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ABSTRACT

Most economic models for time allocation ignore constraints on what people can actually do with their time. Economists recently have emphasized the importance of considering prior consumption commitments that constrain behavior. This research develops a new model for time valuation that uses time commitments to distinguish consumers' choice margins and the different values of time these imply. The model is estimated using a new survey that elicits revealed and stated preference data on household time allocation. The empirical results support the framework and find an increasing marginal opportunity cost of time as longer time blocks are used.

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I. INTRODUCTION

Most economic models for time allocation ignore institutional constraints on what people can actually do with their time. For example, in the choice of a mix of work and leisure, conventional practice holds that workers are free to set their hours, or equivalently there is a continuous array of total earnings and hours combinations so that choices appear as though marginal evaluations were undertaken. However, for most occupations these assumptions are not realistic.[1] For most households some time allocations and the choices of some consumption goods are quasi-fixed commitments that are costly to adjust over short time periods. Chetty and Szeidl (2007) use this idea to explain how household responses to income shocks will depend on the extent to which their consumption expenditures are difficult to adjust. Using the consumer expenditure survey in adjoining years they find consumption commitments comprise about 50 percent of the average household's annual expenditures. For workers in conventional full time jobs the amount of time available for household activities, including leisure, may be even more constrained. Inevitably work time, commitments for routine household chores, and family related activities require significantly more than 50% of non-sleeping hours. These alternatives involve differing transaction costs for adjustment and re-allocations of time are not costless.

This paper proposes a new method for evaluating how people tradeoff money for time. Our framework begins with the recognition that the opportunity cost of time depends on the context in which that time is to be used, following the key insight of DeSerpa's (1971) early model.[2] As a result, time valuation cannot be undertaken independent of what a person wants to do with the time. If the objective is seeing a movie or attending a basketball game, a marginal minute has little relevance. On the other hand, snooze alarms suggest a few minutes may mean a lot in the context of time spent resting. To adequately resolve these issues it might seem a complete description of the dynamic tradeoffs implied by inter-temporal choices is essential. Such a framework requires not only a record of the sequencing and duration of activities, but perhaps more importantly, an understanding of the constraints to the allocation of time over the course of a day, week, or month. At this time both data and modeling limitations preclude such a fully dynamic model. At the other extreme, one might argue instead that a completely static approach in which all time allocations are simultaneously modeled for a set of individuals might be preferable. Unfortunately, the cascading set of maintained hypotheses would be hidden from view because they would be part of the data construction.

In contrast to these two extremes, our approach decomposes a dynamic sequence of temporally ordered choices into decision steps. Each step generates a shadow value for relaxing the relevant constraint in that step. The shadow values at one step are only one factor influencing decisions in subsequent steps. Thus, time allocation is the result of a mixed set of sequenced and simultaneous choices. Our formulation of the problem parallels the Chetty and Szeidl (2007) description of how prior commitments affect an individual's perceived responsiveness to shocks. In their analysis, decisions on quasi-fixed goods are made in an initial period, recognizing that uncertain shocks may impose greater costs after commitments have been made. Their model treats these period zero decisions as exogenous and considers how the subsequent costs of adjustment affect behavior. In our analysis, we hypothesize that there are two types of time commitments: those that are exceptionally costly to alter and those that are more readily modified. The former might correspond to the time commitments to work or other aspects of one's lifestyle (e.g. commuting time, commitments to civic or religious groups, etc.) and are comparable to the Chetty-Szeidl consumption commitments. The latter type corresponds to necessary but more flexible chores that can be re-allocated from one time interval to another.

The cost of obtaining larger blocks of time therefore results from the incremental costs of shifting home production between time intervals.

Our approach cannot be implemented with conventional data or even a diary such as would be available from some surveys. We address the issues associated with relaxing the time constraints people face by offering our survey respondents opportunities to alter them. That is, we ask two hypothetical questions. One asks about a respondent's desire to adjust his or her work time and a second offers a new service that allows the constraints each person faces in time allocation to be relaxed. Our analysis combines three sets of information. The first involves choices consistent with a conventional censored labor supply model, as in Heckman (1974). The second component involves a set of reported time uses. Finally our new stated choice question offers the ability to relax constraints that are imposed by personal circumstances.

