A Microeconomic Theory-based Latent Class Multiple Discrete-Continuous Choice Model of Time Use and Goods Consumption

Sebastian Astroza
The University of Texas at Austin
Department of Civil, Architectural and Environmental Engineering
301 E. Dean Keeton St. Stop C1761, Austin, TX 78712, USA
Phone: 512-471-4535, Fax: 512-475-8744
Email: sastroza@utexas.edu

Abdul Rawoof Pinjari
University of South Florida
Department of Civil and Environmental Engineering
4202 E. Fowler Ave., ENC 2503, Tampa, FL 33620, USA
Phone: 813-974-9671, Fax: 813-974-2957
Email: apinjari@usf.edu

Chandra R. Bhat *(corresponding author)*
The University of Texas at Austin
Department of Civil, Architectural and Environmental Engineering
301 E. Dean Keeton St. Stop C1761, Austin, TX 78712, USA
Phone: 512-471-4535, Fax: 512-475-8744
Email: bhat@mail.utexas.edu
and
The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong

Sergio R. Jara-Díaz
Universidad de Chile
Transport System Division
Casilla 228-3, Santiago, Chile
Phone: (562) 29784380, Fax: (562) 6894206
Email: jaradiaz@ing.uchile.cl

ABSTRACT
This paper develops a microeconomic theory-based multiple discrete continuous choice model that accommodates: (a) both time allocations and goods consumption as decision variables in the utility function, (b) both time and money budget constraints governing the activity participation and goods consumption decisions, (c) a finite probability of zero consumptions and zero time allocations (*i.e.*, corner solutions), and (d) technical constraints in the form of minimum consumption levels for any good that is consumed and minimum time allocation for any activity conducted. The proposed model is applied in the form of a latent class model (to consider heterogeneity) on a Dutch dataset to understand the determinants of weekly time use and goods consumption behavior.

1. INTRODUCTION

To explain individuals' activity participation and travel behavior, the traditional, goods consumption-based consumer theory requires the incorporation of time along with goods into the utility functions, their interrelations, and the recognition of constraints on available time and money (*1–3*). These models are able to disentangle different values of time estimates: value of time as a resource, value of working time, and value of assigning time to an activity/travel. This capability is important for the evaluation of transportation policies, because the benefits of travel time reductions can be economically measured using the different estimated values of time.

Although the microeconomic time use models have been gaining traction in the recent past, they are still saddled with at least a couple of limitations. First, traditional microeconomic models were used to analyze consumption among broad consumption categories (housing, education, etc.). In such analyses, allowing zero consumptions (or corner solutions) was not necessary; this property was extended when time was included. However, modern activity-based, time use and goods consumption analysis requires a detailed categorization of activities and goods, due to which the consideration of corner solutions becomes important. Second, model formulations should allow the presence of minimum necessary amounts of time for taking part in activities (*e.g.* minimum necessary time for eating). The few microeconomic models that allow minimum time allocations in the form of technical constraints do not simultaneously allow for corner solutions (*i.e.*, non-participation of activities; see for example, DeSerpa (*2*), Jara-Díaz *et al*. (*4*), Jara-Díaz and Astroza (*5*), or Jara-Díaz *et al*. (*6*)).

In the past decade, a separate stream of research has made significant advances in the context of using sophisticated utility functions for modeling individuals' time-use choices while allowing corner solutions. For example, the multiple discrete-continuous extreme value (MDCEV) model proposed by Bhat (*7*) is based on a microeconomic utility maximization formulation with random utility functions that are easy to interpret, accommodates corner solutions, and yields closed form probability expressions for observed time allocation patterns. Such multiple discrete-continuous (MDC) model formulations have been applied largely for contexts with time allocations to activities as the only decision variables entering the utility function and a single budget constraint associated with time, which leaves goods consumption out of the picture. In the recent literature, however, there is an increasing recognition that both time allocations and goods consumption generate utility and that both time and money budget constraints govern time use and consumption decisions (*5*, *8*, *9*); albeit none of these studies recognize corner solutions in time allocations or goods consumption. More generally, there has been limited research on the use of multiple types of decision variables and multiple constraints within the context of MDC models (*9–11*). Castro *et al*. (*9*) presented the multiple constraint-MDCEV (or MC-MDCEV) model structure, considering two constraints: a monetary budget constraint and a time constraint. However, the formulation does not consider both time allocations and goods consumption separately as decision variables in the utility function, and does not accommodate technical constraints, such as minimum values for the decisions variables.

The aim of this paper is to develop a microeconomic theory-based MDC choice model that considers: (a) both time allocations and goods consumption separately as decision variables in the utility function, (b) both time and money constraints as determinants of activity participation and goods consumption decisions, (c) a finite probability of zero-consumptions and zero time allocations (*i.e.*, corner solutions), and (d) technical constraints in the form of minimum consumption levels for any good that is consumed and minimum time allocation for any activity pursued. In addition, following Jara-Diaz *et al*. (*6*), our utility function includes time assigned to work also as a decision variable (*i.e.*, work duration is endogenously determined) along with the time allocations to non-work activities. The work activity provides the link between the two constraints (monetary budget and total available time) and represents the trade-offs portrayed in our model; individuals may assign more (less) time to work to generate more (less) money for buying more (less) goods, but less (more) free-time to perform non-work activities. The application of our proposed model to different segments of the population allows the analyst to capture demographic heterogeneity in preferences and to estimate values of time that vary based on observed demographic variables such as gender, age, and income (see Konduri *et al*. (*8*), Jara-Díaz and Astroza (*5*), and Jara-Diaz *et al*. (*6*)). In this paper, we capture heterogeneity in preferences using the latent class model formulation that allows a discrete-mixture distribution for model parameters based on observed demographic variables allowing the analyst to endogenously segment the population (see Bhat (*12*)).

We apply the proposed model to a 2012 Dutch data set on weekly time use and goods consumption. The empirical model is used to understand the sociodemographic determinants of time allocation and goods consumptions as well as to derive different values of time – value of work time and value of leisure (non-work) time. We compare these values of time with those from other time use models in the literature that: (1) ignore corner solutions and minimum consumptions and/or time allocations, and (2) ignore that goods consumptions also enter the utility functions along with time allocations. We also demonstrate that the latent class model helps identify different segments of the population, each one of them with distinct preferences and values of time. To our knowledge, this is the first effort that brings together a multitude of recent advances in microeconomic time use modeling and MDC choice modeling – (1) utility specified as a function of both time allocation to activities and consumption of goods, (2) explicit recognition of both time and money constraints, (3) inclusion of work time in the utility function as well as a generator of income needed for consumption, (4) corner solutions in both time allocation and goods consumption, and (5) technical constraints in the form of minimum time allocations and minimum goods consumptions, and (6) endogenous market segmentation to capture heterogeneity – into a unified framework that is behaviorally more realistic than earlier models and offers useful empirical insights on the determinants of values of leisure and work time.

