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SENSITIVITY OF THE SUBJECTIVE VALUE OF TRAVEL TIME FOR DIFFERENT MICROECONOMIC MODELS: EMPIRICAL EVIDENCE FOR UNIVERSITY STUDENTS[1]

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Abstract: This paper analyses the sensitivity of the subjective value of travel time (SVT) by considering different models based on the microeconomic theory of time allocation, as well as different econometric specifications of discrete choice models, and provides empirical evidence of this.

Thus, the objective is to estimate wage rate and expenditure rate models together with a model that includes cost-weighted income. For this purpose we use discrete choice econometric models in which heterogeneity among individuals is introduced.

Taking into account that the most important benefit of a transport infrastructure project is the value of the travel time saved, the subjective value of time (SVT), the results allow us to determine which microeconomic model and empirical specification are the most robust. In addition, we can obtain comparisons of the values obtained for different countries and areas of study.

For estimates, data from an origin-destination survey conducted among students at the University of Cantabria in the city of Santander (Spain) have been used.

Keywords: Discrete choice models, subjective value of time, heterogeneity.
JEL Classification: C25, J22, R41.

1. Introduction

Time savings are the greatest benefit in the evaluation of transport projects anywhere in the world (Ortúzar and Willumsen, 2001). For this reason, their calculation remains of particular importance in publications both in terms of the value obtained and the mode used.

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The generally accepted method for estimating the subjective value of time (SVT) is to calculate the marginal rate of substitution (MRS) between the travel time and cost from disaggregate discrete choice models based on Random Utility Theory, interpreting its value as the willingness to pay in order to reduce travel time by one.

The classical microeconomic formulation (Train and McFadden, 1978) proposes that the best way to introduce the cost is to divide it by the wage rate as it assumes that individuals are free to choose the number of hours spent at work. In some applications, income rather than the wage rate has been used.

There is another formulation widely used in publications (Jara-Díaz and Farah, 1987), which proposes introducing the cost divided by the expenditure rate, calculated as the ratio between the income and the time available for it, since they imply that individuals cannot freely choose the number of hours spent at work. In this case, what matters is the time that individuals have to spend and not their own income. This approach has been widely used because it provides very good results when working with individuals on fixed incomes (fixed working hours) (Jara-Díaz and Ortúzar, 1989; Cherchi and Ortúzar, 2002).

The study of the sensitivity of SVT over different econometric specifications has been discussed in several previous international publications (Train and McFadden, 1978; Gaudry et al., 1988; Jara-Díaz and Farah, 1987) some of which also deal with a population composed of university students (Alonso Henríquez, 2002; Sainz-González, 2005; González and Amador, 2005; Coto-Millán et al., 2007; Rotaris et al., 2012).

Generally, SVT is usually lower when considering the expense rate model for individuals with fixed incomes and also in models which use Hierarchical Logit (HL) versus those that use Multinomial Logit (MNL) (Alonso Henríquez, 2002).

This paper will show which microeconomic specification is best when considering spending rate, wage rate and income models, as well as the best econometric specification, HL or MNL, to determine SVT. The estimation of different data models for college students will be developed in order to corroborate the results obtained.

The paper is organised as follows: the second section shows the microeconomic models associated with different ways to enter the cost in the utility function, and the discrete choice models that will later be estimated. The following section presents the data used for the empirical application and an analysis of these data. Finally, the results of the estimates and the main conclusions are presented.

2. Theoretical basis

2. 1. *Microeconomic models*

The theoretical basis for the economic value of time has been extensively studied worldwide over recent decades, as the classical model of consumer behaviour is considered to provide little explanation in the case of transport. The theories underlying all transport demand models share three basic assumptions:

1. Each individual allocates his / her resources in order to maximise his / her utility or satisfaction.
2. Time is a fundamental economic resource with which all individuals are endowed with the same amount (24 hours daily), but, unlike money (which is another basic resource) time cannot be stored and must necessarily be transferred between different activities that are interchangeable at any given time, so that individuals are free to allocate it as preferred.
3. The various allocations of time made by an individual to a number of activities have different values, which can be measured in terms of money.

