Title

Simulation Techniques to Obtain Confidence Intervals for Willingness to Pay Measures

Authors
Espino, Raquel
Ortuzar, Juan de Dios
Roman, Concepcion

Publication Date
2004-12-01

Institute of Transportation Studies
University of California at Berkeley

Simulation Techniques to Obtain Confidence Intervals for Willingness to Pay Measures

Raquel Espino, Juan de Dios Ortuzar and Concepcion Roman

WORKING PAPER
UCB-ITS-WP-2004-2

December 2004
ISSN 0192 4141

SIMMULATION TECHNIQUES TO OBTAIN CONFIDENCE INTERVALS FOR WILLINGNESS TO PAY MEASURES

Raquel Espino
Departamento de Análisis Económico Aplicado, Universidad de Las Palmas de Gran Canaria
Edificio Departamental de C.C. E.E. y E.E., módulo D, Campus de Tafira
35017 Las Palmas, España; Tel: 34 928 458207; Fax: 34 928 458183
respino@daea.ulpgc.es

Juan de Dios Ortúzar
Departamento de Ingeniería de Transporte, Pontificia Universidad Católica de Chile
Casilla 306, código 105, Santiago 22, Chile; Tel: 56 2 686 4822; Fax: 56 2 553 0281
jos@ing.puc.cl

and

Concepción Román
Departamento de Análisis Económico Aplicado, Universidad de Las Palmas de Gran Canaria
Edificio Departamental de C.C. E.E. y E.E., módulo D, Campus de Tafira
35017 Las Palmas, España; Tel: 34 928 451796; Fax: 34 928 458183
croman@daea.ulpgc.es

ABSTRACT

We obtain confidence intervals for willingness-to-pay (WTP) measures derived from a mode choice model estimated to analyse travel demand for suburban trips in the two main interurban corridors in Gran Canaria island, using a mixed RP/SP data base. We considered a specification of the systematic utility that incorporates income effect and interactions among socioeconomic variables and level-of-service attributes, as well as between travel cost and frequency. As our model provides rather complex expressions of the marginal utilities, we simulated the distribution of the WTP (in general, unknown) from a multivariate Normal distribution of the parameter vector. For every random draw of the parameter vector, the corresponding simulation of the WTP was obtained applying the sample enumeration method to the individuals in the RP database. The extremes of the confidence interval were determined by the percentiles on this distribution.

After trying different simulation strategies we observed that the size of the intervals was strongly affected by the outliers of the simulation as well as by the magnitude of the simulated parameters. In all cases analysed, the simulated distribution of the corresponding WTP measure presented an asymmetric shape that was very similar for the two model specifications considered. This is consistent with previous findings using a radically different approach. We also observed that the upper extreme of the confidence interval for the value of time in private transport presented a very unstable behaviour as the number of random draws varied.

KEY WORDS: *Confidence Intervals, Willingness to Pay, Mode Choice.*

1. INTRODUCTION

Most applied research concerning the value of travel time savings (VTTS) or other willingness to pay (WTP) measures is based on the formulation of simplified models that impose strong restrictions on the distribution of the random error terms (e.g. IIA property of the multinomial logit model). Also, the specification of the systematic utility does not consider the interaction of other variables with the main policy attributes. WTP measures are derived as the ratio of the marginal utility of the corresponding attribute and the marginal utility of income. In most cases (i.e. linear systematic utilities) these are represented by a fixed value equal to the time (or other attribute) parameter divided by the cost parameter of the utility function. As both the numerator and denominator in the WTP expression are obtained from point estimates of the corresponding parameters, the computed WTP measure is also just a point estimate of the true value of the WTP. As maximum likelihood estimators in discrete choice models are asymptotically distributed multivariate Normal, the probability distribution of the WTP estimator is unknown. In fact, obtaining confidence intervals for the WTP estimates is not straightforward in most cases (Armstrong *et al*, 2001).

In spite of the fact that obtaining confidence estimates for the WTP measures may be relevant for sensitivity analysis in project evaluation, the research work done is this line is rather scarce. The work of Ettema *et al* (1997) can be cited among recent research in this field. Armstron *et al* (2001) compare the results obtained after applying different methods proposed in the literature to calculate confidence intervals for the value of time. They also propose two new methods that are simple to apply in many circumstances: the asymptotic t-test and the likelihood ratio test. The first one provides a way for obtaining an explicit expression for the extremes of the confidence interval in terms of the estimated parameters, the t-ratios and the correlation coefficient. The main drawback of this method strives in the difficulty of obtaining this explicit expression when the specification of the utility is not linear in the attributes. The likelihood ratio test obtains the extremes of the confidence interval from the application of a search algorithm that requires the estimation of a restriction of the original model at every step. Armstrong *et al* (2001) show that these two methods provide similar results to those obtained by the multivariate Normal simulation method of Ettema *et al* (1997).

The availability of specialised software as well as recent improvements in simulation procedures has made it possible an easy implementation of the multivariate Normal simulation method that, on the other hand, can be considered the closest to reality because it obtains the simulated distribution of the WTP from simulations of the true distributions of the parameters involved in the WTP expression. This method seems to be more appropriate in cases where the utility specification yields WTP expression different from a simple ratio between two parameters.

The aim of this paper is to provide confidence intervals for the WTP measures obtained from the estimation results of a mode choice model that analyse travel demand for suburban trips in the two main interurban corridors in Gran Canaria island. The analysis is based on the use of a mixed revealed preference/stated preference (RP/SP) data base. The SP data were obtained from a SP choice experiment, between car and bus that allowed for interactions among the main policy variables: travel cost, travel time and frequency. The experiment also included parking cost and comfort attributes. A previous RP survey gathered information about travel decisions in the corridors. This information was used to adapt the SP choice experiment to each individual experience.

