied houses for which there was a transfer of ownership between 1992 and 2001. A random sample of 9,000 residents, stratified by geographical location, was drawn from this population.

Two components of the survey are the primary focus of this paper. First, we solicited time usage for the respondent and spouse (if any) for fifteen activities including primary and secondary employment, commuting, and a wide variety of non-work activities. We asked how much paid help the household used for maintenance duties, and whether they could freely choose how much time was allocated to each activity. In addition, we asked about the flexibility they had in time allocation and whether they would prefer to work more or less hours (i.e., the same question used by Feather and Shaw [1999]), and asked about various time-saving market products currently used by the household.

Second, we presented a stated preference question soliciting households' willingness to participate in a (hypothetical) market for personal assistance services that would (potentially) allow the person to replace his time devoted to maintenance activities with purchased labor. After describing the services available and presenting a market price per hour, we asked if the respondent would purchase the service and, if so, how many hours in a typical week. This question was followed by several regarding how they would use any time made available by purchasing the service. The relevant portions of the survey instrument are reproduced in Appendix A.

We also collected information on the earnings and non-labor income of the household, some job characteristics, and a variety of other socio-economic variables. The survey provided nearly 2,000 responses with answers to the questions used here, although when we sorted and added certain variables the sample was reduced to approximately 1,700.⁸ The variables used and their descriptive statistics are given in Table 1.

A crucial variable for our application is the amount of the household time devoted to 'maintenance'. We interpreted survey responses on time devoted to *household activities* (e.g.

cleaning, cooking, etc.), *yard work/gardening*, *activities related to your children*, and *shopping for routine needs/running errands* as activities included in our definition of maintenance and where assistance might be employed. Different individuals will get varying disutility or utility from these activities, but these are the regularly scheduled activities that are done not simply for personal enjoyment. The baseline level of time assumed to be allocated to own maintenance is the sum of times reported in these four categories. Our analysis uses time spent on own maintenance when the hypothetical personal services are available. The time that they reported they would purchase was subtracted from the baseline time.⁹

6. Empirical implementation and results

Specifications

As described in section 4, our strategy requires estimates of the long run shadow value of time and the parameters of the marginal product of maintenance. The Feather and Shaw [1999] model is used in the first step to estimate each respondent's shadow value of time based on their long run labor market choices. The model requires specification of empirical shadow wage and market wage functions. The relationship between the shadow wage and market wage for a person is determined based on the responses given to survey questions on labor market status. For people with a flexible work schedule the market and shadow wages are presumably equal, while for unemployed, under-employed, and over-employed people the relationship between the shadow and market wages is an inequality. The form of the estimating equation for each person in the sample depends on their responses to the question about adjusting their hours, and maximum likelihood is used to jointly recover estimates of the parameters of the shadow wage and market wage functions.

We specify the market and shadow wage functions to include variables similar to Feather and Shaw. The shadow wage function includes a constant and variables for work hours, non-work income, spouse work hours, and indicators for young children, gender, and the interaction of gender and young children. The market wage function includes a constant and variables for age, education, and indicators of race and gender. A table of parameter estimates for the model is shown in Appendix B. The estimated coefficients are generally significant and with signs that are consistent with *a priori* expectations. For the individuals in our sample, the mean predicted shadow wage is \$26.64 and the median is \$19.61.

Estimation of the marginal product of maintenance requires specification of the personal maintenance production function. We expect that this function would vary by individual and exhibit diminishing marginal product. The latter condition can either be imposed or tested. In this initial application we consider two simple forms, one that imposes this condition and another where it is not imposed but rather confirmed by the estimation.