Models that recognise that time influences the choices and constraints faced by consumers are an alternative to the classical model of consumer behaviour. Within these models, there are fundamentally two types:

1. Classic models: these assume that consumer goods are continuous or divisible and introduce time directly into the utility function (Becker, 1965; Johnson, 1966; Oort, 1969; DeSerpa, 1971; Evans, 1972).
2. Discrete choice models: these represent discrete type consumer goods (Train and McFadden, 1978; Jara-Díaz and Farah, 1987).

In this article we will focus on the models by Train and McFadden, 1978, and Jara-Díaz and Farah, 1987, since these are the models that present the introduction of income in the utility function through wage rate and rate of expense.

Until Train and McFadden, 1978, proposed their model, the classical theory of utility maximisation was carried out with aggregated data, but their major contribution was to incorporate transport as a discrete choice good, thus differing from the rest of goods, which are assumed to be continuous. They suggested a model of choice between goods and leisure in which they try to analyse what role wages play in consumer decisions when consumers are faced with the problem of choosing a mode of transport, and how this varies when considering different functional forms in the utility function that represents individual preferences.

2. 2. *Discrete choice models*

Aggregated demand models are based on relationships observed for average individuals or groups of individuals in certain areas, while disaggregated models (discrete choice) are based on the observed choices of individual travellers. Furthermore, the latter models consider that individuals make rational decisions, i.e. they maximise their individual utility. They are the random utility models, Manski 1977. The choice probabilities depend on the attractiveness of each mode and the socioeconomic characteristics of individuals.

Discrete choice models consider a population of individuals acting rationally by maximising their net profit utility – homo economicus – subject to environmental, legal, social, physical or budgetary restrictions. Under this approach, the set of alternatives among which the individual must choose is predetermined- that is, the effect of the restrictions has already been taken into account, and does not affect the determination of the set of alternatives available nor the process of selecting the most suitable option.

Random utility theory assumes that there is a certain set $A = \{A_1,\dots, A_n\}$ corresponding to the alternatives available to the population's individuals. For a particular individual, the set of available alternatives "q" is $A(q) \in A$. Furthermore, there is a set, X, of vectors of individuals' features and attributes that can be measured for each individual.

As the modeller does not have complete information there are situations in which two individuals, apparently identical and subjected to the same set of alternatives, behave differently. An individual can choose an option that is not the one that provides more utility as estimated by the model, so a stochastic term (ε_{iq}) is added to the utility function, being as follows:

$$U_{iq} = V_{iq} + \varepsilon_{iq}$$

Where

$$V_{iq} = \sum_{k=1}^{K} \theta_{iq} X_{ikq} \cdot$$

Thus, an individual q will choose Ai, if and only if:

$$U_{iq} \geq U_{jq}\,,\ \forall A_i \in A(q)$$

As the stochastic terms are unknown, a probability of choosing Ai must be specified:

$$P_{iq} = prob\{\varepsilon_{jq} \geq \varepsilon_{iq} + V_{iq} - V_{jq}, \forall A_i \in A(q)\}$$

Based on random utility theory, for cases in which the random factors distribute independent and identical Gumbel with zero mean and equal variance, the result will be the MNL model, MacFadden, 1973. Thus, the probability that an individual q chooses an alternative i, Train 2003, is given by;

$$P_{iq} = \frac{\exp(\beta \cdot V_{iq})}{\sum_{A_j \in \underline{A}(q)} \exp(\beta \cdot V_{jq})} \text{, where } \beta = \frac{\pi}{\sigma\sqrt{6}}$$

And σ is the standard deviation common to ε_i.

The most important property of this model is its independence from irrelevant alternatives, Luce, 1959, and this is derived from the assumption that ε_i are independent. This property basically means that when taking the ratio of the probabilities of choosing two options, they do not depend on the utility of any other alternative, which is an advantage as new options may be included without having to recalibrate the model. However, if the unobservable associated with any two alternatives are correlated with each other, the model fails by providing prediction errors.