During the specification searches we detected the presence of income effect following the theoretical approach proposed by Jara-Díaz and Videla (1989); hence we included income in the utility specification by dividing travel costs by the expenditure rate[1]. On another hand, significant interactions between travel cost and frequency were found and we were also able to define interactions between some socio-economic variables and some level-of-service attributes; as well as between comfort and travel time. The specification of interactions yields WTP measures that are not constant across individuals. As an example, in our analysis, we were able to find models in which the subjective value of time (SVT) for the bus mode was expressed in terms of the level of comfort, the frequency, the individual's expenditure rate, and if s/he worked or not. For car alternatives, SVT was expressed in terms of the expenditure rate, the sex and if the individual was employed or not. In a similar fashion, we were able to derive the willingness to pay for increases in frequency, reductions in walking time and improvements in the level of comfort.

As our model provided rather complex expressions of the WTP measures, a MATLAB code was created in order to obtain the simulated distribution of the corresponding WTP from multivariate Normal simulations of the parameter vector. Confidence intervals were determined by the 0.025 and 0.975 percentile points Different simulation strategies were used in order to reduce the amplitude of these intervals.

The rest of the paper is organised as follows. Section 2 presents the theoretical background, the data base used in the study, the model specification as well as the derivation of the different WTP measures. The procedure followed to obtain the confidence intervals is presented in Section 3. Section 4 discuses the estimation and simulation results and finally, the Section 5 summarises our main conclusions.

2. THEORETICAL BACKGROUND

The WTP for reductions in travel time or improvements in any other attribute determining travel demand is represented by the marginal rate of substitution (i.e. the trade-off) between travel cost and the corresponding attribute. WTP measures, also referred as the subjective value of a given attribute (SV_k), are derived from the estimation of discrete choice models as the ratio between the marginal utility of this attribute (q_{kj}) and the marginal utility of travel cost (c_j) that coincides with minus the marginal utility of income (see for example, Jara-Díaz 1998):

$$SV_k = -\frac{dc_j}{dq_{kj}} = \frac{\frac{\partial V_j}{\partial q_{kj}}}{\frac{\partial V_j}{\partial c_j}} \tag{1}$$

Where V_j is the conditional indirect utility on the alternative *j* obtained from the maximization problem under the assumption that the individual consumes continuous goods and chooses among a set of discrete alternatives (McFadden, 1981). When V_j is linear, the expression (1) is equal to the quotient between the coefficients of the attribute q_{kj} and the travel cost respectively. Armstrong et al (2001) propose two methods to obtain confidence intervals for the subjective value of time (SVT). They are based on the asymptotic t-test and on the likelihood ratio test. The first one, is based on a hypothesis test where the null hypothesis estates that the true value of time is equal to a given point estimate VT as shown in expression (2)

[1] Defined as per capita family income divided by available time.

$$
\begin{aligned}
H_0 &: \frac{\theta_t}{\theta_c} = VT \\
H_1 &: \frac{\theta_t}{\theta_c} \neq VT
\end{aligned}
\tag{2}
$$

This null hypothesis can be transformed into the linear restriction $\theta_t - VT\theta_c = 0$. As parameters estimators θ_t and θ_c in discrete choice models distribute asymptotically Normal, any linear combination also distributes Normal. Thus, the $(1-\alpha)$ confidence interval for the true value of time is represented by the set of values *VT* that satisfy the condition:

$$
-z_{\alpha/2} \leq \frac{\hat{\theta}_t - VT\hat{\theta}_c}{\sigma_{\hat{\theta}_t - VT\hat{\theta}_c}} \leq z_{\alpha/2} \tag{3}
$$

When the utility is linear it is relatively easy to obtain an explicit expression of both, the lower and upper extremes of the confidence interval (See Armstrong et al 2001; and Garrido and Ortúzar, 1993 for a detailed explanation). However other specifications of the systematic utility incorporating income effect and/or interactions between variables provide more complex expressions of the marginal utilities, making it rather cumbersome the obtaining of an explicit expression of the extremes of the confidence interval by simply manipulating the inequalities in expression (3).

The likelihood ratio test is based on the same hypothesis test but now using as a test statistic the likelihood ratio test. Thus there are two models, the general or unrestricted, where the utility is expressed as $V_{iq} = \theta_t t_{iq} + \theta_c C_{iq} + ...$, and the restricted model considering the linear restriction given by the null hypothesis in (2), where the utility is expressed as $V_{iq} = \theta_c (VTt_{iq} + C_{iq}) + ...$. In this case the $(1-\alpha)$ confidence interval for the true value of time is given by the set of values *VT* that satisfy the condition:

$$
-2\left\{ l(\theta_r / VT) - l(\theta) \right\} \leq \chi^2_{1,(1-\alpha)} \tag{4}
$$

Where $l(\theta_r / VT)$, and $l(\theta)$ are the log-likelihood of the restricted and unrestricted models respectively. Armstrong et al (2001) develop a search algorithm to obtain the extremes of the confidence interval. This method requires the estimation of the restricted model at every step.

As parameters estimators distribute asymptotically Multivariate Normal, it is possible to obtain a simulated distribution of the WTP from random draws of the Multivariate Normal distribution and then to obtain the confidence interval for the WTP measure. This method proposed by Ettena et al (1997) is appropriated in cases where interactions between variables are present and, in general, for non linear specifications of the utility function.