We first specify the total product of own labor (production function) by

$$TP = \exp(A + z\beta) \ln(L + 1), \quad (10)$$

where the vector z represents socio-economic characteristics of the individual that might influence productivity. Since L is restricted to be greater than or equal to zero, adding one guarantees that the logs will always be positive. The marginal product is

$$MP = \frac{\exp(A + z\beta)}{(L + 1)}, \quad (11)$$

and inverting and using the equality form of equation (8) yields

$$L + 1 = \frac{\exp(A + z\beta)}{\rho^s / w_s}, \quad (12)$$

where ρ^s is the shadow wage and w_s is price of personal services. The estimating equation is

$$\ln(L + 1) = A + z\beta - \ln\left(\frac{\rho^s}{w_s}\right) + \varepsilon \quad (13)$$

In recovering estimates for the structural parameters needed to measure the value of time we must account for transformation bias (Goldberger [1968]) when converting the estimated coefficients to the parameters of the production function. This issue will be discussed subsequently but does not affect the qualitative arguments here.

Our second specification uses a quadratic form for the production function:

$$TP = aL^2 + bL. \quad (14)$$

Here one can test whether b is positive and a negative as implied by the theory. The marginal product is

$$MP = 2aL + b, \quad (15)$$

and the estimating equation is given as

$$L = \beta_0 + z\beta_z + \beta_1\left(\frac{\rho^s}{w_s}\right) + \varepsilon, \quad (16)$$

where $\beta_1 = 1/(2a)$ and $\beta_0 = -b/(2a)$, or $a = 1/(2\beta_1)$ and $b = -2a\beta_0$. Thus, the prediction would be $\beta_0 > 0$ and $\beta_1 < 0$. Socio-economic differences between individuals can be incorporated by allowing b to vary with observable characteristics. With this functional form the marginal product is not strictly positive, even for parameters with the theoretically predicted signs. Some individuals could have a negative marginal product if the allocation of own labor to maintenance is large enough that the quadratic term dominated the linear term in the production function.

Results

An individual decides how much of his own time to devote to maintenance and how much personal services to purchase. For this analysis, we assume that for each hour of

personal services an individual purchases, he reduces his own maintenance effort by one hour. Because of the diminishing marginal productivity of own maintenance, this assumption implies an increase in total maintenance. If the individual chooses the service, he will be better off with the new option available. While there may be feedback effects that lead the individual to further adjust his own maintenance, these are likely of second order importance, and are unlikely to be reflected in the answers to our stated preference question in practice. The individual's own household labor decision will depend on the relative price of own versus purchased labor, and may be affected by the characteristics of the household.

We first estimate equation (13) using maximum likelihood assuming a censored normal distribution for the error. Theory implies that the coefficient on the implicit price ratio is equal to negative one. The results are present in Table 2. In the first column we report a parsimonious specification limited to include relative price and a constant included. Based on the estimation strategy used here, the constant is the important parameter to be estimated, although it should be noted that the relative price term varies for each observation and is important in explaining the own maintenance decision. In this sense the relative price term can be interpreted as a non-estimated individual fixed effect. The constant is positive and highly significant as expected.

We hypothesized that the characteristics of households also play a major role in explaining the differences in behavior with respect to maintenance. The second column of Table 2 provides the results for a more complete specification, utilizing variables that might be available in a typical (albeit fairly complete) recreation survey. There are a number of variables that play a significant role in the maintenance decision. Some of the effects are obvious. *SIGOTHER* represents households where there is a "significant other," typically a

spouse, present in the household. We would expect this to increase the maintenance production. *HOUSEFAM*, the number of family members in the house, also has a positive effect on maintenance, as expected. As partial support for the unitary household model, the sex of the respondent was not a significant variable in this specification.

The coefficient on *AGE* indicates that older individuals do less of their own maintenance. Higher levels for the earned income for a respondent also led to less own maintenance. *RGTS10* attempts to capture differences if the respondent worked significantly more or less hours than the spouse. The variable is one if the respondent works at least ten hours more per week than the spouse, zero if there is less than a ten hour difference between the work weeks for the couple, and it takes a value of negative one if the respondent works at least ten hours less than the spouse. This variable was intended to capture differences in the perceptions of the respondent. While there are a variety of sociological explanations possible for the significant positive sign, we will not pursue those based on this evidence alone. The race of the respondent had no effect in any of the specifications and was not included.