Many uses of time require contiguous blocks, so the way the available 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. Finding a large enough block of time 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. Shifting these activities between time periods will involve a household production function for household maintenance. If there is diminishing marginal productivity of time in these alternative activities in a given block of time, completing household tasks in one period in order to free another period for leisure implies that, as a greater amount of time is shifted, there is an increasing marginal opportunity cost of the time being made available.[3]

We test the hypothesis that different sized blocks of leisure time have different marginal opportunity costs for the same person. The different choice margins for time allocation are used in a two-step estimation strategy that measures the shadow values of different sized blocks of leisure time. Our results confirm that this strategy appears to have genuine potential for evaluating how people make non-work time allocation choices. Section two describes the context for our proposal in terms of past efforts to use labor/leisure choices to uncover measures of the opportunity cost of time. In section three we outline the model and section four describes our empirical implementation of the model. After describing the data used for estimating the model in section five, we discuss our estimates in section six and conclude by offering some general observations about the potential application of the framework in addressing the role of non-market activities in the national accounts.

II. WHAT IS KNOWN?

Most of the new literature on labor supply estimates considers workers who have flexible hours (e.g. Camerer et al., 1997; Farber, 2005). As we noted, these studies test the restrictions implied by conventional models of labor supply. They do not consider other time allocations. Recent attention to time use surveys expands the scope of activities considered but offers only indirect information on the opportunity cost of alternative non-work time allocations. For example, Hamermesh (2005) finds that income does influence whether individuals seek to avoid "routine" time uses day to day. In another application, exploiting time use surveys, Connolly (2005) investigates whether rainy conditions affect time allocated to work, home production, and leisure activities. She finds greatest effects for males in Sunbelt areas substituting out of leisure and home production and into work during rainy days. Both studies confirm inter-temporal substitution is made but do not offer insights on how it might compare with the tradeoffs revealed in labor market choices.

The closest intellectual antecedents for our model can be found in the early papers by Johnson (1966) and DeSerpa (1971). Johnson's analysis demonstrated that when work and leisure enter preferences separately, the value of any use of time will be less than the wage rate. DeSerpa's analysis extends this framework distinguishing time uses where the amount of time required for an activity is a constraint versus where it is discretionary. In the latter case, he argues "time prices" have no effect on choice. We extend this analysis to demonstrate that when there is discretion in the amounts and scheduling of the time used as well as the requirement that some time is essential to accomplishing required activities, there is the potential for different marginal values of time.

In another strand of the literature, Heckman's labor supply model explains why workers without flexibility in their hours worked reveal little about their value of time, even if work does not affect utility. Individuals without flexibility are at the kink in their budget constraint, so the analyst does not know what they would do if they were able to adjust. By contrast, individuals with second jobs reveal an excess demand for work and thus a reservation value for leisure less than the wage on their primary job. It might seem that the only opportunity to measure the value of time with traditional full time workers is through their job change decisions, and even here discontinuities would cause problems. An alternative strategy was implemented by Feather and Shaw (2000) by adapting Heckman's (1974) labor supply model to recover information about shadow values of time for individuals unable to adjust their work time. They asked respondents how they would adjust their hours worked, if given the opportunity. Their answers determined whether a non-flexible individual's existing wage was an upper or lower bound on their reservation wage.

While this early research highlights the different margins at which time allocations are made, recognition of the effects of these choice margins has not been incorporated into the measurement of the implied values for time. Labor/leisure commitments associated with most labor supply models are longer-term, quasi-fixed employment choices. These choices affect, but are different from, the short term allocation of discretionary time.

III. CONCEPTUAL MODEL

Our model of individual behavior assumes decisions take place over different time horizons. Employment and residential location are decisions made as part of long run choices. There is another set of activities where decisions are also made over a longer time horizon. We refer to these activities as 'household maintenance'. Household maintenance includes home production tasks such as preparing food, caring for children, cleaning the house, and caring for the yard. The amount of time spent on household maintenance can vary over short time periods, but over a longer time horizon the total level of maintenance is determined by the personalities and habits of the members of the household. For short-run decisions (Chetty and Szeidl's period one), households take employment, residential location, and total maintenance level as predetermined.