2.1 The data

The empirical application is based on a previous study (Espino et al, 2004) that analyses mode choice decisions for suburban trips in the two main corridors in Grand Canaria (Spain). These corridors connect the capital city of the island (Las Palmas de Gran Canaria) with the city of Arucas in the North and the city of Telde in the South, covering a distance around 40 km. The analysis is based on an RP/SP data base. A previous RP survey collected information about actual trip behaviour in the two corridors obtaining a total of 710 observations. Near 80% of the people were car users, being most of them car drivers; and concerning trip purpose 55% of the trips correspond to commuters that travel by working or educational motives. Near 17% of the trips were made by shopping purpose and 15% by leisure motives. The SP data were obtained from a SP choice experiment between car and bus. This experiment allowed for interactions between travel time, travel cost and frequency. The experiment also included parking costs for car and the latent variable comfort for bus. In order to gain realism, the levels assigned to the attributes in the SP exercise were customised to each respondent experience using the information provided by the RP survey.

2.2 Model specification

The econometric model is based on the random utility theory (Domencich and McFadden, 1975; Ortúzar and Willumsen, 2001). It states that the utility of alternative *j* (this is the CIU of the preceding section) for individual *q* has the expression:

$$U_{jq} = V_{jq} + \varepsilon_{jq} \qquad (5)$$

where V_{jq} is the representative or systematic utility and ε_{jq} is a random term that includes unobserved effects. V_{jq} depends on the observable attributes of alternative *j* and on socio-economic characteristics of individual *q*. Depending on the hypotheses made about the distribution of the random term, we obtain the different discrete choice models. Thus, when ε_{jq} are distributed iid Gumbel we obtain the multinomial logit (MNL) model. The nested logit (NL) model (Williams, 1977) is appropriate when the set of options faced by a decision-maker can be grouped into nests in such a way that the independence of irrelevant alternatives property of the MNL holds for alternatives within the same nest and does not hold for options belonging to different nests.

The mixed RP/SP estimation is based on the hypothesis that the difference between the error terms in the RP and SP data may be represented in terms of the differences between their variances (Ben-Akiva and Morikawa, 1990), i.e. $\sigma_\varepsilon^2 = \mu^2 \sigma_\eta^2$, where σ_ε^2 and σ_η^2 are the variances of the RP and SP data respectively. Hence, in order to mix the data we postulate the following utility functions for a given alternative *j*:

$$\begin{aligned} U_j^{RP} &= V_j^{RP} + \varepsilon_j = \theta X_j^{RP} + \alpha Y_j^{RP} + \varepsilon_j \\ \mu U_j^{SP} &= \mu(V_j^{SP} + \eta_j) = \mu(\theta X_j^{SP} + \omega Z_j^{SP} + \eta_j) \end{aligned} \qquad (6)$$

where θ, α and ω are parameters to be estimated; X_j^{RP} and X_j^{SP} are common attributes to the RP and SP data sets; and Y_j^{RP} and Z_j^{SP} are attributes that only belong to the designated data set.

Bradley and Daly (1997) proposed an estimation method based on the construction of an artificial NL structure where RP alternatives are placed just below the root and each SP alternative is placed in a single-alternative nest with a common scale parameter μ (see, Ortúzar and Willumsen, 2001 for details).

We detected the presence of income effect following the procedure proposed by Jara-Díaz and Videla (1989).Therefore, income was specified in the utility function dividing both travel and parking costs by the expenditure rate (*g*); the latter is defined as per capita family income (PCFI) divided by the available time (i.e. 24 hours minus the individual's working hours). In our sample the share of income spent in transport does not exceed 5.77% for car drivers, 1.68% for car passengers and 2.45% for bus users. Following Jara-Díaz (1998), this result implies that it is not required to include a cost squared term divided by the expenditure rate in the utility specification. Hence, the models analysed include this specification.

We also considered two alternative specifications for the latent variable *Comfort*. This variable took 3 levels in the SP experiment: high, standard, and low. In the first case *Comfort* was included as a dummy variable, hence we include the linear term $\theta_{CL}CL + \theta_{CH}CH$, where *CL* is equal to one when *Comfort* is low and zero otherwise; and *CH* is equal to one when *Comfort* is high and zero otherwise. In the second case, *Comfort* was included in the utility function interacting with *Travel time*. In this case the non-linear term $\left(\theta_{CL}CL + \theta_{CH}CH\right)*t$ was included.

When *Comfort* does not interact with *Travel time*, the utility specifications for the RP (car-driver, car-passenger and bus) and the SP (car-driver and bus) alternatives are as follows:

$$\begin{aligned}
V_{Car-Diver}^{RP} &= \theta_{C_D}^{RP} + (\theta_t + \theta_{t_W} W)\cdot t + (\theta_{c/g} + \theta_{c/g_S}\cdot S)\cdot c/g + (\theta_{pc/g} + \theta_{pc/g_M}\cdot M)\cdot pc/g \\
V_{Car-Pass}^{RP} &= \theta_{C_P}^{RP} + (\theta_t + \theta_{t_W}\cdot W)\cdot t + (\theta_{c/g} + \theta_{c/g_S}\cdot S)\cdot c/g + (\theta_{pc/g} + \theta_{pc/g_M}\cdot M)\cdot pc/g \\
V_{Bus}^{RP} &= (\theta_t + \theta_{t_W}\cdot W)\cdot t + (\theta_{c/g} + \theta_{c/g_S}\cdot S)\cdot c/g + (\theta_{wt} + \theta_{wt_O}\cdot O)\cdot wt + (\theta_f + \theta_{f_A}\cdot A)\cdot f \\
V_{Car-Driver}^{SP} &= \theta_{C_D}^{SP} + (\theta_t + \theta_{t_W}\cdot W)\cdot t + (\theta_{c/g} + \theta_{c/g_S}\cdot S)\cdot c/g + (\theta_{pc/g} + \theta_{pc/g_M}\cdot M)\cdot pc/g \\
V_{Bus}^{SP} &= (\theta_t + \theta_{t_W}\cdot W)\cdot t + (\theta_{c/g} + \theta_{c/g_S}\cdot S + \theta_{f\cdot c/g}\cdot f)\cdot c/g + (\theta_f + \theta_{f_A}\cdot A)\cdot f + \theta_{CL}\cdot CL + \theta_{CH}\cdot CH
\end{aligned} \tag{7}$$

Where *t* is the travel time, *wt* is the walking time, *c* the travel cost, *pc* the parking cost and *f* the frequency of the bus. *W, S, M, A* and *O* are socioeconomic variables taking the value one for workers, men, mandatory trips, older than 35 and people who travels in the north corridor respectively; and cero otherwise.