The final column in the table adds variables that would only be available in a specialized survey such as ours. *NONWORKDIFF* represented the difference in number of non-work hours calculated in two ways. The first used the number of hours in a week and subtracted the number of hours that were reported devoted to all employment plus the time spent commuting plus an allowance for time spent sleeping. Since we expect the respondent to be quite accurate in reporting work and commute time, this probably represents a fairly accurate measure of non-work time. The second measure was the total of all the time reported for non-work activities.¹⁰ The difference in the two measures captures the accuracy and completeness of the respondent's accounting for non-work time. As expected, if the

accounting for non-work activities in general was higher, the reported time spent on maintenance was also higher. The other two variables were based on the responses to the question about what they would do with the new time made available by employing the hypothetical personal services. The variables are dichotomous variables for those who said they would work longer hours and for those that said they would devote the time to housework. The omitted category was for those who would use the time for leisure activities. The individuals who would take more leisure tended to report more time spent on maintenance.

The estimated coefficients are used to develop estimates of the marginal product of own maintenance labor. Since this was a non-linear transformation of the estimated semi-log parameters, the variance of the parameter estimates was used in the Goldberger [1968] approximation. Using the marginal product function, the marginal value of time was generated as discussed above. Table 3 provides the quantiles of the predicted marginal value of time distribution for trips that displaced 2, 4, 6, and 8 maintenance hours, as well as the long-run shadow value of time of these individuals. The specification in column three of Table 2 was used in generating these values of time.

Given that the production function used the natural log of own maintenance time, the transformations that generate these values for time net out the effects of the specific socio-economic variables. Thus, the function describing the marginal value of time depends only on the shadow wage. This could be an advantage or a disadvantage depending on one's perspective. For the practical needs of some benefit transfer tasks it is an advantage. All that would be needed would be an estimate of the distribution of baseline values of time. On the other hand, the functional form is important in generating these results. Thus we consider if

similar outcomes result from a more flexible functional form. The quadratic form discussed above provides somewhat more flexibility in that the marginal value of time function depends on the household characteristics.

The same explanatory variables were used in estimating equation (16) as in the earlier specification. The results are reported in Table 4. From the first column we see that, even in the parsimonious specification, the marginal product is positive (at least initially) and diminishing as expected. These results carry through to the more complete specifications. In column two of Table 4, the results are similar to the log specification, except *AGE*, *FLEX*, and *RGTS10* are no longer significant. When the additional variables unique to our survey are added in column three, *AGE* remains insignificant, but *RGTS10* is significantly positive as before. Interestingly, *FLEX* becomes negative and significant, whereas in the log specification it was positive and significant.

For the quadratic specification, the estimates of the various values of time depend on the socio-economic characteristics of the individual as well as the shadow wages. The quantiles of the distributions of the marginal value of time for different length trips for the quadratic specification are given in Table 5. The increases in the value of time as the trips become longer are not as great as they were for the log specification, but the value still increases as one takes longer recreation trips.

7. Discussion

People's choices about their time allocations take place on a variety of margins. They are made sequentially with some choices constraining others that come later (at least until the consequences are important enough to warrant incurring the costs of revision). This recursive structure has been implicitly discussed in the literature with some authors taking the

labor/leisure choice as fixed (e.g., De Serpa, Larson and Shaikh) and other (e.g., Bockstael et al.) suggesting it will be differentially constraining for different individuals.

Three features distinguish the implications of these models for measures of the opportunity cost of time. They arise from: (a) the role for time allocations in preferences; (b) the interconnections between time and money constraints; and (c) the discretion in time requirements per unit of consumption of market goods. Our model demonstrates how all three attributes of past research can be modified within a simple model of individual choice. This model incorporates the multiple time constraints that one faces and results in the value of time varying with the amount of other activities that must be shifted between time periods.

Our empirical application highlights a new role for stated choice questions. Most applications in environmental economics have focused on new choices, offering individuals the opportunity to decide about an amenity that has previously been outside the domain of their choice set (or one where it was difficult to make large changes). Efforts at joint estimation are designed to use revealed preference data to calibrate stated preference responses. Our model relies on an integrated strategy in which the stated preference model offers a different type of choice margin that may serve to relax time constraints for some individuals.