2. METHODOLOGY

Consider an individual q (q = 1, 2, …, Q) belonging to a segment g (g = 1, 2, …, G) who maximizes his/her utility of consuming different goods k (k = 1, 2, …, K) and time allocations to different non-work activities n (n = 1, 2, …, N) and work activity w, subject to two binding constraints, as below:

$$\max\left(U_q(\boldsymbol{x}_q,\boldsymbol{t}_q,t_{qw})\,|\,(q\in g)\right)=\sum_{k=1}^{K}u_{gk}(x_{qk})+\sum_{n=1}^{N}\tilde{u}_{gn}(t_{qn})+\tilde{u}_{gw}(t_{qw}) \tag{1}$$

$$\sum_{k=1}^{K}p_{qk}x_{qk}=E_q+\omega_q\,t_{qw}, \tag{2}$$

$$\sum_{n=1}^{N}t_{qn}+t_{qw}=T_q, \tag{3}$$

In Equation (1), $U_q(\boldsymbol{x}_q,\boldsymbol{t}_q,t_{qw})\,|\,(q\in g)$ is a quasi-concave, increasing and continuously differentiable utility function with respect to consumption of goods and time allocation to activities, given that individual q belongs to market segment g. Specifically, $\boldsymbol{x}_q$

$(= x_{q1}, x_{q2}, ..., x_{qk}, ..., x_{qK}\, ; x_{qk} \geq 0,\ \forall k = 1, 2, \ldots, K)$ is the vector of consumption of different goods, $\boldsymbol{t}_q$ $(= t_{q1}, t_{q2}, ..., t_{qn}, ..., t_{qN}\, ; t_{qn} \geq 0,\ \forall n = 1, 2, \ldots, N)$ is the vector of time allocation to different non-work activities, and t_{qw} is the time allocation to work.

Equation (2) is the money budget constraint, where p_{qk} is the unit price of consuming good *k* for individual *q*, E_q is the non-work income of individual *q* minus fixed expenses such as housing and utilities, and ω_q is the individual's wage rate. Equation (3) is the time budget constraint, where T_q is the total available time for individual *q*. It is worth noting here that our model is implemented for individuals from single-worker households.

Note from Equation (1) that the utility function is defined as an additively separable function of sub-utilities derived from consuming goods, $u_{gk}(x_{qk})$, sub-utilities derived from allocating time to non-work activities, $\tilde{u}_{gn}(t_{qn})$, and sub-utility from the time allocated to work, $\tilde{u}_{gw}(t_{qw})$. The functional from of the sub-utilities follows the linear expenditure system (LES) utility form originally proposed by Bhat (*7*), which was extended by Van Nostrand *et al.* (*13*) to accommodate minimum required consumptions and time allocations, as below:

$$
\begin{aligned}
u_{gk}(x_{qk}) &= \psi_{qgk} x_{qk} && \text{if} \quad x_{qk} \leq x_{qk}^0 \\
&= \psi_{qgk} x_{qk}^0 + \gamma_{qgk} \psi_{qgk} \ln\left(\frac{x_{qk} - x_{qk}^0}{\gamma_{qgk}} + 1 \right) && \text{if} \quad x_{qk} > x_{qk}^0 \\
\tilde{u}_{gn}(t_{qn}) &= \tilde{\psi}_{qgn} t_{qn} && \text{if} \quad t_{qn} \leq t_{qn}^0 \\
&= \tilde{\psi}_{qgn} t_{qn}^0 + \tilde{\gamma}_{qgn} \tilde{\psi}_{qgn} \ln\left(\frac{t_{qn} - t_{qn}^0}{\tilde{\gamma}_{qgn}} + 1 \right) && \text{if} \quad t_{qn} > t_{qn}^0 \\
\tilde{u}_{gw}(t_{qw}) &= \tilde{\psi}_{qgw} t_{qw}^0 && \text{if} \quad t_{qw} \leq t_{qw}^0 \\
&= \tilde{\psi}_{qgw} t_{qw}^0 + \tilde{\psi}_{qgw} \ln(t_{qw} - t_{qw}^0) && \text{if} \quad t_{qw} > t_{qw}^0
\end{aligned}
\tag{4}
$$

where x_{qk}^0 is the minimum required consumption of good *k* (if it is consumed), t_{qn}^0 is the minimum amount of time required to conduct activity *n* (if that activity is conducted), and t_{qw}^0 is the minimum required duration for work.[1] As discussed in Van Nostrand *et al.* (*13*), the utility derived from consuming a good (time allocation to a non-work activity) increases linearly until the minimum required amount of consumption (time) is allocated to that good (activity), after which the functional form takes a non-linear shape to allow diminishing marginal utility. Due to this

[1] We considered, as with many previous studies (*4*, *14*), exogenously given minimum levels of good consumption and time allocation. Endogenously determining the minimum levels is beyond the scope of this paper. Specifically, x_{qk}^0 is set as the observed minimum level of consumption of good *k* in the dataset, t_{qn}^0 is set as the observed minimum level of time allocation to activity *n*, and t_{qw}^0 is set as the observed minimum work duration minus 1. Note that the minus 1 in the utility function of work activity ensures that the function is defined and continuously differentiable at all values of t_{qw}. While this assumption is made for algebraic convenience, it is innocuous because one can interpret t_{qw}^0 as one unit less than the minimum required work duration (as opposed to the minimum work duration).

functional form, if a good is consumed (time is allocated to an activity), the consumption (time allocation) has to be greater than the minimum values defined above. Note also that the functional form for $\tilde{u}_{gw}$ implies that work plays the role of an '*essential alternative'* that is always allocated a positive amount of time by all workers. For all goods and non-work activities, the functional form allows corner solutions (*i.e.*, zero consumptions or time allocations) because of the presence of +1 in the utility form (see Bhat (*7*)).

For an individual q who belongs to segment g, ψ_{qgk}, $\tilde{\psi}_{qgn}$, and $\tilde{\psi}_{qgw}$ are the baseline marginal utility parameters associated with good k, non-work activity type n, and work activity, respectively, representing marginal utilities at zero values of the corresponding consumptions or time allocation. A greater value of the baseline marginal utility parameter for an alternative good or non-work activity suggests a greater likelihood of choice and a greater amount of consumption of that alternative. γ_{qgk} and $\tilde{\gamma}_{qgn}$ are satiation parameters for good k and non-work activity n, respectively; a greater value of the satiation parameter suggests a greater amount of consumption of that alternative.