On the other hand, when *Comfort* interacts with *Travel time*, the specification for the SP Bus option changes to the expression (8):

$$V_{Bus}^{SP} = (\theta_t + \theta_{t\_W}\cdot W + \theta_{t\cdot CL}\cdot CL + \theta_{t\cdot CH}\cdot CH)\cdot t + (\theta_{c/g} + \theta_{c/g\_S}\cdot S + \theta_{f\cdot c/g}\cdot f)\cdot c/g + (\theta_f + \theta_{f\_A}\cdot A)\cdot f \tag{8}$$

2.3 Derivation of the WTP expressions

The application of expression (1) to the hybrid utility[2] obtained from (7) and (8) yields the WTP expressions showed in Table 1 for model 1 (comfort specified as a dummy variable) and model 2 (comfort interacting with travel time). The specification of interactions produces WTP that varied among individuals. As an example, in our analysis, we were able to find models in which the subjective value of time (SVT) for the bus mode is expressed in terms of the level of comfort, the frequency, the individual's expenditure rate, and if s/he works or not. For car alternatives, SVT is expressed in terms of the expenditure rate, gender and if the individual works or not. In a similar fashion, we obtained WTP for increases in frequency, reductions in walking time and improvements in the level of comfort.

[Insert Table 1 about here]

[2] This utility is built from common and non-common RP-SP parameters (Louviere *et al*, 2000). If attributes were only defined for the SP case (i.e. *Comfort*) their parameters must be scaled by the SP scale factor μ .

3. CONFIDENCE INTERVALS FOR THE WTP MEASURES

The vector $\hat{\theta}$ of Maximum Likelihood estimators in discrete choice models are asymptotically distributed Multivariate Normal $N(\theta, \Sigma)$ where θ is the true vector of parameters and Σ is the asymptotic covariance matrix of the estimates that depends on θ and on the vector of attributes. Since θ is unknown, we generally use an estimated covariance matrix S that is obtained by evaluating Σ at the estimated parameters b and the sample distribution of the attributes to estimate their true distribution (Ben-Akiva and Lerman, 1985). Thus the asymptotic distribution is approached by $N(b, S)$.

A random draw θ from the Multivariate Normal $N(b, S)$ was obtained from $\theta = b + L\eta$, where η is a vector of random draws from the standard normal and L is the Cholesky factor of S, that is $LL' = S$ (see for example, Train, 2002). For every simulated vector of parameters we obtained a simulated value of the WTP distribution. As the WTP varied across individuals (see Table 1), the application of sample enumeration method was required to obtain a simulated observation of the WTP. This process was repeated a sufficiently large number of times in order to obtain the simulated distribution. Percentiles 0.025 and 0.975 determined the lower and upper extremes of the 95% confidence interval respectively.

Four different simulation strategies were used. The first one considered all individuals in the sample during the sample enumeration process, and included the outliers[3] of the marginal simulated distributions. The second removed these outliers during the simulation of the parameter vector; the third also remove from the sample those individuals for which the simulated parameters provided marginal utilities that were inconsistent with microeconomic principles (that is, with the wrong sign); and finally a fourth strategy removed also the outliers of the simulated distribution of the WTP.

4 RESULTS OF THE MODEL

4.1 Estimation results

Table 2 shows the estimation results for two different specifications of the utility function. In model 1, C*omfort* is specified as a dummy variable, while in model 2, this latent variable interacts with *Travel time*. All parameter estimates have the expected sign (perhaps with the exception of the ASC for Car passenger). The ASC for the SP Car alternative was not significantly different from zero and was removed from the final specification. Although the base parameters of *Travel* time and *Parking cost/g* are not significantly different from zero in both models of Table 2, this is explained by the inclusion of interaction terms with the socio-economic variables (Ortúzar and Willumsen, 2001).

[Insert Table 2 about here]

Estimation results show, in general, that *Travel time* produces more disutility for workers than for non-workers; in fact, the former have less time available and in general exhibit a higher WTP for travel time savings. There are also differences in the perception of *Cost* between men and women. The parameter corresponding to the interaction term of *Cost* with *Sex* (θ_{c/g_S}) is positive, which means that the MUI is bigger for women than for men. For mandatory trips (work and education),

[3] We consider outliers those values θ_k of the simulated distribution such that $|\theta_k - b_k| > 2\sigma_k$.

parking costs produce more disutility than for other motives. Finally, for people older than 35 years of age improvements in the bus frequency are more valued than for the rest of the travellers.

4.2 Simulation results

Confidence intervals for the WTP measures were obtained using a MATLAB code created for this purpose. The process time for the case of 50.000 simulations ranged from 90 minutes to 9 hours approximately, depending on the simulation strategy. The size of the confidence interval also varied strongly with the strategy used (see graphs in Figure 1). For all the cases analyzed, the narrowest intervals were obtained for the last simulation strategy i.e. removing the outliers of the WTP distribution. The graphs in Figure 1 also show the evolution of the amplitude of the interval with the number of simulations. The size of the intervals remains pretty stable for the third and fourth simulation strategies, with the exception of that obtained for the value of time for private transport. This fact could be explained by the high variance obtained for the simulated distribution. Concerning the model specification, model 1 presents narrower intervals for the value of time, the value of frequency and the WTP for improving the comfort of the bus from standard to high. However, these differences are not significantly high.