A key difficulty raised in research on valuing non-market production has been the challenges in collecting time diaries (see CBASSE [2000]). Gronau and Hammermesh [2003], for example, note that none of the studies considering household production has considered how different uses of time are related to goods and the activities sought by individuals. This is not surprising because information about time allocation and information about goods consumption expenditures are generally collected separately. Moreover, there

are significant difficulties in asking for time allocations, whether in diaries or recall questions. Our strategy suggests an alternative, potentially supplementary source of information on the important features of time allocations, using stated preference questions to offer new margins for relaxing different types of the constraints together with pre-existing information of time allocations.

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Table 1: Variable Definitions and Summary Statistics

Variable Name	Definition	Mean	Std. Dev. ^a
HWORK	Hours of household maintenance	42.40259	29.83309
VTOVERW	Value of time divided by personal services price	2.243046	3.711943
REARNING	Respondent's labor income	65346.77	50477.3
SIGOTHER	Spouse, etc. in household	.8662013	-
AGE	Age	44.45782	9.839713
RGTS10	Work distribution in household	.1809191	-
HOUSEFAM	Number of family members in house	2.970913	1.355055
FLEX	Flexibility in work hours	.1204188	-
NONWORKDIFF	Accuracy and completeness of response	-69.48926	52.00754
ADDWORK	Choose more paid work	.0390071	-
ADDHW	Choose more housework	.1985816	-

^aStandard deviation not given for discrete variables

Table 2: Estimation Results for the Log Model

Variable	Estimated coefficient (t-statistic)		
CONSTANT	6.329304 (52.82)	4.576594 (11.52)	4.758088 (14.31)
VTOVERW	-1.0	-1.0	-1.0
REARNING		-5.46e-06 (-4.16)	-5.66e-06 (-5.27)
SIGOTHER		1.576958 (6.99)	2.075767 (10.57)
AGE		-.0193155 (-2.62)	-.0121396 (-1.96)
RGTS10		.8707963 (8.01)	.9040024 (9.92)
HOUSEFAM		.3690822 (6.43)	.3068729 (6.55)
FLEX		-.7732239 (-3.55)	-.4896135 (-2.64)
NONWORKDIFF			.0148082 (12.25)
ADDWORK			-1.723844 (-4.09)
ADDHW			-1.831244 (-9.26)
Sigma	2.186861	1.710801	1.356804
Log Likelihood	-1062.2651	-876.39517	-761.30763
# of obs.	1907	1719	1719
# uncensored	310	282	282

Table 3: Quantiles of Marginal of Time for Trips of Different Lengths
Based on the Log Model (in \$'s)

Quantile	Baseline	2-hour trip	4-hour trip	6-hour trip	8-hour trip
10%	1.65	1.81	1.96	2.06	2.07
25%	5.70	6.04	6.51	6.87	6.53
50%	19.61	20.73	22.82	24.57	26.09
75%	31.89	34.83	38.53	42.09	46.22
90%	57.64	63.08	69.65	76.54	86.37

Table 4: Estimation Results for the Quadratic Model

Variable	Estimated coefficient (t-statistic)		
CONSTANT	115.4196 (32.76)	59.75629 (5.93)	60.24332 (7.60)
VTOVERW	-2.293956 (-5.03)	-2.107934 (-5.16)	-2.503224 (-8.01)
REARNING		-.000144 (-4.38)	-.000138 (-5.47)
SIGOTHER		27.10695 (4.68)	41.29866 (8.66)
AGE		-.1528989 (-0.83)	.055812 (0.38)
RGTS10		2.807107 (1.00)	4.975289 (2.26)
HOUSEFAM		12.49298 (8.51)	10.1307 8.91
FLEX		8.498196 (1.49)	12.3714 (2.74)
NONWORKDIFF			.3683349 (13.73)
ADDWORK			-31.67793 (-3.00)
ADDHW			-43.48503 (-8.75)
Std. Error	55.24422	44.96906	33.97197
Log Likelihood	-2104.8189	-1836.2277	-1718.6582
# of obs.	1907	1719	1719
# uncensored	310	282	282