For cases in which the alternatives are correlated, the HL model is developed, Ben-Akiva 1972, which incorporates correlations between the available modes, grouping the correlated alternatives in hierarchies or nests (e.g. the bus mode and train mode could be incorporated in a nest of public transport). If the model is calibrated sequentially as a series of MNL models, the usefulness of the alternative composed within each nest has the following form:

$$U_i = \phi_i \cdot EMU + \underline{\alpha} \cdot \underline{W}$$

where φ and $\underline{\alpha}$ are parameters to be estimated, $\underline{W}$ is the set of attributes common to the nest's alternatives and EMU is the expected value of the maximum utility among the nest's options and is defined as follows:

$$EMU = Ln\left(\sum_{A_j \in Nido} \exp(\overline{V_j} / \phi) \right)$$

It is important to note that $0 < \varphi \leq 1$ should always be fulfilled and, in cases where there is only one level of hierarchy, if $\varphi = 1$ or $\varphi \approx 1$ the HL model is mathematically equivalent to MN, Henscher, 1998. In this case, it is necessary to re-estimate the model as MNL, as the HL is less efficient and requires more parameters. If there is more than one hierarchical level, $0 < \varphi_1 \leq \varphi_2 \leq \ldots \leq \varphi_S \leq 1$ must be satisfied, where φ_1 corresponds to the parameter of the innermost nest and φ_S corresponds to the nest at the top of each branch of the tree. In the event of $\varphi_i \approx \varphi_j$ the nest should be collapsed and if $\varphi_i \approx 1$, the nest should be collapsed to the higher level. If the model is estimated simultaneously, as is the case of *ALOGIT*, the probability that an individual chooses the alternative $A_i \in \underline{A}^I(q)$ is given by:

$$P_{iq} = \frac{\exp\left(U_i + \underline{\theta}^S \cdot \underline{Z}^S\right)}{\sum_{A_j \in \underline{A}^S(q)} \exp\left(U_i + \underline{\theta}^S \cdot \underline{Z}^S\right)} \cdot \frac{\exp\left(\underline{\theta}^I \cdot \underline{Z}_i^I / \phi\right)}{\sum_{A_j \in \underline{A}^I(q)} \exp\left(\underline{\theta}^I \cdot \underline{Z}_i^I / \phi\right)}$$

where I is the lowest hierarchical level, S is the highest hierarchical level, $\underline{Z}^n$ are the attributes of the alternatives available at level n and $\underline{\vartheta}$, $\underline{\alpha}$, φ are the estimated coefficients.

When performing the statistical estimation of the models it should be considered that the utility function has the following form:

$$U_{mq} = \sum_{x=1}^{X} \theta_{mx} x_{mq} + K_m$$

where U_{mq} is the utility perceived by the individual q in the mode m; ϑ_{mx} is the parameter to be calibrated for the variable x by mode m; x_{mq} is the variable dependent on each individual q and mode m, and K_m is the constant of modal penalty for mode m.

To estimate the parameters of U_{mq}, i.e. ϑ_{mx} and K_m, a computer program called *ALOGIT* is used, which allows the formulation of HL models while also calibrating the φ parameters associated with each node. Various tests can be performed with these parameters to find the predictive power and robustness of the models, in order to compare them later, Ortuzar and Willumsen, 2001.

3. Preliminary analysis of the database

In the aim of estimating various modal split models, a database with information drawn from a survey of Revealed Preferences (RP) has been used. This survey was conducted among college students at the University of

Cantabria (Spain) in 2010. The sample consists of 662 observations for the trips made in a representative day for each of the 212 individuals considered.

Below are some of the tables corresponding both to the theoretical analysis of the variables considered and the statistical analysis of the data available for performing the empirical study.

TABLE 1 shows the definition of the variables initially obtained through the survey and their relative importance, units and expected sign (effect on the utility of each alternative).

TABLE 1. Definition of variables, units, expected signs and significance.