[Insert Figure 1 about here]

Table 3 presents the lower and upper extremes of the confidence intervals for the WTP measures obtained with the optimal simulation strategy (i.e.: the fourth) for model 1 and model 2 in the case of 50.000 random draws. These values are compared with the mean of the simulated distribution as well as with the point estimate of the corresponding WTP measure. In all the cases, the point estimate is located to the left of the mean of the distribution, with the only exception of the subjective value of the frequency. Note that the subjective value of this attribute is negative because the corresponding marginal utility is positive. Graphs in Figure 2 show the evolution of these confidence intervals with the number of simulations. In all the cases, the mean of the simulated distribution is located below the mid point of the interval, with the exception of the frequency for the reasons stated before. It can also be observed that the variability of the confidence interval for the value of time in private transport is explained by the variability of its upper extreme in the two models analyzed.

[Insert Table 3 about here]

[Insert Figure 2 about here]

Finally, the graphs in Figure 3 represent the histograms of the simulated distributions of the WTP measures. All the distributions present the same asymmetric shape, with the exception of that for the subjective value of the frequency.

[Insert Figure 3 about here]

5 CONCLUSIONS

In this paper we obtained confidence intervals for the WTP measures derived from mode choice models that use a RP/SP data base analyse demand for suburban trips. These models also incorporate the latent variable comfort and interaction effects. To analyze the systematic heterogeneity in individual tastes the specification included non-linear terms in the form of interactions between some socio-economic variables and modal attributes. We also accounted for the presence of income effect in mode choice decisions including the expenditure rate (dividing the cost terms) in the utility specification. This complexity in the utility specification yielded expressions for the WTP measures that were not a simple ratio between two parameters and that took a different value for every individual in the sample. This fact suggested us to obtain the confidence intervals for the different WTP measures from the Multivariate Normal simulation method.

Results of our model indicated that the size of the interval was affected by the outliers of the simulation as well as by the magnitude of the simulated parameters. As the specification of our behavioural model was based on the microeconomic analysis of consumer decisions, the magnitude of the simulated parameters should be consistent with all microeconomic principles derived from the analysis. In our case, this meant that the marginal utilities of the different attributes must present the correct sing for every individual in the sample before applying the sample enumeration to obtain the corresponding WTP measure. Otherwise, these individual should be removed. The elimination of the outliers in two steps (first, form the simulated Multivariate normal distribution and second, from the simulated distribution of the WTP) as well as the removal of individuals that yielded inconsistent marginal utilities was the simulation strategy that provided narrower confidence intervals. In this case the amplitude of the intervals remained constant as we increase the number of simulations.

Finally, in all the cases analyzed the simulated distribution of the corresponding WTP measure presented a very similar asymmetric shape for the two model specifications considered.

References:

Armstrong, P., Garrido, R. and Ortúzar, J.D. (2001). Confidence intervals to bound the value of time. *Transportation Research E,* 37, 143-161.

Ben-Akiva, M. and S.R. Lerman (1985). *Discrete Choice Analysis: Theory and Application to Travel Demand*. The MIT Press, Cambridge. Mass.

Ben-Akiva, M.E. and Morikawa, T. (1990). Estimation of travel demand models from multiple data sources. *Proceedings 11th International Symposium on Transportation and Traffic Theory,* Yokohama, July 1990.

Bradley, M.A. and Daly, A. J. (1997). Estimation of logit choice models using mixed stated preference and revealed preference information. In P.R. Stopher and M. Lee-Gosselin (eds.), *Understanding Travel Behaviour in an Era of Change*, Pergamon, Oxford.

Domencich, T. A. and McFadden, D. (1975). *Urban Travel Demand*. *A Behavioural Analysis*. North Holland, Amsterdam.

Espino, R., Román, C., and Ortúzar, J.D. (2004). Analysing demand for suburban trips: a mixed RP/SP model with latent variables and interaction effects. Submited to Transportation.

Ettema, D., Gunn, H., De Jong, G. and Lindveld, K. (1997). A simulation method for determining the confidence interval of a weighted group average value of time. *Proceedings 25th European Transport Forum,* Brunel University, England.

Garrido, R.A. and Ortúzar, J.D. (1993). The Chilean value of time study: methodological developments. *Proceedings 21st PTRC Summer Annual Meeting*, University of Manchester Institute of Science and Technology, England, 13-17 September 1993.

Jara-Díaz, S.R. (1998). Time and income in travel choice: towards a microeconomic activity-based theoretical framework. In T. Garling, T. Laitila and K. Westin (eds): *Theoretical Foundations of Travel Choice Modelling.* Elsevier Science, New York.

Jara-Díaz, S. and Videla, J. (1989). Detection of income effect in mode choice: theory and application. *Transportation Research 23B*, 393-400.

McFadden, D. (1981). Econometric models of probabilistic choice. In C. Manski and D. McFadden (eds), *Structural Analysis of Discrete Data: With Econometric Applications*. MIT Press, Cambridge, Mass.

Ortúzar, J. de D. and Willumsen, L. G. (2001). *Modelling Transport*. 3rd edition, John Wiley & Sons, Chichester.

Train, K. (2002). *Discrete Choice Methods with Simulation*. Cambridge University Press, Cambridge.

Williams, H.C.W.L. (1977). On the formation of travel demand models and economic evaluation measures of user benefit. *Environment and Planning 9A*, 167-219.