Table 5: Quantiles of Marginal of Time for Trips of Different Lengths
Based on the Quadratic Model

Quantile	Baseline	2-hour trip	4-hour trip	6-hour trip	8-hour trip
10%	1.65	1.74	1.80	1.88	1.97
25%	5.70	5.94	6.10	6.17	6.39
50%	19.61	20.14	20.80	21.48	22.19
75%	31.89	33.10	34.32	35.61	37.00
90%	57.64	61.19	64.20	66.58	69.05

Appendix A: Survey Sections on Time Use and Values

B. Time Use and Time Saving Activities

6. Now we would like you to think about your typical weekly schedule and what you and your spouse/partner do with your time on average. In a typical week, about how much time do you and your spouse/partner (if relevant) spend on each of the following activities? For some categories you may hire paid help. If so, the third column asks how many hours in a typical week you pay someone to help with some of these activities. Finally, if you feel you are able to freely choose the amount of time you spend each week on an activity please check the associated line in the last column.

<u>Activities/Tasks</u>	<u>You</u>	<u>Spouse/Partner</u>	<u>Paid Help</u>	<u>Freely Choose</u>
commuting to work	___ hrs	___ hrs		___
paid work (primary job)	___ hrs	___ hrs		___
second job (if relevant)	___ hrs	___ hrs		___
household activities (e.g. cleaning, cooking, etc.)	___ hrs	___ hrs	___ hrs	___
yard work / gardening	___ hrs	___ hrs	___ hrs	___
activities related to your children	___ hrs	___ hrs	___ hrs	___
reading newspapers, books, magazines	___ hrs	___ hrs		___
shopping for routine needs and running errands (e.g. food)	___ hrs	___ hrs	___ hrs	___
watching TV/video	___ hrs	___ hrs		___
family related social activities	___ hrs	___ hrs		___
outdoor leisure activities away from your house (e.g. walking, fishing, boating, riding a bike, etc.)	___ hrs	___ hrs		___
time on the computer/internet away from work	___ hrs	___ hrs		___
entertainment away from home	___ hrs	___ hrs		___
church activities	___ hrs	___ hrs		___
exercise/workouts	___ hrs	___ hrs		___

5. Is the time you have available for leisure flexible in terms of both the day of the week and the time of day? (Choose one)

_____ flexible - can use time for leisure activities anytime of the day or week

_____ limited by work schedule

_____ limited by non-work commitments (e.g., volunteer, children's activities, etc.)

_____ limited by both work and non-work commitments

6. If you had the opportunity to work fewer hours and receive less income or work more hours and receive more income with the rate of pay in each case consistent with your current earnings (on approximately a per hour basis), would you change your hours? Please check the appropriate response.

_____ I would work more hours and receive more income

_____ I would work less hours and receive less income

_____ I would not change my working time

9. There are many ways people try to save time. We buy time saving appliances, shop with catalogs or online, hire others to help with activities around the house, etc.

Please check any of the following types of time saving appliances or services that you have purchased or used because you wanted to save time.

- shop with catalog or on an internet web site
- used on-line banking
- used an ATM
- used a home cleaning service
- used a lawn service
- used clothes cleaning services
- used a drive-up pharmacy
- ate at a fast food restaurant
- purchased frozen dinners or ready made meals
- used periodic babysitting services
- had daily childcare service
- used a mobile phone regularly
- used a food shopping service
- purchased delivery pizza
- used dog walking service

10. Personal Assistance Services

It is becoming more common to see firms that provide personal assistant services starting up. These types of businesses organize and perform many household tasks such as house cleaning, lawn care, food shopping, and a wide array of other tasks. Clients typically contract for a specific number of hours per week and specify the activities employees of the firm are to do. If transportation is needed for the tasks, it is provided by the firm and included in the number of hours that are purchased. Guarantees are made that the service is safe and reliable. It is not necessary for clients to be present when the tasks are performed. In spite of the growth in this industry, little is understood about how much of these services would be used.

If this personal assistance service was \$5.50 per hour used, would you purchase any time?