We assume that choices in period one are decomposed into J weeks. Each week offers the same discretionary time (which can be allocated to leisure activities and maintenance) as any other week, based on the period zero decisions. T^j represents the total amount of non-work (and non-sleep) time that is available in week j. This time is used for household maintenance and short term leisure activities. We 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 notational convenience. The marginal product of own time is assumed to be positive but exhibits diminishing returns. While maintenance is defined for each week, we also assume it is possible to shift maintenance activities between weeks. This simple strategy is a key element in isolating the short-term, inter-temporal substitution that identifies how people tradeoff non-work time uses. It translates the way most people keep track of time into a specific element in our model of choice behavior. Total maintenance, M, is the sum of maintenance in the various weeks and is predetermined. In the absence of other considerations, if the weekly maintenance functions were the same, each individual would spend equal amounts of time each week to minimize the total time costs of reaching the fixed level of total maintenance.[4] To the extent the functions differ 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.

In our model, the alternative use of non-work time is leisure. It could be, for example, going to a movie, socializing with friends and family, or walking or jogging at a local park. For convenience we will refer to it as local recreation and denote it R^j. Recreation is produced using time spent in the activity and complementary purchased goods. Again suppressing these other inputs for notational convenience we denote the recreation production function for week j by $R^j(t_r^j)$. The marginal product of time for recreation is positive, and the marginal productivity of time in recreation is increasing over the relevant range. Larger blocks of recreation time are proportionally more useful in producing recreation.

The individual gets satisfaction from allocating time to the leisure activity (recreation) and from purchased goods. Purchased goods are denoted by x, where price has been normalized to one, and income for the period is y. She allocates non-work time and income to maximize utility subject to income and time constraints as well as to meet the maintenance requirement. Formally the individual solves the constrained maximization problem

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

This model combines elements from several earlier treatments of time. Time can make different contributions to utility through the various *R*'s. There could also be contributions from both work and maintenance time allocations. These are not explicitly entered in this definition of the choice problem because both are assumed to be pre-determined in period zero. Inverting the *J* time constraints and substituting them into the maintenance function reduces the *J*+2-constraint problem reduces to a more familiar two-constraint case with maintenance serving a role comparable to the time constraint:

$$M = \sum_j M^j(T^j - t_r^j). \tag{2}$$

Maximizing utility subject to (2) and the income constraint leads to solutions for the optimal time allocation and the indirect utility function $V(y,T^1,\ldots,T^J,M)$. With λ and μ, the Lagrangian multipliers for money and maintenance, respectively, the Envelope Theorem implies $V_y = \lambda$ and $V_M = \mu$. More importantly we also have:

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

The marginal utility of time depends on the marginal product of time in maintenance. As a result, the marginal opportunity cost of time can be defined in terms of this household production activity where time displacement is possible.

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

Maintenance's role as a recurring activity offers repeated time allocations, which provide opportunities for short term adjustments. Properties of the maintenance activity imply 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. If little time is spent on maintenance, the marginal productivity of maintenance effort is high, and the opportunity cost of spending that time in leisure activities is also high. As a consequence, the shadow value of different blocks of leisure time will depend on their size (i.e., the amount of time that must be "assembled"). For a given individual these choices can result in differing marginal values of time for leisure activities of different lengths.

IV. EMPIRICAL STRATEGY

The model in the last section is based on choices within individual weeks, and the time spent in both recreation and maintenance can vary by week. The marginal value of time for recreation in a given week will vary depending on the marginal product of maintenance, which in turn depends on the time spent on maintenance that week. Implementing the model requires estimates of the household production function for maintenance. Those estimates must be based on a survey of household maintenance behavior. Our survey solicits time budgets for a "typical" week. The response of a household represents a mean allocation of time. Because of this the estimating equation is based on a simplified version of the model in section 3. The estimates also use the responses to a stated preference question that provides an "external" opportunity to obtain maintenance services. This opportunity is defined with a question that offers the possibility of purchasing (at a fixed hourly price w_s) regularly scheduled hours of weekly services that can be used for maintenance (i.e., lawn services, cleaning services, and a variety of other time saving market services).