Tables and Figures

Table 1. WTP expressions

<table>
<tr><th colspan="2">Model 1: Comfort as dummy</th><th colspan="2">Model 2: Comfort interacting with travel time</th></tr>
<tr><th colspan="4">Subjective value of time</th></tr>
<tr><td>Car</td><td>Bus</td><td>Car</td><td>Bus</td></tr>
<tr><td>$\frac{\theta_t + \theta_{t\_W} W}{\theta_{c/g} + \theta_{c/g\_S} \cdot S} g$</td><td>$\frac{\theta_t + \theta_{t\_W} W}{\theta_{c/g} + \theta_{c/g\_S} \cdot S + \theta_{f \cdot c/g} \cdot f} g$</td><td>$\frac{\theta_t + \theta_{t\_W} W}{\theta_{c/g} + \theta_{c/g\_S} \cdot S} g$</td><td>$\frac{\theta_t + \theta_{t\_W} \cdot W + \mu \cdot \theta_{t \cdot CL} \cdot CL + \mu \cdot \theta_{t \cdot CH} \cdot CH}{\theta_{c/g} + \theta_{c/g\_S} \cdot S + \theta_{f \cdot c/g} \cdot f} g$</td></tr>
<tr><th colspan="4">Subjective value of walking time</th></tr>
<tr><td colspan="4">$\frac{\theta_{wt} + \theta_{wt\_O} \cdot O}{\theta_{c/g} + \theta_{c/g\_S} \cdot S + \theta_{f \cdot c/g} \cdot f} g$</td></tr>
<tr><th colspan="4">Subjective value of the frequency</th></tr>
<tr><td colspan="4">$\frac{\theta_f + \theta_{f\_A} \cdot A + \theta_{f \cdot c/g} \cdot c/g}{\theta_{c/g} + \theta_{c/g\_S} \cdot S + \theta_{f \cdot c/g} \cdot f} g$</td></tr>
<tr><th colspan="4">WTP for improvements in comfort</th></tr>
<tr><td colspan="2">Low to Standard</td><td colspan="2">Low to Standard</td></tr>
<tr><td colspan="2">$\frac{\mu \cdot \theta_{CL}}{\theta_{c/g} + \theta_{c/g\_S} \cdot S + \theta_{f \cdot c/g} \cdot f} g$</td><td colspan="2">$\frac{\mu \cdot \theta_{CL}\ t}{\theta_{c/g} + \theta_{c/g\_S} \cdot S + \theta_{f \cdot c/g} \cdot f} g$</td></tr>
<tr><td colspan="2">Standard to High</td><td colspan="2">Standard to High</td></tr>
<tr><td colspan="2">$\frac{-\mu \cdot \theta_{CH}}{\theta_{c/g} + \theta_{c/g\_S} \cdot S + \theta_{f \cdot c/g} \cdot f} g$</td><td colspan="2">$\frac{-\mu \cdot \theta_{CH}\ t}{\theta_{c/g} + \theta_{c/g\_S} \cdot S + \theta_{f \cdot c/g} \cdot f} g$</td></tr>
</table>

Table 2. Estimation results

Parameters(1)		Model 1	Model 2
$C^{RP}_{Car-Driver}$	$\theta^{RP}_{C\_D}$	3.321 (6.9)	3.402 (7.1)
$C^{RP}_{Car-Pass}$	$\theta^{RP}_{C\_P}$	-0.871 (-2.7)	-0.841 (-2.6)
Travel time (t)	θ_t	-0.018 (-1.7)	-0.0156 (-1.4)
Travel time-Worker (t∗W)	θ_{t_W}	-0.0549 (-2.9)	-0.0572 (-3.0)
Cost/g (c/g)	$\theta_{c/g}$	-0.3218 (-3.1)	-0.3542 (-3.5)
Cost/g-Sex (c/g∗S)	θ_{c/g_S}	0.2024 (2.6)	0.2251 (2.8)
Frequency∗Cost/g (f∗c/g)	$\theta_{f\cdot c/g}$	-0.0479 (-2.2)	-0.0505 (-2.2)
Parking cost/g (pc/g)	$\theta_{pc/g}$	-0.0370 (-0.4)	-0.0175 (-0.2)
Parking c/g-Mandatory (pc/g∗M)	θ_{pc/g_M}	-0.4391 (-2.5)	-0.4471 (-2.4)
Walking time (wt)	θ_{wt}	-0.0790 (-2.0)	-0.0784 (2.0)
Walking time-Origin (wt∗O)	θ_{wt_O}	-0.1432 (-2.6)	-0.1426 (-2.5)
Frequency (f)	θ_f	0.1020 (2.1)	0.0944 (1.8)
Frequency-Age (f∗A)	θ_{f_A}	0.1373 (2.3)	0.1606 (2.5)
Comfort low (CL)	θ_{CL}	-1.929 (-3.4)	-
Comfort high (CH)	θ_{CH}	0.5013 (1.5)	-
Travel time-C .low (t∗CL)	$\theta_{t\cdot CL}$	-	-0.0561 (-3.4)
Travel time-C. high (t∗CH)	$\theta_{t\cdot CH}$	-	0.0196 (1.8)
Scale factor(2)	μ	0.7225 (3.3) [1.28]	0.6185 (3.4) [2.11]
ρ^2	$\rho^2(C)$	0.1279	0.1247
Log-Likelihood	$l(\hat{\theta})$	-585.191	-587.302
Nº of observations		1,286	1,286