The optimal values of goods consumption, non-work time allocation, and work time allocation may be solved by forming the following Lagrangian function for the optimization problem in Equations (1-3) and deriving the Karush-Kuhn-Tucker (KKT) conditions of optimality. The Lagrangian function for the individual q given he/she belongs to segment g corresponds to:

$$l_{qg}\left(\boldsymbol{x}_q, \boldsymbol{t}_q, t_{qw}, \lambda_{qg}, \mu_{qg}\right) = U_q(\boldsymbol{x}_q, \boldsymbol{t}_q, t_{qw}) + \lambda_{qg}\left(E_q + \omega_q\, t_{qw} - \sum_{k=1}^{K} p_{qk} x_{qk}\right) + \mu_{qg}\left(T_q - t_{qw} - \sum_{n=1}^{N} t_{qn}\right) \quad (5)$$

where λ_{qg} and μ_{qg} are segment g-specific Lagrangian multipliers for the budget and time constraints, representing the marginal utilities of expenditure and time, respectively (i.e., the marginal utilities due to a marginal relaxation of the time and budget constraints, respectively). The KKT conditions for optimal consumption and time allocations (x^*_{qk}, t^*_{qn} and t^*_{qw}) are as below:

$$\begin{aligned}
&u'_{gk}(x^*_{qk}) - \lambda_{qg}\, p_{qk} = 0 \ \text{ if } x^*_{qk} > 0,\ k = 1,2,...,K \\
&u'_{gk}(x^*_{qk}) - \lambda_{qg}\, p_{qk} < 0 \ \text{ if } x^*_{qk} = 0,\ k = 1,2,...,K \\
&\tilde{u}'_{gn}(t^*_{qn}) - \mu_{qg} = 0 \ \text{ if } t^*_{qn} > 0,\ n = 1,2,...,N \\
&\tilde{u}'_{gn}(t^*_{qn}) - \mu_{qg} < 0 \ \text{ if } t^*_{qn} = 0,\ n = 1,2,...,N \\
&\tilde{u}'_{gw}(t^*_{qw}) + \omega_q \lambda_{qg} - \mu_{qg} = 0
\end{aligned} \quad (6)$$

where, $u'_{gk}(x^*_{qk}), \tilde{u}'_{gn}(t^*_{qn})$, and $\tilde{u}'_{gw}(t^*_{qw})$ are the marginal utility functions, defined as:

$$\begin{aligned}
u'_{gk}(x^*_{qk}) &= \psi_{qgk} \ \text{ if } x^*_{qk} \le x^0_{qk} \\
&= \psi_{qgk}\left(\frac{x^*_{qk} - x^0_{qk}}{\gamma_{qgk}} + 1\right)^{-1} \ \text{ if } x^*_{qk} \ge x^0_{qk} \ ,
\end{aligned}$$

$$\tilde{u}'_{gn}(t^*_{qn}) = \tilde{\psi}_{qgn} \;\text{ if }\; t^*_{qn} \le t^0_{qn} \tag{7}$$

$$= \tilde{\psi}_{qgn}\left(\frac{t^*_{qn} - t^0_{qn}}{\gamma_{qgn}} + 1\right)^{-1} \;\text{ if }\; t^*_{qn} \ge t^0_{qn}, \text{ and}$$

$$\tilde{u}'_{gw}(t^*_{qw}) = \tilde{\psi}_{qgw} \;\text{ if }\; t^*_{qw} \le t^0_{qw}$$

$$= \tilde{\psi}_{qgw}(t^*_{qw} - t^0_{qw})^{-1} \;\text{ if }\; t^*_{qw} > t^0_{qw}.$$

The optimal consumptions (of goods) and time allocations (to activities) satisfy the KKT conditions in Equation (6) and the money budget and time constraints (Equations (2) and (3) respectively). Denote good 1 as the good to which the individual allocates non-zero consumption (the individual has to participate in at least 1 of the *K* purposes). The corresponding KKT condition is: $\psi_{qg1}\left(\frac{x^*_{q1} - x^0_{q1}}{\gamma_{qg1}} + 1\right)^{-1} - \lambda_{qg} p_{q1} = 0$, using which λ_{qg} may be expressed as:

$$\lambda_{qg} = \frac{\psi_{qg1}}{p_{q1}}\left(\frac{x^*_{q1} - x^0_{q1}}{\gamma_{qg1}} + 1\right)^{-1} = \frac{u'_{g1}(x^*_{q1})}{p_{q1}} \tag{8}$$

Due to the form of Equation (8), the subsequent expressions in which λ_{qg} is involved will be also expressed in reference to activity 1. Now, since all individuals assign non-zero amount of time to work (and at least 1 unit above the minimum work duration), the KKT condition for working time is:

$$\tilde{\psi}_{qgw}(t^*_{qw} - t^0_{qw})^{-1} + \omega_q \lambda_{qg} - \mu_{qg} = 0 \tag{9}$$

Replacing (8) in (9) the expression for μ_{qg} may be written as:

$$\mu_{qg} = \tilde{\psi}_{qgw}(t^*_{qw} - t^0_{qw})^{-1} + \omega_q \frac{\psi_{qg1}}{p_{q1}}\left(\frac{x^*_{q1} - x^0_{q1}}{\gamma_{qg1}} + 1\right)^{-1} = \tilde{u}'_{gw}(t^*_{qw}) + \omega_q \frac{u'_{g1}(x^*_{q1})}{p_{q1}} \tag{10}$$

Substituting λ_{qg} and μ_{qg} into Equation (6), the KKT conditions may be rewritten as:

$$\begin{aligned}
&\frac{u'_{gk}(x^*_{qk})}{p_{qk}} = \frac{u'_{g1}(x^*_{q1})}{p_{q1}} \;\text{ if }\; x^*_{qk} > 0,\; k = 2,\ldots,K \\
&\frac{u'_{gk}(x^*_{qk})}{p_{qk}} < \frac{u'_{g1}(x^*_{q1})}{p_{q1}} \;\text{ if }\; x^*_{qk} = 0,\; k = 2,\ldots,K \\
&\tilde{u}'_{gn}(t^*_{qn}) = \tilde{u}'_{gw}(t^*_{qw}) + \omega_q \frac{u'_{g1}(x^*_{q1})}{p_{q1}} \;\text{ if }\; t^*_{qn} > 0,\; n = 1,2,\ldots,N \\
&\tilde{u}'_{gn}(t^*_{qn}) < \tilde{u}'_{gw}(t^*_{qw}) + \omega_q \frac{u'_{g1}(x^*_{q1})}{p_{q1}} \;\text{ if }\; t^*_{qn} = 0,\; n = 1,2,\ldots,N
\end{aligned} \tag{11}$$

The above KKT conditions have an intuitive interpretation. For any good *k*, its optimal consumption will either be (a) positive such that its price-normalized marginal utility at optimal consumption is equal to the price-normalized marginal utility of good 1 (or any other consumed good) at its optimal consumption point, or (b) zero if the price-normalized marginal utility at zero consumption for good *k* is less than the price-normalized marginal utility of good 1 or any other consumed good. Similar is the case of time allocation, where all the activities that are performed have the same marginal utility, following a common result in time use models since DeSerpa (*2*), who proposed that all the freely chosen activities (activities that are assigned more time than the necessary minimum) have the same marginal utility. In the context of work, as in Equation (9), marginal utility of time allocated to work plus the wage rate multiplied by the marginal utility associated with relaxing the budget constraint should be equal to the marginal utility of activities that are assigned more time than the minimum necessary.