Variable	Definition	Units	Sign	Importance
EDAD	Age of students	Years	?	Low
CARNE	Availability of driving license (0=Not, 1=Yes)	-	+	Low
VEHIC	Availability of motor vehicle (0=Not, 1=Yes)	-	+	Low
INGREIN	Monthly individual income (1=Low, 2=Medium-Low, 3=Medium, 4=Medium-High. 5=High)	€ (year 2010)	+	High
INGREHOG	Monthly Household Income (1=Low, 2=Medium-Low, 3=Medium, 4=Medium-High. 5=High)	€ (year 2010)	+	High
NAUT	Number of cars in household	Cars	+	Medium
SEXO	Gender of students (0=Male, 1=Female)	-	?	Low
ESTUDIOS	Studies undertaken by the students (0=Business administration, 1=Economics)	-	?	Low
RESIDENCIA	Habitual residence of students (1=Santander, 2=Bay Area, 3=Eastern zone, 4=West zone, 5=Torrelavega)	-	?	Low
TVIA_(Modo)	Total travel time of transport mode	Minutes	-	High
COST_(Modo)	Monetary outlay associated with the mode	€ (year 2010)	-	High
MOTIVO	Reason for travel (1=Household, 2=Studies, 3=Work, 4=Personal affairs, 5=Shopping, 6=Leisure, 7=Health, 8=Others)	-	?	Medium

Source: Own elaboration

The criteria for assigning the level of importance and the expected sign of each variable mean that variables with high significance will be considered as policy variables and those with negative signs will cause disutility in individuals. The level of significance and the expected sign will allow coherency throughout the work as they facilitate choosing the model that best describes reality.

TABLE 2 presents the variables generated from the initial variables, which have been entered directly or through interactions in the utility functions.

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TABLE 2. Variables generated.

Variable	Definition	Sign	Importance
I1	(If INGREIN low then 1; Otherwise=0)	?	Medium
I2	(If INGREIN medium-low then 1; Otherwise=0)	?	Medium
I3	(If INGREIN medium then 1; Otherwise=0)	?	Medium
I4	(If INGREIN medium-high then 1; Otherwise=0)	?	Medium
I5	(If INGREIN high then 1; Otherwise=0)	?	Medium
D1	(If not car=1; Otherwise=0)	?	Medium
D2	(If one car=1; Otherwise=0)	?	Medium
D3	(If two or more cars=1; Otherwise=0)	?	Medium
D11	(If have car=1; Otherwise=0)	?	Medium
I11	(If INGREHOG low then 1; Otherwise=0)	?	Medium
I12	(If INGREHOG medium-low then 1; Otherwise=0)	?	Medium
I13	(If INGREHOG medium then 1; Otherwise=0)	?	Medium
I14	(If INGREHOG medium-high then 1; Otherwise=0)	?	Medium
I15	(If INGREHOG high then 1; Otherwise=0)	?	Medium
w	Wage rate (€/minute)	?	Medium
COSW_(Mode)	COST_(Mode)/w	-	High
g	Expenditure rate (€/minute)	?	Medium
COSG_(Mode)	COST_(Mode)/g	-	High
COSING_(Mode)	COST_(Mode)/INGREIN	-	High

Source: Own elaboration

The sample contains information on gender, age, courses taken, place of residence and the monthly income category (individual and family) to which the individual making the journey belongs.

It also includes information about driving licence and motor vehicle availability, the number of cars in each individual's household, the motivation behind each trip and the availability of each mode of transport as well as the modal choice made, considering both pure and combined modes (1=walking, 2=car-driver, 3=car-passenger, 4=motorbike, 5=urban bus, 6=intercity bus, 7=bicycle, 8=bus/train). It also includes information on the service levels of the modes available for each of the trips (travel time and cost).

Below, the statistical analysis is performed on the variables associated to the time and cost of the trips within the sample obtained, where initially the main descriptive statistics of the variables associated with service levels (TABLE 3) are obtained. Note that the costs associated with modes 1 and 3 are non-existent.

TABLE 3. Descriptive statistics of variables related to service levels.