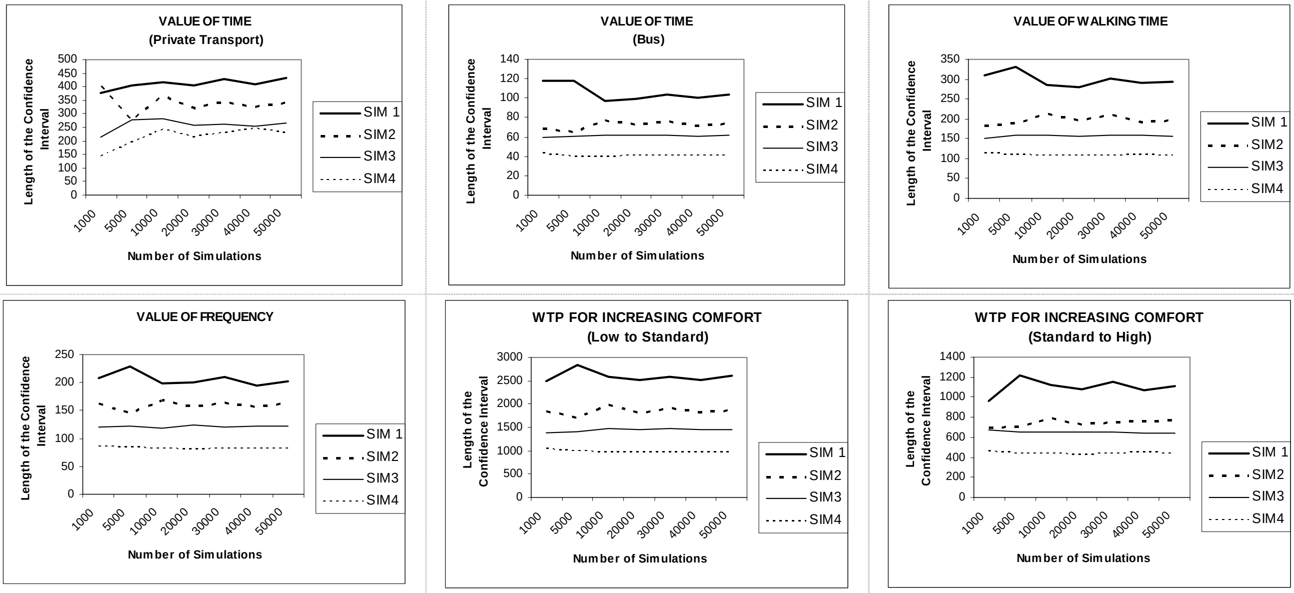
(1) t-statistics. (2) t-statistics ($\mu = 1$).

Table 3. Confidence intervals for the WTP measures

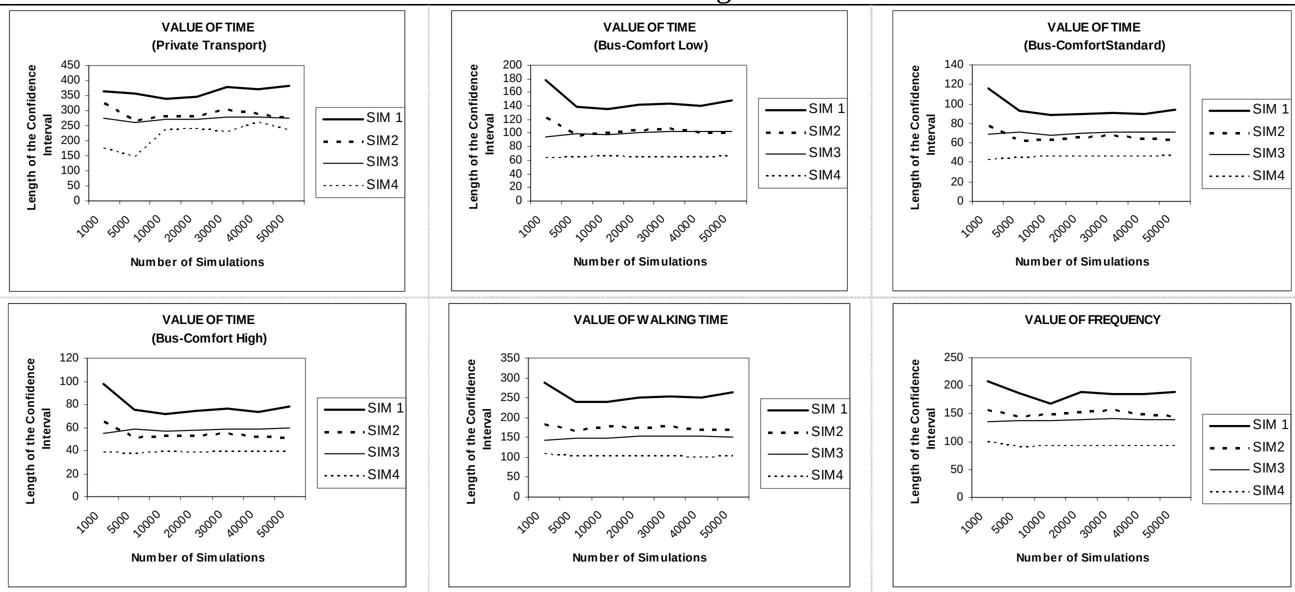
Willingness to pay measure	Point estimate	Simulated mean	Lower extreme	Upper extreme
Model 1: Comfort as dummy				
SV of time private transport (pts./min)	48.25	73.10	25.41	256.55
SV of time bus comfort low (pts/min)	27.95	32.59	17.08	57.46
SV of walking time (pts/min)	68.22	72.37	28.60	136.24
SV of frequency (pts/bus per hour)	-58.24	-67.26	-116.29	-34.11
WTP for improving comfort from low to standard (pts)	718.79	764.32	385.08	1357.27
WTP for improving comfort from standard to high (pts)	186.35	199.66	24.91	461.64
Model 2: Comfort interacting with travel time				
SV of time private transport (pts./min)	44.65	77.13	24.87	262.37
SV of time bus comfort low (pts/min)	42.84	53.94	29.01	94.86
SV of time bus comfort standard (pts/min)	33.44	35.22	17.18	63.90
SV of time bus comfort high (pts/min)	25.68	28.62	13.06	52.35
SV of walking time (pts/min)	63.23	69.21	27.04	129.92
SV of frequency (pts/bus per hour)	-58.24	-71.56	-126.62	-34.69
WTP for improving comfort from low to standard (pts)	602.32	669.40	337.48	1205.41
WTP for improving comfort from standard to high (pts)	209.65	228.94	40.15	506.92