The most interesting property of this model is the ability to calculate the value of time as a resource, or value of leisure (VL), and the value of allocating time assigned to work (VW):

$$VL = \frac{\mu_{qg}}{\lambda_{qg}} = \frac{\tilde{u}'_{gw}(t^*_{qw}) + \omega_q \dfrac{u'_{g1}(x^*_{q1})}{p_{q1}}}{\dfrac{u'_{g1}(x^*_{q1})}{p_{q1}}} = \frac{\tilde{u}'_{gw}(t^*_{qw})}{\dfrac{u'_{g1}(x^*_{q1})}{p_{q1}}} + \omega_q \tag{12}$$

$$VW = \frac{\mu_{qg}}{\lambda_{qg}} - \omega_q = \frac{\tilde{u}'_{gw}(t^*_{qw})}{\dfrac{u'_{g1}(x^*_{q1})}{p_{q1}}} \tag{13}$$

Note that VL is equal to the total value of work, *i.e.*, VW plus the wage rate, a common result for time use models in which work duration enters the utility function (*2*, *4*).

2.1 Model Estimation

We introduce observed heterogeneity across individuals within segment g and stochasticity through the baseline marginal utility functions, as below:

$$\begin{aligned} \psi_{qgk} &= \exp(\boldsymbol{\beta}'_{qg}\boldsymbol{z}_{qk} + \varepsilon_{qgk}), \\ \tilde{\psi}_{qgn} &= \exp(\tilde{\boldsymbol{\beta}}'_{qg}\tilde{\boldsymbol{z}}_{qn} + \tilde{\varepsilon}_{qgn}), \\ \tilde{\psi}_{qgw} &= \exp(\tilde{\varepsilon}_{qgw}). \end{aligned} \tag{14}$$

where $\boldsymbol{z}_{qk}$ is a D-dimensional vector of observed attributes characterizing good k and individual q; and $\boldsymbol{\beta}_{qg}$ is the corresponding vector of coefficients (of dimension $D\times 1$), including alternative-specific constants to capture intrinsic preferences for each good. Similarly, $\tilde{\boldsymbol{z}}_{qn}$ is a $\tilde{D}$-dimensional vector of observed attributes characterizing individual q; and $\tilde{\boldsymbol{\beta}}_{qg}$ is the corresponding vector of coefficients, including alternative-specific constants to capture intrinsic preferences for each activity. For identification purposes, for each individual attribute entering $\boldsymbol{z}_{qk}$ in the goods consumption utility function, the coefficient for one good is normalized to zero. Similarly, the alternative-specific constant for one good is normalized to zero (*i.e.*, one good is treated as the base alternative). The time allocation utility function is normalized by treating the work activity as the base alternative (with no observed variables or a constant entering the utility function).

Using stochastic baseline marginal utility expressions from Equation (14) in the KKT conditions of Equation (11) leads to the following stochastic KKT conditions:

$$
\begin{aligned}
&\ln\left(\frac{V_{qgk}}{p_{qk}}\right)+\boldsymbol{\beta}'_{qg}\boldsymbol{z}_{qk}+\varepsilon_{qgk}=-\ln\left(\frac{1}{p_{q1}}\left(\frac{x^*_{q1}-x^0_{q1}}{\gamma_{qg1}}+1\right)\right)+\boldsymbol{\beta}'_{qg}\boldsymbol{z}_{q1}+\varepsilon_{qg1}\ \text{ if } x^*_{qk}>0,\ k=2,\ldots,K\\
&\ln\left(\frac{V_{qgk}}{p_{qk}}\right)+\boldsymbol{\beta}'_{qg}\boldsymbol{z}_{qk}+\varepsilon_{qgk}<-\ln\left(\frac{1}{p_{q1}}\left(\frac{x^*_{q1}-x^0_{q1}}{\gamma_{qg1}}+1\right)\right)+\boldsymbol{\beta}'_{qg}\boldsymbol{z}_{q1}+\varepsilon_{qg1}\ \text{ if } x^*_{qk}=0,\ k=2,\ldots,K\\
&\ln\left(\tilde{V}_{qgn}\right)+\tilde{\boldsymbol{\beta}}'_{qg}\tilde{\boldsymbol{z}}_{qn}+\tilde{\varepsilon}_{qgn}=\ln\left(\tilde{u}'_{gw}(t^*_{qw})+\omega_q\frac{u'_{g1}(x^*_{q1})}{p_{q1}}\right)\ \text{ if } t^*_{qn}>0,\ n=1,2,\ldots,N\\
&\ln\left(\tilde{V}_{qgn}\right)+\tilde{\boldsymbol{\beta}}'_{qg}\tilde{\boldsymbol{z}}_{qn}+\tilde{\varepsilon}_{qgn}<\ln\left(\tilde{u}'_{gw}(t^*_{qw})+\omega_q\frac{u'_{g1}(x^*_{q1})}{p_{q1}}\right)\ \text{ if } t^*_{qn}=0,\ n=1,2,\ldots,N
\end{aligned}
\tag{15}
$$

where,

$$
\begin{aligned}
V_{qgk}&=1\ \text{ if } x^*_{qk}\le x^0_{qk}\\
&=\left(\frac{x^*_{qk}-x^0_{qk}}{\gamma_{qgk}}+1\right)^{-1}\ \text{ if } x^*_{qk}\ge x^0_{qk}\\
\tilde{V}_{qgn}&=1\ \text{ if } t^*_{qn}\le t^0_{qn}\\
&=\left(\frac{t^*_{qn}-t^0_{qn}}{\gamma_{qgn}}+1\right)^{-1}\ \text{ if } t^*_{qn}\ge t^0_{qn}
\end{aligned}
$$