For the empirical model assume an individual's utility for a representative week is given by $U(x,H;M)$ where M is average time per week devoted to maintenance and is predetermined as before.[5] H represents leisure of all types. Let the individual's labor devoted to household maintenance production be L and purchased hours of maintenance service labor be 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

$$M = f(L) + L^S. \tag{4}$$

Utility is maximized subject the budget constraint $y = x + w_s L^S$, where x is the numeraire, 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

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

There are two types of solutions to this utility maximization problem. The first involves individuals who purchase a positive amount of service at the offer price, resulting in an interior solution. In this case, the value of time in a typical week with the option of purchased maintentance services, ρ^s, is

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

In the second case we have individuals who choose not to purchase service at the offered price. As a result, it is not possible to collapse the maintenance and time constraints into the budget constraint. The value of time for these individuals is determined by a corner solution in the purchased service market:

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

where μ is the Lagrange multiplier for the maintenance constraint.

Estimating equations can be derived from (6) and (7). Using censored regression and a specification for f we can estimate a transformation of the weak inequality given in equation (8),

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

where L is the amount of own maintenance labor when the service is available at a price w_s and ρ^s is the mean value of time, which is determined in period zero. We use the Feather and Shaw (2000) approach, discussed in section 2, to estimate that long run work/leisure tradeoff. The responses to our actual and hypothetical behavior survey questions allow equation (8) to be estimated. Our description of the hypothetical service is presented in the next section.

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:

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

Since labor decisions and overall maintenance levels are determined in period zero, the marginal utilities of income and of maintenance are constant over the short time period that is the focus of this analysis. Thus, the primary influence on the short run value of time from equation (3) will be due to time allocated to maintenance. With estimates for the marginal product of maintenance as well as the long horizon shadow wage, our model allows estimation of the time cost of varying leisure time allocations.

V. DATA

Between May and September 2003 a mail survey was sent to a sample of homeowners in Wake County, North Carolina, USA. The target population was homeowners who had purchased their homes between 1992 and 2001. A random sample of 9,000 of these households, stratified by geographical location, was drawn from this population. To verify that the survey would be sent to the owner (and resident) of the house, the addresses listed for tax purposes were cross checked with names and addresses of the individuals purchasing each house. The sample was limited to cases where the addresses of the housing unit and the individual receiving the tax bill matched. 7,554 surveys reached valid addresses where it would be possible to receive a response.[8] The Dillman (1978) method for mailed surveys was followed with two mailings and a reminder postcard. Returned surveys amounted to 31.7 percent of the mailings to correct addresses. After screening for missing and implausible values, there were 1,719 useable responses for this analysis.[9] Thus, the sample for this analysis is less than the number of returned valid questionnaires due to item non-response.

Our response rate is at the lower end of what conventionally has been considered desirable based on experience in the nineties. However, recent research on the topic suggests that low response rates alone do not signal non-response bias. For example, Holbrook, Krosnick, and Pfent (2005) conclude their detailed evaluation of 100 random digit dialed telephone studies over a 10 year period noting that "…lower response rates seem not to substantially decrease demographic representativeness within the range we examined" (p.38).[10] Our comparison with Census information suggests our survey is consistent with their findings. To confirm this, we estimated a selection model. The results are virtually identical to those from the estimation described here. The coefficient of the inverse Mills ratio is not significant at the 5% level and the coefficients of each of the variables are not different between the two equations. There is also no economically significant difference in the resulting marginal values of time. Since non-response bias appears to make no significant difference, we have not included the adjustment for it here.[11]

Two aspects of the questionnaire are directly relevant to our model. 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. The survey also includes questions about how much paid help the household hired for maintenance services, and whether they could freely choose how much time they allocated to each of the activities. In addition, we asked about the flexibility they had in their work time. Our survey also asked about labor supply choices using the same question developed by Feather and Shaw (2000).[12]

Second, each household was asked about a personal assistance service (i.e., the stated choice question discussed earlier) that offers a substitute for each respondent's time in household tasks. 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. The framing of the question implies that it could be used for any of the activities undertaken by adults in the household. We assume all hours allocated to household maintenance can be aggregated. The personal assistant question was followed by several regarding how respondents would use any time made available by purchasing the service. The specific question about the potential purchase is reproduced in Appendix A.[13] We also collected information on the earnings and non-labor income of the household, job characteristics, and a variety of other socio-economic variables. The variables used and their descriptive statistics are given in the first three columns of Table 1.