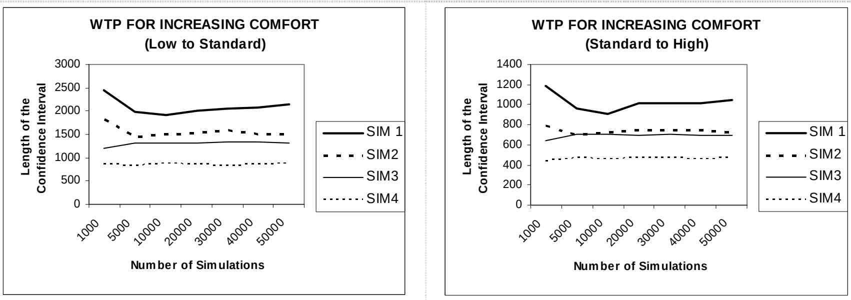
Figure 1. Amplitude of the confidence intervals

Model 1: Comfort as dummy



Model 2: Comfort interacting with travel time





SIM 1: Simulation strategy 1
SIM 2: Simulation strategy 2
SIM 3: Simulation strategy 3
SIM 4: Simulation strategy 4

Figure 2. Confidence Intervals

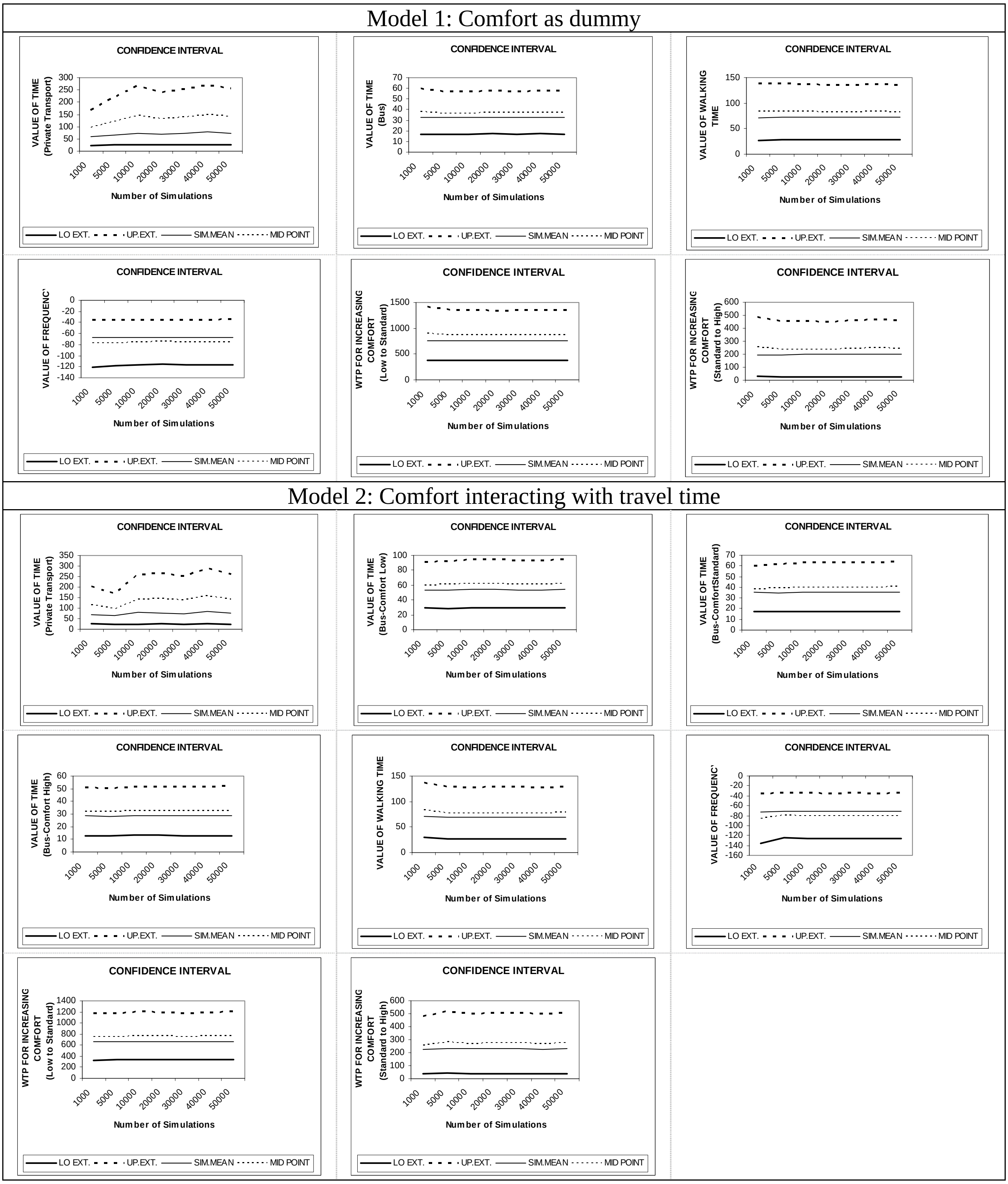


Figure 3. WTP simulated distribution