Assuming that the stochastic terms are IID type-1 extreme value distributed, the probability that an individual q (who belongs to segment g) consumes M of the K goods and assigns time to $\tilde{M}$ of the N non-work activities is:

$$
\begin{aligned}
&P_{qg}\left(x^*_{q1},x^*_{q2},\ldots,x^*_{qM},0,\ldots,0,t^*_{q1},t^*_{q2},\ldots,t^*_{q\tilde{M}},0,\ldots,0,t^*_{qw}\right)=\frac{1}{\sigma_g^{M-1}}\left[\prod_{k=2}^{M}c_{qgk}\right]\left[\prod_{n=2}^{\tilde{M}}\tilde{c}_{qgn}\right]\\
&\qquad\int_{\varepsilon_{qg1}=-\infty}^{\infty}\int_{\tilde{\varepsilon}_{qgw}=-\infty}^{\infty}\prod_{k=2}^{M}h\left(\frac{W_k\left|(\varepsilon_{qg1},\tilde{\varepsilon}_{qgw})\right.}{\sigma_g}\right)\times\prod_{n=1}^{\tilde{M}}h\left(\frac{W_n\left|(\varepsilon_{qg1},\tilde{\varepsilon}_{qgw})\right.}{\sigma_g}\right)\\
&\qquad\times\left\{\prod_{l=M+1}^{K}H\left(\frac{W_l\left|(\varepsilon_{qg1},\tilde{\varepsilon}_{qgw})\right.}{\sigma_g}\right)\times\prod_{r=\tilde{M}+1}^{N}H\left(\frac{W_r\left|(\varepsilon_{qg1},\tilde{\varepsilon}_{qgw})\right.}{\sigma_g}\right)\right\}\\
&\qquad\times f_g(\varepsilon_{qg1})f_g(\tilde{\varepsilon}_{qgw})d\varepsilon_{qg1}d\tilde{\varepsilon}_{qgw}.
\end{aligned}
\tag{16}
$$

where, $c_{qgk}=\dfrac{1}{x^*_{qgk}-x^*_{qg0}+\gamma_{qgk}}$, $\tilde{c}_{qgn}=\dfrac{1}{t^*_{qgn}-t^*_{qg0}+\tilde{\gamma}_{qgk}}$,

$$
W_k\left|(\varepsilon_{qg1},\tilde{\varepsilon}_{qgw})\right.=-\ln\left(\frac{1}{p_{q1}}\left(\frac{x^*_{q1}-x^0_{q1}}{\gamma_{qg1}}+1\right)\right)+\boldsymbol{\beta}'_{qg}\boldsymbol{z}_{q1}+\varepsilon_{qg1}-\ln\left(\frac{V_{qgk}}{p_{qk}}\right)-\boldsymbol{\beta}'_{qg}\boldsymbol{z}_{qk},
$$

$$
W_n\left|(\varepsilon_{qg1},\tilde{\varepsilon}_{qgw})\right.=\ln\left(\tilde{u}'_{gw}(t^*_{qw})+\omega_q\frac{u'_{g1}(x^*_{q1})}{p_{q1}}\right)-\ln\left(\tilde{V}_{qgn}\right)-\tilde{\boldsymbol{\beta}}'_{qg}\tilde{\boldsymbol{z}}_{qn},
$$

h is the standard extreme value density function, H is the standard extreme value cumulative distribution function, and $f_g(\varepsilon)$ is the probability density function of the extreme value distributed ε term with scale parameter σ_g. σ_g is estimable if there is price variation across different goods; its value needs to normalized (typically to 1) if there is no price variation.

The derivation thus far was based on the assumption that individual q belongs to a single segment g. Now, consider the case when individual q belongs to a finite mixture of segments. That is, the actual assignment of individual q to a specific segment is not observed, but we are able to attribute different probabilities $\pi_{qg}\ (g=1,2,\ldots,G)$ that the individual belongs to different latent segments. We require that $0 \le \pi_{qg} \le 1$, and $\sum_{g=1}^{G}\pi_{qg}=1$ using the logit link function below:

$$\pi_{qg} = \frac{\exp(\boldsymbol{\delta}'_g \boldsymbol{w}_q)}{\sum_{g'=1}^{G}\exp(\boldsymbol{\delta}'_{g'} \boldsymbol{w}_q)}, \tag{17}$$

where $\boldsymbol{w}_q$ is a vector of individual exogenous variables and $\boldsymbol{\delta}_g$ is the vector of coefficients determining the influence of $\boldsymbol{w}_q$ on the membership of individual q in segment g, with all the elements in $\boldsymbol{\delta}_1$ set to zero for identification purposes. Using these latent segmentation probabilities, the overall likelihood for observation q may be written as:

$$P_q = \sum_{g=1}^{G}\pi_{qg}P_{qg}, \tag{18}$$

and the likelihood function for the entire data may be written as:

$$P = \prod_q P_q. \tag{19}$$

The use of latent classes requires labeling restrictions for identifiability. In particular, the parameter space includes $G!$ subspaces, each associated with a different way of labeling the mixture components. To prevent the interchange of the mixture components, we impose the restriction that the constants specific to the second alternative (good) are increasing across the segments. Such a labeling restriction is needed because the same model specification results simply by interchanging the sequence in which the segments are numbered, so multiple sets of parameters result in the same likelihood function. Note that the second alternative is used for labeling restrictions because all parameters for the first alternative are fixed to zero.

3. EMPIRICAL APPLICATION

We apply the modeling methodology presented above using a Dutch data set drawn from the Longitudinal Internet Studies for the Social Sciences (LISS) panel. It is worth noting here that survey datasets of the type needed for analysis in this paper, with both time use and goods consumption (and expenditures) information, are rare. Therefore, previous studies had to resort to alternative approaches to impute data or to merge data from separate time use surveys and consumer expenditure surveys (see, for example, Konduri *et al*. (*8*).

3.1 Data Description and Sample Selection

The LISS panel is based on a probability sample of Dutch households drawn from the country's population register. Administered via the internet in the form of monthly surveys in 2009, 2010, and 2012, the LISS panel included a survey of time use and expenditures (see Cherchye *et al*. (*15*) for a detailed description). In the current paper, we will focus on the data from the latest wave (October 2012). In this survey, respondents reported: (a) their time allocation to various activities (including work) during seven days before the survey, and (b) their average monthly monetary expenditure (in euros) in 30 expense categories for 12 months before the survey. In this analysis, the monetary expenditures were considered as a proxy for goods consumption. This is because the surveyed information did not include the amount of goods consumed. To achieve consistency between activity durations and expenditures, monthly expenditures and monthly income were divided by 4 to obtain weekly expenditures and weekly income, respectively. After a sample cleaning process, the final estimation sample has 1,193 workers. A detailed description of the sample selection can be found in the online supplement available at: http://www.caee.utexas.edu/prof/bhat/ABSTRACTS/ITM/OnlineSupplement.pdf. Among these individuals, 48 percent are female; 20 percent are 18-34 years old, 37 percent are 35-49 years old, and 43 percent are 50 years or over; 29 percent have at least a graduate degree; 28 percent live alone; 39 percent live in households with children; and 84 percent live in an urban area.