_____ yes _____ no

If you answered yes, how much personal service time would you purchase in a typical week? Please check the relevant box or write in the value. (If no, skip to Part C, "Leisure Outings").

Hours Purchased In a Typical Week	Total Weekly Cost	Please Check the Relevant Box
1	\$5.50 x 1 = \$5.50	<input type="checkbox"/>
2	\$5.50 x 2 = \$11	<input type="checkbox"/>
3	\$5.50 x 3 = \$16.50	<input type="checkbox"/>
4	\$5.50 x 4 = \$22	<input type="checkbox"/>
5	\$5.50 x 5 = \$27.50	<input type="checkbox"/>
If your purchase would be more than five hours, please indicate how many:		_____ hours per week

The hours I would purchase would replace paid services I currently use for some household tasks.

yes

no

On average, how would you most likely use the time you saved by purchasing this service? (check most likely use)

Use the time to work additional hours

Use the time for activities I enjoy

Use the time for other household tasks

Appendix B

Appendix Table: Feather and Shaw Model Parameter Estimates

<u>Shadow wage variables</u>	<u>Estimate</u>	<u>t-statistic</u>
Constant	0.4209	1.55
Work hours	0.0661	7.293
Non-work income	0.0455	4.71
Spouse hours	-0.0097	-4.472
Kids<6	0.7184	6.668
Kids<6×male	-0.7553	-5.63
male	-0.0799	-0.492
<u>Market wage variables</u>		
Constant	4.1693	12.964
Male	0.6765	4.532
Black/Hispanic	-0.5793	-7.049
Age	0.318	2.178
Education	0.0749	2.87
<u>Error variance</u>		
Std. dev. Shadow wage	2.5543	39.176
Std. dev. Market wage	3.2322	39.085
Correlation ^a	1.7867	4.857

^acorrelation is $\rho = \exp(\delta) / (1 + \exp(\delta))$ where δ is estimated

Notes

¹ Smith et al. [1983] also showed, using a related model, that the relationship between the value of time and the wage rate varied extensively.

² A recent article that is closely related is Larson, et al. [2004] where they estimate willingness to pay in terms of both the time numeraire and the money numeraire. They are then able to infer the value of time from the relationship between the two WTP's.

³ As De Serpa notes the time constraint is not effective and "time requirements" per unit of consumption have no role unless the time spent in consumption is binding.

⁴ Some restrictions on preferences can be useful, but the constraints must also play a role. McConnell's [1992] proposal to treat on-site time and goods as subject to "two-way weak complementarity" is the first effort to reconsider the implications of the linearity assumption for the budget constraint in linking time and monetary constraints to choice.

⁵ Our empirical analysis treats this choice as a household decision. Thus we implicitly adopt a unitary model for household behavior with the survey respondent's choices assumed to accurately convey the choices as if one individual makes them. Our survey collects information on activities of different adults in the household. While it might be possible to exploit these data and implement a collective or Nash bargained model of labor allocation choices, as discussed by McConnell [1999], this task is beyond the scope of this paper.

⁶ In deriving the intermediate horizon model we use L to denote own maintenance labor to distinguish the amount of planned labor, decided at the intermediate time horizon, from the actual amount of labor t_m^j , decided at the short time horizon.

⁷ An alternative way to interpret this equation would be to divide both sides by the marginal product of own labor. The individual should equate the marginal cost of own production to the price for purchased maintenance services.

⁸ We eliminated observations with a predicted shadow wage greater than \$500, those with reported own maintenance hours greater than 150 hours/week, and those who reported they would purchase more hypothetical hours of services than they reported actually doing themselves.

⁹ Some of the respondents indicated that they were using hired assistance already for household tasks. For those that indicated that the hypothetical services we offered would be substituted for the services they already used, we added their own household time and the hired time before subtracting their purchase of the offered services. For those who said the offered services would not be substituted for the hired services they were currently using, we used the current own time and subtracted their purchase of the offered services.

¹⁰ We may have missed potential categories, but our list was fairly exhaustive and included all activities mentioned in the focus groups.