Households' reports of the 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* were assumed to correspond to maintenance. Following the assumption of unitary household[14] the times reported for the respondent and the spouse or partner (if present) were combined. The amount of time for household maintenance is assumed to be the sum of times reported in these four categories. Time allocated to maintenance when the hypothetical personal services are available is estimated by subtracting stated time purchases from the baseline measure of their time allocated to maintenance.[15]

VI. EMPIRICAL IMPLEMENTATION AND RESULTS

Specifications

Our estimation of the short-run value of time function for households requires estimates of the long-run shadow wage, which is determined in period zero. The Feather and Shaw (2000) framework assumes the market and shadow wages are equal for respondents with flexible work schedules. 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. Assuming normally distributed errors, a maximum likelihood estimator is used to estimate the parameters of the shadow wage and market wage functions.

Our specifications for these functions follow the Feather and Shaw application. The shadow wage function includes a constant and variables for work hours, non-work income, spouse work hours, and qualitative variables indicating the presence of young children, gender, and an interaction term between gender and the presence of young children. The market wage function includes a constant and variables for age, education, and indicators of race and gender. The parameter estimates are given in Appendix B. The estimates are generally consistent with *a priori* expectations with most coefficients significant at conventional levels. For the individuals in our sample, the mean predicted shadow wage is $26.64 and the median is $19.61 (in 2003 dollars).

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. We focused on two specifications for this function, a log form and a quadratic form. The results were quite comparable. Since the quadratic form introduces more flexibility, those results are presented here.[16]

The simple quadratic household production is given in equation (10).

$$TP = aL^2 + bL \tag{10}$$

This form allows testing for diminishing MP. A vector z including any observable individual/family characteristics that might influence productivity can be included in this equation. Inverting the marginal product function and using the equality form of the first order condition given in equation (8) (recalling that ρ^s is the shadow wage and w_s is price of personal services), the estimating equation is then equation (11).

$$L = \beta_0 + z\beta_z + \beta_1\left(\frac{\rho^s}{w_s}\right) + \varepsilon \tag{11}$$

Algebraic transformations allow the structural parameters of the marginal product for time in maintenance to be recovered from the estimated coefficients. That is: β_1=1/(2a) and $\beta_0 + z\beta_z$ =−b/(2a), or a=1/(2β_1) and b=−2a($\beta_0 + z\beta_z$). Thus, the prediction would be β_0>0 and β_1<0. With this functional form, the marginal product may not be strictly positive even for parameters with the theoretically predicted signs, so this can be tested empirically as well.

Results

The dependent variable is the number of hours devoted to household maintenance. We use maximum likelihood assuming a censored normal distribution for the error. The estimates are presented in columns 4 through 7 of Table 1. Column four reports a parsimonious specification limited to include relative price and a constant. Even in this specification, the marginal product is positive in the range of the data and diminishing as expected. Our two step estimation strategy uses an estimate of the conditional expectation for ρ^S in the numerator of the ratio of shadow value to service price. As a result, the estimated model can be expected to have a non-spherical error. To take account of this issue, all of our tests use Huber's (1967) robust covariance matrix for the estimated model parameters.

We hypothesized that the characteristics of households also play an important role in explaining the differences in behavior with respect to maintenance. Column five of Table 1 provides the results for a more complete specification. There are a number of factors that play a significant role in the maintenance decisions. Households with higher labor income and thus probably higher opportunity costs of time do less own maintenance. Households where a "significant other," typically a spouse, is present do more own maintenance production. Recall that maintenance is the sum of both members' home production, so this does not represent any substitution within the household but rather a difference by household type. The number of family members in the house also increases maintenance. There is partial support for the logic associated with our unitary household model in that the sex of the respondent was not a significant variable in this or other specifications and was not included. Similarly, race was never significant and was omitted. Age is not significant here but was included since it had explanatory power in other specifications.