3.2 Variable Specification and Model Formulation

From the various activities reported in The LISS panel, the following 11 categories of activities were constructed for the analysis: (1) work, (2) travel, (3) household chores, (4) personal care, (5) education, (6) activities with children, (7) entertainment, (8) assisting friends and family, (9) administrative chores and family finances, (10) sleeping and relaxing, and (11) going to church and other activities. A detailed description of the activity categories can be found in the online supplement mentioned earlier. There are activities that individuals must perform despite their preference to avoid those activities (e.g. commuting and other travel that must be undertaken to get to different activity locations).[2] Such activities are assigned the minimum necessary time and, therefore, can be left out of the decision variables in the empirical model. Since our time frame of analysis is a week, the total weekly time available for any individual is 168 hours (24×7 hours), from which the total time assigned to commute and other travel should be subtracted. Three of the ten activities entering the utility function – work, sleeping and relaxing, and personal care – are treated as "essential alternatives" in that all working individuals participate and spend time in these activities (*i.e.*, the corresponding utility functions were specified not to allow corner solutions).

As indicated earlier, since we only have information about expenditures in composite categories, we assume that the expenditures enter the utility functions as a proxy for consumption of goods. Therefore, the same expenditures enter the money budget constraint with unit prices. To do so, the 30 categories of expenses recorded in the database were combined into the following six composite expense categories (see Jara-Diaz *et al*. (*6*) for details about the definition of these categories): (1) commute, (2) household chores, (3) personal care, (4) education, (5) activities with children, and (6) entertainment. Note that these six categories are in the activity type categorization (*i.e.*, in the context of time allocation) as well. Among the other activities, it is reasonable to assume that work activity has no expenditures (as it generates income). It is also reasonable that the remaining five activities – assisting friends and family, administrative chores, sleeping and relaxing, and other activities – do not have expenditures. Further, similar to the time-allocation

[2] Arguably, other activities such as household chores and personal care might be considered as mere maintenance tasks. However, individuals can derive utility from household chores such as cooking, gardening, and shopping. Similarly, personal care activities such as visiting the beauty salon may also provide utility. Therefore, such activities might be allocated more than the minimum necessary time and, therefore, are part of the decision variables.

case, we assume that individuals do not incur in commuting expenses more than the minimum necessary. As a result, the expenditures (aka, goods consumption) in only the following five categories are true decision variables: household chores, personal care, activities with children, education, and entertainment (*i.e.*, $K = 5$). Further, the monetary budget available for expenditures is computed by subtracting commute expenses from the individuals' available income. Finally, note that although all individuals participated in personal care activities, not all of them spent money on associated consumptions. Therefore, while time allocation to personal care was viewed as an essential alternative, expenditure in personal care was not treated as essential (*i.e.*, corner solutions were allowed).

The descriptive statistics of activity time allocations and goods expenditures are presented in Table 1. As discussed earlier, all individuals in the sample allocate time to work, sleeping and relaxing: on average, individuals work (6.6 hrs./day), sleep/relax (8.4 hrs./day), and personal care (1.3 hrs./day). Most workers allocate some time to commute, entertainment and personal care, while education and activities with children present the lowest participation rates suggesting the importance of accommodating corner solutions for (*i.e.*, zero time allocations) to these activities. In the context of expenditures, personal care presents the highest average value and it is also the most expenditure-intensive activity (average of 10 euros/hour). Although people spend a relatively large amount of money in entertainment activities, these represent an expenditure rate of only 2.2 euros/hour, which is considerably lower than the average wage of 18 euros/hour. The values of E_q and ω_q were obtained as explained in Section 3.1. We set the minimum time allocations (t_{qn}^0) and minimum consumption of goods (x_{qk}^0) as equal to the minimum non-zero values observed in the sample for the corresponding categories (see the fifth and ninth columns of Table 1), except for the essential alternatives. The minimum work duration t_{qw}^0 and the minimum time of the essential alternatives were set to be the corresponding observed minimum duration in the sample minus 1. Finally, it is worth noting here that by minimum time allocation to an activity (consumption of a good), we mean the minimum required time allocation (consumption of the good) if the individual participates in that activity (consumed that good). The concept of minimum required time allocation (consumption) does not arise if the individual does not allocate time to that activity (consume that good).

3.3 Estimation Results

A number of different empirical specifications were explored, with different sets of explanatory variables, different functional forms of variables, and different groupings. All the demographic variables available in the data were considered for characterizing the latent segments as well as the baseline preference specification. These variables include respondents' gender, age, presence of children in the household, income level, marital status, level of education, race, household size, household location (urban or rural area), and dwelling type (renter or owner). The final specification was based on the presence of adequate observations in each category of explanatory variables, a systematic process of rejecting statistically insignificant effects, combining effects when they made sense and did not degrade fit substantially, and judgment and insights from earlier studies. To identify the appropriate number of latent segments (G), we estimated the model for increasing values of G until we reached a point where an additional segment did not significantly improve model fit. Details of the evaluation of model fit can be found in the online supplement. In our analysis, the three-segment model provided the best fit. The log-likelihood value at convergence for this model was -8,486.12. The Rho-squared value of our final model specification with respect to the naïve mode (no latent segmentation and only constants) is 0.462.

3.3.1 Latent Segmentation Variables

The first row panel in Table 2 corresponds to the probabilistic assignment of individuals to each of the three latent segments (first segment is the base). The constants in this latent segmentation part of the model contribute to the size of each segment and do not have a substantive interpretation. The other parameter estimates in the top panel of Table 2 indicate that the second segment, relative to the other two segments, is likely to have proportions of individuals who are single (*i.e.*, living alone) and individuals aged 50 years or older between that of the first and third segments, and more likely to include individuals with children and be low-income. The third segment comprises individuals who tend to belong to the old age category (older than 50), who are unlikely to be living alone, and unlikely to have children. The first segment, on the other hand, is more likely than the other two segments to consist of younger individuals and those who live alone. Similar to the third segment, this segment also has a low proportion of individuals with children. A better way to characterize the different segments is to estimate the means of the demographic variables in each segment (see Bhat (*12*). The results are presented in Table 3, which shows the means of the demographic variables in each segment as well as the overall sample (and supports our observations from the model estimation results on the characteristics of the three market segments). Based on these results, we will refer to the first segment as the "younger and singles" (YS) segment, the second as the "low income parents or single mothers" (LIPSM) segment, and the third as the "older couples without kids" (OCWOK) segment. The segment sizes are estimated and results show that LIPSM is the most prominent segment in the population (44.8%), followed by OCWOK (29.6%), and lastly YS (25.6%).