	Average	Std. Dev.	Maximum	Minimum
TVIA_01	16.15	8.46	65	5
COST_01	0	0	0	0
TVIA_02	16.5	9.39	47	3
COST_02	1.4	1.36	5.67	0.11
TVIA_03	15.6	10.32	56	0
COST_03	0	0	0	0
TVIA_04	7.27	2.65	12	5
COST_04	0.5	0.43	1.35	0.15
TVIA_05	41.33	15.69	110	16
COST_05	0.44	0.13	0.6	0
TVIA_06	67.14	18.08	120	45
COST_06	1.88	1.44	5.85	0.9
TVIA_07	14.67	7.48	22	5
COST_07	0.5	0	0.5	0.5
TVIA_08	45.06	17.58	80	22
COST_08	1.34	0.27	1.85	0.75

Source: Own elaboration

With respect to the modal split, TABLE 4 shows that in an aggregated way, the car-driver mode is the most used (38.67%), while modal weight is much higher for private transport modes compared to public modes. This pattern of behaviour regarding the choice of transport mode is characteristic of the European or North American context, in contrast to Latin America, where public transport use is higher.

TABLE 4. Number of trips by mode chosen.

Modal Split			
Codification	Mode	Travels	%
1	Walking	110	16.62%
2	Car-driver	256	38.67%
3	Car-passenger	124	18.73%
4	Motorbike	11	1.66%
5	Urban bus	81	12.24%
6	Intercity bus	54	8.16%
7	Bicycle	9	1.36%
8	Bus/Train	17	2.57%
Total		662	100%

Source: Own elaboration

Analysis of the trips made on each mode based on its availability (TABLE 5) shows that the car-passenger mode (87.94%) is the most widely used while the train/bus mode (10.69%) is the least used. In addition, individuals who

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TVIA_03	15.6	10.32	56	0
COST_03	0	0	0	0
TVIA_04	7.27	2.65	12	5
COST_04	0.5	0.43	1.35	0.15
TVIA_05	41.33	15.69	110	16
COST_05	0.44	0.13	0.6	0
TVIA_06	67.14	18.08	120	45
COST_06	1.88	1.44	5.85	0.9
TVIA_07	14.67	7.48	22	5
COST_07	0.5	0	0.5	0.5
TVIA_08	45.06	17.58	80	22
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Analysis of the trips made on each mode based on its availability (TABLE 5) shows that the car-passenger mode (87.94%) is the most widely used while the train/bus mode (10.69%) is the least used. In addition, individuals who have private transport modes are the ones who less frequently choose other alternatives available, which characterise them as captive users.

TABLE 5. Mode choice according to availability.

Codification	Mode	Availability mode	% Availability	Mode choice	% choice
1	Walking	346	20.22%	110	31.79%
2	Car-driver	400	23.38%	256	64.00%
3	Car-passenger	141	8.24%	124	87.94%
4	Motorbike	26	1.52%	11	42.31%
5	Urban bus	338	19.75%	81	23.96%
6	Intercity bus	269	15.72%	54	20.07%
7	Bicycle	32	1.87%	9	28.13%
8	Bus/Train	159	9.29%	17	10.69%

Source: Own elaboration

As choice variables, TABLE 6 shows the average time and cost of transport modes once chosen. It is noted that the highest average cost is for the intercity bus (€ 1.88). In addition, the intercity bus mode presents the highest average time (67.44 minutes), which justifies why it is rarely chosen when available as it is a very unattractive option.

It is important to highlight that the bicycle cost (0.50 €) refers to the use of the public bicycle service. At the time when the survey was done, the city of Santander was implementing a new transport policy aimed at increasing the use of bicycles by renting them in different points around the city, specifically at University campus. In addition to this, the low cost associated with the city bus service (0.44 €) is determined by the fact that it is subsidized for college students.

TABLE 6. Average time and cost for modes chosen.

Codification	Mode	Cost	Travel time
1	Walking	0.00	16.15
2	Car-driver	1.40	16.50
3	Car-passenger	0.00	15.60
4	Motorbike	0.50	7.27
5	Urban bus	0.44	41.33
6	Intercity bus	1.88	67.14
7	Bicycle	0.50	14.67
8	Bus/Train	1.34	45.06

Source: Own elaboration

4. Estimation and analysis of the models

Regarding the methodology used for the specification of the models, those variables that are considered most relevant (policy variables), which in this case are the time and cost associated with each of the modes of transport, are initially introduced into the MNL models. Once it is determined that the parameters associated with them present the appropriate signs and are statistically significant, this model is used as a starting point to gradually add other minor variables which allow us to establish utility functions that are more representative of the behaviour of individuals (Ortuzar and Willumsen, 2001).