The difference in the number of hours worked by the respondent compared to his or her spouse is also hypothesized to influence reported own maintenance. Our formulation of this effect codes this variable as 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 negative one if the respondent works at least ten hours less than the spouse. This variable was included to control for any differences in perceptions depending on the relative workforce participation of the respondent.[17] It is not significant in column 5 but is in the more complete specification in column 6. This pattern is repeated with the work flexibility variable.

The sixth column in the table reports the last and most complete specification of the model. The first of the additional variables uses the number of non-work hours calculated in two ways. The first uses the number of hours in a week and subtracts the number of hours that respondents reported they devoted to all employment plus the time spent commuting plus an allowance for time spent sleeping. We expect the respondent to be quite accurate in reporting work and commute time. As a result, this measure probably represents a fairly accurate measure of non-work time. The second strategy simply uses the total of all the time reported for non-work activities.[18] The difference in the two measures captures the accuracy and completeness of the respondent's accounting for non-work time.[19] 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 included in this full specification are based on the responses to the question about what survey respondents 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. Finally, the time flexibility measure is positive and significant, whereas in the previous specification it was not significant. Households where there was flexibility in shifting the work schedule devote more time to household maintenance. Diminishing marginal product in household maintenance is more of an issue if work hours cannot be shifted, so this is a plausible result.

This last specification of the quadratic model is our preferred model and is used in calculating the marginal value of different blocks of time. In estimating the household's maintenance services production function, we used the exogenous price of purchased services that was given in the survey. However, the individual's value of time is based on her actual choices. To calculate the value using equation (6), we use the marginal product of own labor, calculated at the actual level of household services. 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. Table 2 provides the quantiles of the distribution of the predicted marginal value of time for blocks of leisure time that displaced 2, 4, 6, and 8 maintenance hours, as well as the long-run shadow value of time of these individuals.

The marginal value of time increases as the blocks of recreation time become longer, as hypothesized. Non-work choices convey information about the value of time. To use these choices effectively, we must recognize the constraints on how time must be "assembled" to undertake activities and evaluate how people make choices that allow them to put time blocks together.

VII. CONCLUSIONS

People's choices about their time allocations are made sequentially with some choices serving as commitments that constrain others that come later (at least until the consequences are important enough to warrant incurring the costs of revision). In this paper we have shown that it is possible to use recognition of these commitments to estimate a short-run shadow value of time. Many leisure time activities take place in relatively small blocks of time, and the value of time may differ depending on the size of the block. Our strategy for valuing time for non-working activities has used information from revealed and stated preferences and decisions made over different time horizons. The results indicate that the marginal value of time can be increasing as the size of the block time increases.

This framework seems likely to have applicability for a wide range of extra-market valuation problems. In particular there has been recent discussion of methods needed for augmenting the national income and product accounts to reflect non-market activities (see Nordhaus, 2006; and Frazis and Stewart, 2004) as well as attention to non-work time allocation in general. As we have shown, the frequency and timing of the non-market activities matter and short-run time constraints and the production technology imply a shadow value of time (and hence opportunity cost of the non-market output) that need not be equal to the wage rate nor constant. Our research shows how a strategic stated preference question might be used to define the non-market commodity, partially understand its production technology, and assess its shadow value. As well, we demonstrate the importance of including questions in time use surveys that acquire information about the decisions on how much home production to undertake as a means of gauging short-run time constraints and values.

Finally, our method highlights a new role for stated choice questions. Most applications have focused on new choices, offering individuals the opportunity to decide about an amenity that has previously been outside their choice set. In addition, many previous efforts at joint estimation were 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. This new information can be combined with data on actual time allocation decisions to derive new insights on the tradeoffs people implicitly make through a sequential set of market and non-market choices.