3.3.2. Variables in the Utility Functions

The second panel of rows in Table 2 presents the parameter estimates corresponding to the baseline marginal utility function specifications of the MDCEV model corresponding to each segment.[3] Within each segment, the baseline marginal utility parameters corresponding to time and/or goods consumptions utility components are presented for each demographic variable (depending on the utility functions the variable enters). The first demographic variable in the table, household size enters the utility functions of the time-allocation utility functions for two activities – assisting friends and family and administrative chores and family finances – and the expenditure (goods consumption) utility function corresponding to activities with children. As expected, people in the LIPSM segment are more likely to spend time assisting family/friends and doing administrative chores or family finances as their household size increases (see Bhat *et al*. (*16*) for similar findings). A larger family implies a greater need to spend time on these activities, especially for families with children or single-mothers. Similarly, people from larger households are more likely to expend more money on activities with children.

Another variable that impacts the baseline utilities is the household's residential neighborhood type. Workers living in urban neighborhoods are likely to spend more time and money in entertainment, perhaps because of a greater proximity (than those living in rural neighborhoods) to activity centers such as restaurants, theaters, cinema, museums, or parks. Consistent with our findings, Born *et al.* (*17*) find that individuals living in urban areas

[3] To conserve space, the alternative specific constants in the baseline marginal utility functions and the satiation parameters are not presented in the table but they are available from the authors.

participate more in out of home entertainment. Individuals who have completed graduate school are more likely to spend time and money in education (than those with lower levels of education), probably because they are more likely to continue their education or they spend for the education of other, non-workers in the household. Interestingly, well-educated individuals spend less time and less money on personal care, as can be observed from the negative coefficients on the graduate school variable in all three segments. Reasons behind this particular effect should be explored in detail in future research.

3.3.3 Values of Time

Average values of leisure time and work for each market segment identified from the latent class model are reported at the end of Table 3. Notably, the values of time for different market segments are quite different, highlighting the importance of the latent segmentation model. The OCWOK segment has the greatest value of work, followed by the YS segment, while the lowest value of work corresponds to the LIPSM segment. This is perhaps due to the following three reasons. First, workers who have children generally present a negative value of work time (*6*, *18*), indicating that they do not derive pleasure from work at the margin (*i.e.*, they would work less if they could). This is perhaps because individuals who do not have to economically support children might choose a more satisfying job than workers who need to provide for their family. An alternative explanation is that parents prefer to spend time out of work with their children (*19*). Second, younger workers (aged 50 years or less) have a smaller value of work, while older workers (aged more than 50 years) have a greater value. It is possible that younger workers, compared to older workers, have more debt or commitments (college debt, mortgage) that, to some extent, force them to choose less satisfying jobs. Furthermore, younger workers in Europe may experience different working conditions than older workers since the recent deregulation of labor markets in Europe and Netherlands lead to weaker work protection levels for younger workers (see Heyes and Lewis (*20*) for insights on how labor deregulation has impacted employment among younger individuals in Europe). Also, earlier studies have shown that older workers generally have more positive job attitudes (such as overall job satisfaction, satisfaction with work itself, satisfaction with pay, job involvement, or satisfaction with coworkers) than younger workers (see Mather and Johnson (*21*), and Ng and Feldman (*22*)). Third, income is a relevant determinant of value of time. Our results show that lower income workers (monthly income less or equal to 3,000 euros) have a lower valuation of time than higher income workers.

3.4 Comparison with Alternative Model Formulations

We compared our models results with those from three alternative model formulations. One of them is a simpler version of our model that does not allow corner solutions, called an "all essential alternatives model":

$$\max U(\boldsymbol{x},\boldsymbol{t},t_w)=\sum_{k=1}^{K}\psi_k\ln(x_k-\vec{x}_k^{\,0})+\sum_{n=1}^{N}\tilde{\psi}_n\ln(t_n-\vec{t}_n^{\,0})+\tilde{\psi}_w\ln(t_w-t_w^0)$$

$$\sum_{k=1}^{K}p_k x_k=E+\omega t_w, \tag{20}$$

$$\sum_{n=1}^{N}t_n+t_w=T$$

In the above equation, $\vec{x}_k^0$, $\vec{t}_n^0$, and t_w^0 correspond to exogenous minimum consumption for good *k,* exogenous minimum time allocation for activity *n,* and exogenous minimum duration for work respectively. These values are computed as the observed minimum in the sample minus one. Note that the minus one ensures that the utility function is defined at zero consumption values as well.

The second formulation is the MC-MDCEV model proposed by Castro *et al.* (*9*) whose utility specification is only a function of time allocation (but not goods consumption) and does not allow for minimum time allocation, as below:

$$\max U(\boldsymbol{x}) = \sum_{k=1}^{K} \frac{\gamma_k}{\alpha_k} \psi_k \left(\left(\frac{x_k}{\gamma_k} + 1 \right)^{\alpha_k} - 1 \right)$$

$$\text{s.t.} \quad \sum_{k=1}^{K} p_k x_k = E \qquad \sum_{k=1}^{K} g_k x_k = T \tag{21}$$

The third formulation is the Jara-Díaz *et al.* (*4*) model which specifies utility as a Cobb-Douglas form which is function of both time allocation and goods consumption as well as allows for minimum time allocation but without allowing for corner solutions (zeros) in time allocation or consumptions, as below:

$$\max U(\boldsymbol{x}, \boldsymbol{t}, t_w) = \Omega t_w^{\theta_w} \prod_n t_n^{\theta_n} \prod_k x_k^{\varphi_k}$$

$$\sum_{k=1}^{K} p_k x_k = E + \omega t_w, \quad \sum_{n=1}^{N} t_n + t_w = T, \quad x_k \geq x_k^0, \quad t_n \geq t_n^0 \tag{22}$$

For each individual in the sample, we computed the probability that he/she belongs to each of the three segments (see Equation 17) and we deterministically assigned the individual to one of the segments following those probabilities. Then we computed the values of time within each of the segments. The values of time implied from these alternative models are presented in the last three rows of Table 3 and those implied from our proposed model are presented in the last but fourth row of the table. It can be observed that all the three alternative models overestimate the values of time allocated to both work and leisure. The first alternative model and the Jara-Díaz *et al.* (*4*) formulation do not allow corner solutions and do not allow minimum consumptions and minimum time allocations. In the Castro *et al.* formulation, a linear relation is assumed between time assigned to activities and the expense associated to those activities using money prices of time allocation to different activities. This not only creates a transformation between money and time that is not necessarily always true but also precludes the inclusion of goods consumed (or expenditures for consuming goods) in the utility functions. Also, the Castro *et al.* formulation does not consider minimum consumptions. Therefore, one can conclude that either ignoring corner solutions and minimum consumptions or ignoring goods consumption in time use models can lead to overestimation of the values of leisure and work times.