This paper followed these steps: after entering the time and costs in the utility functions, the number of cars (directly or through dummy variables elaborated for this purpose) and other socioeconomic variables available were added. Furthermore, we introduced interaction variables that collected systematic variations in preferences of individuals based on income categories (systematic heterogeneity), which were not statistically significant. Specific parameters were also used for those variables associated with travel time in public and private transport modes, which worked well with our database. In addition, it should be noted that we worked with the spending rate model, the wage rate model and its degeneration (considering individual income).

Once the best specification of the MNL model had been obtained, different structures of correlation between modes were tested through the Hierarchical Logit model (HL). Notably, the best structure was achieved by applying diagnosis conditions relating to term φ.

Firstly, it was necessary to estimate the MNL model, including only constants specific to the utility functions of each of the modes (Ki; $i=1,\ldots,8$), to be used for the subsequent comparison of models and for performing statistical tests such as the overall fit test, which allows us to determine if it is right to include more explanatory variables (Ortuzar and Willumsen, 2001).

This model can be estimated only if a modal reference variable is set, because the MNL model operates on differences, so it was decided that the reference constant would be that of mode 2 (car-driver), which is the most available mode, so its value is zero.

Applying the above methodology, the result obtained was the best specifications of the utility functions of the spending rate, wage rate and income rate models. The main results of these models are presented in Table 7, which shows that all variables have the right signs.

TABLE 7. Main results obtained from the best MNL and HL models.

	COSW				*COSG*				*COSING*			
	MNL		*HL*		*MNL*		*HL*		*MNL*		*HL*	
Parameters	*Value*	*Test-t*	*Value*	*Test-t*	*Value*	*Test-t*	*Value*	*Test-t*	*Value*	*Test-t*	*Value*	*Test-t*
K1	0.029	0.10	0.059	0.20	0.029	0.10	0.059	0.20	0.029	0.10	0.059	0.20
K2	-	-	-	-	-	-	-	-	-	-	-	-
K3	1.395	4.70	1.445	3.60	1.395	4.70	1.445	3.60	1.395	4.70	1.445	3.60
K4	0.952	1.90	1.033	1.50	0.952	1.90	1.033	1.50	0.952	1.90	1.033	1.50
K5	0.277	0.70	0.321	0.70	0.277	0.70	0.321	0.70	0.277	0.70	0.321	0.70
K6	-0.223	-0.50	-0.220	-0.50	-0.223	-0.50	-0.220	-0.50	-0.223	-0.50	-0.220	-0.50
K7	0.333	0.70	0.377	0.60	0.333	0.70	0.377	0.60	0.333	0.70	0.377	0.60
K8	-1.248	-2.70	-1.309	-2.20	-1.248	-2.70	-1.309	-2.20	-1.248	-2.70	-1.309	-2.20
Qtvia	-0.021	-2.90	-0.022	-2.00	-0.021	-2.90	-0.022	-2.00	-0.021	-2.90	-0.022	-2.00
Qcosg	-	-	-	-	-0.003	-2.00	-0.003	-1.60	-	-	-	-
Qcosw	-0.006	-2.00	-0.006	-1.60	-	-	-	-	-	-	-	
Qcosing	-	-	-	-	-	-	-	-	-0.001	-2.00	-0.001	-1.60
QD3	1.154	3.80	1.246	2.10	1.154	3.80	1.246	2.10	1.154	3.80	1.246	2.10
ϕ	-	-	0.94	3.30	-	-	0.94	3.30	-	-	0.94	3.30
VST	5.466	1.665	5.437	1.687	5.466	1.665	5.437	1.665	5.466	1.666	5.437	1.666
l(0)	-607.14		-607.14		-607.14		-607.14		-607.14		-607.14	
l(θ)	-405.24		-405.22		-405.24		-405.22		-405.24		-405.22	
l(C)	-418.26		-418.26		-418.26		-418.26		-418.26		-418.26	
ρ^2	0.33		0.33		0.33		0.33		0.33		0.33	
$\rho^2_{CORRECTED}$	0.03		0.03		0.03		0.03		0.03		0.03	
LR(0)	403.80		403.84		403.80		403.84		403.80		403.84	
LR(C)	26.04		26.08		26.04		26.08		26.04		26.08	
$\chi^2_{r-k,95\%}$	7.81		7.81		7.81		7.81		7.81		7.81	
$\chi^2_{r,95\%}$	19.7		19.7		19.7		19.7		19.7		19.7	
Travels	662		662		662		662		662		662	