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Table 1: Descriptive Statistics and Parameter Estimates

Variable	Mean	Std. Dev.	Quadratic Model Estimated coefficient (Robust z-statistic)		
Constant	-	-	115.42 (32.20)	59.76 (6.05)	60.24 (8.19)
Shadow wage/ personal services price	2.24	3.71	-2.29 (-4.24)	-2.11 (-4.49)	-2.50 (-7.51)
Respondent's labor income	65346.8	50477.3		-1x10-4 (-4.66)	-1.4x10-4 (-5.73)
Spouse, etc. in household	.866	-		27.11 (4.86)	41.30 (8.68)
Number of family members in house	2.97	1.36		12.49 (8.32)	10.13 (8.77)
Age	44.46	9.84		-0.153 (-0.82)	.056 (0.38)
Work distribution in household	0.18	-		2.81 (1.00)	4.98 (2.31)
Flexibility in work hours	0.12	-		8.50 (1.41)	12.37 (2.61)
Completeness of response	-69.49	52.01			0.37 (14.68)
Choose more paid work	0.04	-			-31.68 (-6.18)
Choose more housework	0.20	-			-43.49 (-11.49)
Sigma			55.24	44.97	33.97
Log Likelihood			-2104.82	-1836.23	-1718.66
# of obs.			1907	1719	1719
# uncensored			310	282	282

Table 2: Quantiles of Marginal Value of Time for Blocks of Different Lengths
(Based on the Quadratic Model with all socio-economic variables)

Quantile	Baseline	2-hour block	4-hour block	6-hour block	8-hour block
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: Excerpt from survey

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	☐
2	$5.50 x 2 = $11	☐
3	$5.50 x 3 = $16.50	☐
4	$5.50 x 4 = $22	☐
5	$5.50 x 5 = $27.50	☐
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

*Prices of $5.50, $8, $10, $20,$30, and $50 were used on different versions of the survey.

Appendix B: Shadow Wage Estimation

Feather and Shaw Model Parameter Estimates[a]

Shadow wage variables	Estimate	t-statistic
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
Market wage variables		
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
Error variance		
Std. dev. Shadow wage	2.5543	39.176
Std. dev. Market wage	3.2322	39.085
Correlation[b]	1.7867	4.857

[a]Dependent variable is the natural log of the wage rate
[b]correlation is ρ=exp(δ)/1+exp(δ) where δ is estimated

Notes

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[1] Recently some research has focused on individuals whose occupations allow labor supply adjustments over short intervals. The findings from these studies have created some controversy (Camerer, et al., 1997; Farber, 2005) about whether labor/leisure choices can be interpreted as responding to the tradeoffs underlying the conventional labor supply model.

[2] DeSerpa's model builds on the insights of Becker (1965) and Johnson (1965).

[3] In a very different context, the model in Hamermesh (2005) discusses the costs of shifting activities between periods to gain variety. His model suggests that variety contributes to utility, but routine behavior reduces the costs of the activity.

[4] This notion is consistent with Hamermesh's (2005) treatment of the role of household production for the timing of activities:

> "Routine (selecting the same time for the same activity and repeating it at the same time over several periods) is productive, in that it enables the producer/consumer to mechanize decisions about when and how to engage in each activity, thus allowing her to produce/consume more of each commodity" (p.82, parenthetical description inserted).

[5] Since total maintenance over the time periods is predetermined as is the number of time periods, the average per period is predetermined.

[6] In this empirical model we use L to denote own maintenance labor to distinguish the amount of planned labor in the typical week 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] This figure reflects adjustment for changes that were not captured with the cross check of tax records. These include household re-location, death, age limiting a designated respondent's ability to answer, and mail loss.

[9] 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.

[10] Response rates in the studies these authors considered ranged from 4 percent to 70 percent. A second study by Keeter et al. (2000) compared a "standard" and "rigorous" survey using identical questionnaires. The standard realized a response rate of 36 percent and the rigorous 60.6. The authors considered 96 comparisons, no difference exceeded 9 percentage points and the average difference was 2 points.

[11] Details of the estimation controlling for non-response are available in an appendix available from the authors.

[12] In the questions preceding the time allocation questions, to orient respondents to time related choices, the survey also asked about a variety of time-saving market products and services they may have used recently.

[13] The complete sections of the survey on time use and time-saving activities are available from the authors on request.

[14] This survey had one interview. It was not possible to exploit the panel structure Couprie (2007) used to identify a collective model for the household. We are forced to maintain the assumption of a unitary household. There is nothing in the conceptual structure that would preclude this extension.

[15] 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.

[16] The results for the log form are available from the authors.

[17] Recall that the dependent variable is the combined hours of maintenance in the household and not hours done by the respondent.

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

[19] See Kahneman et al. (2004) for related discussion of this issue.