4. CONCLUSIONS

This paper develops a microeconomic theory-based MDC choice model that considers utility functions with both time allocation to activities and goods consumption as decision variables, time and money budget constraints, corner solutions, and technical constraints in the form of minimum consumptions and minimum time allocations. The proposed model is applied in the form of a latent class market segmentation model (to consider heterogeneity) on a Dutch dataset. The empirical model is used to understand the sociodemographic determinants of time allocation and goods consumptions behavior as well as to derive different values of time – value of work time and value of leisure (non-work) time. The latent class model helped identify three market segments – "younger and singles", "low income parents or single mothers", and "older couples without kids" – based on differences in the time allocation and goods consumption preferences. The values of time implied by the model are notably different among these market segments. Comparison of the values of time implied by the proposed model with those from simpler models proposed earlier in the literature suggest that ignoring either corner solutions and minimum consumptions or ignoring goods consumption in time use models can potentially lead to overestimation of the values of leisure and work times.

Apart from a better understanding of the determinants of the valuation of time, the empirical model is applicable in many ways. For example, the model can be used to assess the influence of transportation improvements that reduce weekly travel time on overall time allocation and goods consumption patterns (i.e., what happens if the total time budget increases due to reductions in travel time?). Similarly, the model can be used to forecast the impact of changes in demographic characteristics (those in the model) on weekly time-use and expenditure patterns.

A limitation of the model presented in this paper is that the technical constraints – minimum time allocation values and minimum consumption amounts – were treated as exogenous and not related to each other. Recognition of the relationships between goods consumption and time allocation in the form of technical constraints, for example a minimum required time allocation dependent on the amount of goods consumed, while considering corner solutions is an important avenue for future research (see Jara-Diaz *et al*. (*6*) who recognize such relationships albeit without considering corner solutions).

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TABLE 1 Descriptive Statistics

Activity	Participation (%)	Duration (hours/week)*				Expenditure (euros/week)*			
		Mean	St. Dev.	Min.	Max.	Mean	St. Dev.	Min.	Max.
Work	100.0	33.4	13.7	1.0	100.0	-	-	-	-
Household chores	97.8	12.4	9.8	0.3	90.0	5.9	9.8	5.3	107.5
Personal care	100.0	9.1	5.8	0.5	49.0	96.9	66.5	7.2	1005.0
Education	24.7	7.4	9.3	0.2	87.7	1.4	7.4	8.0	125.0
Activities with children	31.2	14.3	11.7	0.5	65.0	17.6	29.1	9.5	166.3
Entertainment	99.8	31.9	16.1	1.0	102.0	38.7	63.1	7.8	725.0
Assisting friends and family	57.6	7.5	7.8	0.2	81.3	-	-	-	-
Administrative chores and family finances	86.6	3.1	3.5	0.2	50.0	-	-	-	-
Sleeping and relaxing	100.0	58.8	11.4	28.0	119.2	-	-	-	-
Other activities	42.5	11.7	12.5	0.3	71.0	-	-	-	-
Number of observations	1193								

(*): Durations and expenditures are computed only for workers participating in the corresponding activity.

TABLE 2 Three Segments Model Estimation Results

Variable	First Segment (YS)		Second Segment (LIPSM)		Third Segment (OCWOC)	
	Estimate	t-stat	Estimate	t-stat	Estimate	t-stat
Segment Probabilities						
Alternative specific constant	-	-	0.956	2.50	0.591	3.16
Gender: male	-	-	-0.175	-2.10	-	-
Age: 50 years or older	-	-	0.166	2.00	0.537	2.72
Single person household	-	-	-0.702	-3.00	-0.813	-3.20
Presence of children in the household	-	-	0.680	3.12	-	-
Income less than $3,000 euros/month	-	-	1.204	2.25	0.322	4.51
Baseline utilities						
Household size specific to						
Assisting friends and family time	-	-	0.328	2.56	-	-
Administrative chores & family finances time	-	-	0.290	2.49	-	-
Activities with children expenditure	-	-	0.210	4.78	-	-
Urban household specific to						
Entertainment expenditure	0.478	3.24	0.497	3.45	0.422	3.20
Entertainment time	0.326	2.07	0.590	3.00	0.371	3.49
Graduate school studies specific to						
Education expenditure	0.046	2.74	0.105	2.30	0.096	2.22
Education time	0.190	4.67	0.341	6.22	0.271	5.10
Personal care expenditure	-3.090	-3.40	-4.223	-5.12	-4.107	-2.60
Personal care time	-0.110	-4.75	-0.486	-9.11	0.214	3.61
Log-Likelihood at Convergence	-8,486.12					

TABLE 3 Quantitative Characterization of the Three Segments

Segmentation Variable		First Segment (YS)	Second Segment (LIPSM)	Third Segment (OCWOC)	Overall Market
Gender	Male	51.1%	43.1%	50.4%	51.6%
	Female	48.9%	56.9%	49.6%	48.4%
Age	Younger than 50	66.8%	58.6%	50.8%	59.9%
	50 years or older	32.2%	41.4%	49.2%	40.1%
Household structure	Single person	38.2%	26.1%	28.0%	27.6%
	Couple	29.9%	28.6%	37.2%	32.6%
	Single parent	3.8%	6.3%	3.3%	4.8%
	Nuclear family, multi family or non-family	28.1%	39.0%	31.5%	35.0%
Income	Less than 3,000 euros/month	55.8%	67.5%	57.4%	56.4%
	More than 3,000 euros/month	44.2%	32.5%	42.6%	43.6%
Segment size		25.6%	44.8%	29.6%	NA
Value of time from the proposed model (euros/hr)	Value of Leisure	37.9	17.3	41.2	**36.2**
	Value of Work	14.8	1.6	18.9	**18.9**
Value of time (euros/hr) using 'all essential alternatives' formulation	Value of Leisure	42.0	17.3	43.7	**39.5**
	Value of Work	23.9	4.1	23.1	**21.4**
Value of time (euros/hr) using Castro *et al.* (2012) formulation	Value of Leisure	51.9	24.7	65.1	**50.3**
	Value of Work	31.3	8.2	43.7	**36.2**
Value of time (euros/hr) using Jara-Díaz *et al.* (2008) formulation	Value of Leisure	44.5	18.1	47.0	**41.2**
	Value of Work	25.5	4.9	25.5	**23.9**

NA: Not applicable