Source: Own elaboration

Thus, the best utility functions will be those which consider the modal constants for all modes (K_i) except for the reference mode, travel times, cost weighted by the expense ratio (except for modes without associated costs) and the dummy that includes whether the individual owns two or more cars (only for car-driver and car-passenger modes).

U(1)=K1+Qtvia*TVIA_01
U(2)= Qtvia*TVIA_02+QCosg*COSG_02+QD3 *D3
U(3)=K3+ Qtvia*TVIA_03+QD3*D3
U(4)=K4+ Qtvia*TVIA_04+QCosg*COSG_04
U(5)=K5+ Qtvia*TVIA_05+QCosg*COSG_05
U(6)=K6+ Qtvia*TVIA_06+QCosg*COSG_06
U(7)=K7+Qtvia*TVIA_07+QCosg*COSG_07
U(8)=K8+ Qtvia*TVIA_08+QCosg*COSG_08

TABLE 7. Main results obtained from the best MNL and HL models.

	COSW				COSG				COSING			
	MNL		HL		MNL		HL		MNL		HL	
Parameters	Value	Test-t	Value	Test-t	Value	Test-t	Value	Test-t	Value	Test-t	Value	Test-t
K1	0.029	0.10	0.059	0.20	0.029	0.10	0.059	0.20	0.029	0.10	0.059	0.20
K2	-	-	-	-	-	-	-	-	-	-	-	-
K3	1.395	4.70	1.445	3.60	1.395	4.70	1.445	3.60	1.395	4.70	1.445	3.60
K4	0.952	1.90	1.033	1.50	0.952	1.90	1.033	1.50	0.952	1.90	1.033	1.50
K5	0.277	0.70	0.321	0.70	0.277	0.70	0.321	0.70	0.277	0.70	0.321	0.70
K6	-0.223	-0.50	-0.220	-0.50	-0.223	-0.50	-0.220	-0.50	-0.223	-0.50	-0.220	-0.50
K7	0.333	0.70	0.377	0.60	0.333	0.70	0.377	0.60	0.333	0.70	0.377	0.60
K8	-1.248	-2.70	-1.309	-2.20	-1.248	-2.70	-1.309	-2.20	-1.248	-2.70	-1.309	-2.20
Qtvia	-0.021	-2.90	-0.022	-2.00	-0.021	-2.90	-0.022	-2.00	-0.021	-2.90	-0.022	-2.00
Qcosg	-	-	-	-	-0.003	-2.00	-0.003	-1.60	-	-	-	-
Qcosw	-0.006	-2.00	-0.006	-1.60	-	-	-	-	-	-	-	
Qcosing	-	-	-	-	-	-	-	-	-0.001	-2.00	-0.001	-1.60
QD3	1.154	3.80	1.246	2.10	1.154	3.80	1.246	2.10	1.154	3.80	1.246	2.10
ϕ	-	-	0.94	3.30	-	-	0.94	3.30	-	-	0.94	3.30
VST	5.466	1.665	5.437	1.687	5.466	1.665	5.437	1.665	5.466	1.666	5.437	1.666
l(0)	-607.14		-607.14		-607.14		-607.14		-607.14		-607.14	
l(θ)	-405.24		-405.22		-405.24		-405.22		-405.24		-405.22	
l(C)	-418.26		-418.26		-418.26		-418.26		-418.26		-418.26	
$\rho 2$	0.33		0.33		0.33		0.33		0.33		0.33	
$\rho^2_{CORRECTED}$	0.03		0.03		0.03		0.03		0.03		0.03	
LR(0)	403.80		403.84		403.80		403.84		403.80		403.84	
LR(C)	26.04		26.08		26.04		26.08		26.04		26.08	
$\chi^2_{r-k\,95\%}$	7.81		7.81		7.81		7.81		7.81		7.81	
$\chi^2_{r,95\%}$	19.7		19.7		19.7		19.7		19.7		19.7	
Travels	662		662		662		662		662		662	

Source: Own elaboration

Thus, the best utility functions will be those which consider the modal constants for all modes (K_i) except for the reference mode, travel times, cost weighted by the expense ratio (except for modes without associated costs) and the dummy that includes whether the individual owns two or more cars (only for car-driver and car-passenger modes).

U(1)=K1+Qtvia*TVIA_01
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U(4)=K4+ Qtvia*TVIA_04+QCosg*COSG_04
U(5)=K5+ Qtvia*TVIA_05+QCosg*COSG_05
U(6)=K6+ Qtvia*TVIA_06+QCosg*COSG_06
U(7)=K7+Qtvia*TVIA_07+QCosg*COSG_07
U(8)=K8+ Qtvia*TVIA_08+QCosg*COSG_08

Through the use of the HL model it is possible to partially relax the assumption of independence of the alternatives present in the MNL model. It also allows for correlation between some of them, by grouping them into one or more nests. We used the best MNL models obtained previously for the wage rate, rate of expenditure and income models. We tested several hierarchical structures in which alternatives were grouped differently according to criteria of similarity between them. Most structures considered presented internal consistency problems since the values of the φ parameters were higher than one (Ortuzar and Willumsen, 2001).

Finally, the best hierarchical structure is that which considers a nest for modes 1 and 3. The variable signs are correct, the associated parameters are statistically significant and φ takes a value of between zero and one, which is also statistically significant, indicating that the structures are correct.

Also, when looking at the results in Table 7 we find that the values for the likelihood ratio test, LR (0) – and the general fit test LR (C) – are higher than their respective values in the Chi-square table, so the null hypotheses are rejected for each of them, i.e. the models are better than both the constants only model and the equiprobable model.

In selecting the best model it is noted that all models deliver good results regarding the statistical significance of the parameters entered in the utility functions and the parameter φ.

In terms of log-likelihood it can be observed that HL models have a value exceeding MNL models and as regards the overall fit test, LR(C), we found that all the models are higher than the constants only model, so the hypothesis that the model is not significantly greater than this is rejected.

Therefore it can be concluded that the best results are those delivered by HL compared to MNL models, for the three models considered. From the best specifications we calculated the subjective value of time in each case using the marginal rate of substitution between time and cost.

5. Summary and conclusion

The main conclusions obtained in this paper are as follows. Firstly, the best models are the HL models for any of the three options considered for incorporating cost into the utility function. This selection is made based on the test developed and the value of the log-likelihood, where HL models reach the best values.

The models selected finally had these variables: travel time, cost (in all three versions used) and ownership of two or more cars for the car-driver and car-passenger modes. Using the above, we obtained models that met all statistical tests and had a log-likelihood of -405.24 and -405.22 for MNL and HL, respectively.

As for the utility function variables, we have shown that travel time and cost in the three models considered always maintained their significance at 95% for MNL, while for HL, cost decreased its significance. In addition, the variable associated with the number of cars is always significant and also has a high importance when considering the value of its coefficient.

With respect to the subjective value of time, we found that its value is 5.46 €/hour in MNL and 5.43 €/hour in HL. Our results are in line, both in absolute and relative values, with previous studies such as Cherchi and Ortúzar, 2002; and González y Amador, 2005, in which SVT results are always lower for HL models.

Furthermore, the fact that there is no variation in SVT among the various MNL and HL, when considering the different ways of introducing cost, shows that the behaviour of individuals is very homogeneous. This is confirmed by the fact that none of the interactions introduced in the utility functions were significant.

This shows that there are no differences in the SVT if we look at the various microeconomic models and their different ways of considering cost in the utility functions, although some differences appear when comparing MNL and HL models, with lower SVT obtained for the latter.

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