Preferences for vehicle ownership and mode choice for commuting trips in Córdoba City

Juan José Pompilio Sartori y Carlos Walter Robledo

Ponencia presentada en 13th World Conference on Transport Research realizada en 2013 en la Universidad Federal de Río de Janeiro. Río de Janeiro, Brasil

WCTR 2013 RIO

SELECTED PROCEEDINGS

PREFERENCES FOR VEHICLE OWNERSHIP AND MODE CHOICE FOR COMMUTING TRIPS IN CORDOBA CITY

JUAN JOSÉ POMPILIO SARTORI. UNIVERSIDAD NACIONAL DE CÓRDOBA, FACULTAD DE CIENCIAS ECONÓMICAS, DEPARTAMENTO DE ECONOMÍA Y FINANZAS, AV. VALPARAÍSO S/N, CIUDAD UNIVERSITARIA, CÓRDOBA, 5000, ARGENTINA. CONTACT: JSARTORI@ECO.UNC.EDU.AR

CARLOS WALTER ROBLEDO. UNIVERSIDAD NACIONAL DE CÓRDOBA, FACULTAD DE CIENCIAS ECONÓMICAS, DEPARTAMENTO DE ECONOMÍA Y FINANZAS, AV. VALPARAÍSO S/N, CIUDAD UNIVERSITARIA, CÓRDOBA, 5000, ARGENTINA. CONTACT: CWROBLEDO@HOTMAIL.COM .

This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

ISBN: 978-85-285-0232-9

13th World Conference on Transport Research

www.wctr2013rio.com

15-18 JULY 2013

Rio de Janeiro, Brazil

unicast

PREFERENCES FOR VEHICLE OWNERSHIP AND MODE CHOICE FOR COMMUTING TRIPS IN CORDOBA CITY

Juan José Pompilio Sartori. Universidad Nacional de Córdoba, Facultad de Ciencias Económicas, Departamento de Economía y Finanzas, Av. Valparaíso s/n, Ciudad Universitaria, Córdoba, 5000, Argentina. Contact: jsartori@eco.unc.edu.ar .

Carlos Walter Robledo. Universidad Nacional de Córdoba, Facultad de Ciencias Económicas, Departamento de Economía y Finanzas, Av. Valparaíso s/n, Ciudad Universitaria, Córdoba, 5000, Argentina. Contact: cwrobledo@hotmail.com .

ABSTRACT

This study presents a nested logit model integrating mode choice decisions for commuting trips, private vehicle ownership and the preferences for car and motorcycle buying as a response to changes in transport modes level of services. The estimation results confirm the hypothesis of interdependence between urban travel mode choice for commuting based on transport modes service levels and the car and motorcycle ownership decision. A scenario analysis and the calculation of demand elasticities allowed us to determine the sensitivity of transport mode use and private vehicle buying preferences to changes in urban travel conditions. Particularly, there would be significant sensitivity of car buying preferences to parking costs and also worse bus travel times could encourage car and motorcycle buying decisions in the short run aggravating the current traffic congestion conditions at rush hours. Also, there is scope for further research, evaluation and implementation of policies such as “guided buses” or “exclusive lanes for transit services” in order to cope with urban traffic congestion promoting the use of public transport alternatives.

Keywords: travel demand, nested logit, vehicle ownership and use.

1. INTRODUCTION

Travel demand estimation plays a significant role in the design and implementation of economic policies for the transport sector. The use of discrete choice models in urban transport planning is the fundamental basis for a correct situation diagnosis and the generation of predictions that allows to know the consequences of different political measures (among them, regulatory or non-regulatory measures, implementation of taxes, ways to setting fares for transit modes, entry market restrictions, the development of transport infrastructure or services, traffic management, etc.).

The present global concern about urban transport planning is based on the high level of car congestion and air pollution, as a consequence of private vehicles ownership and use (cars and motorcycles). Urban transport planning tries to get a better mobility for residents, decreasing private vehicle use at rush hours and encouraging public transport modes use.

Travel choice for commuting has been analyzed in several studies applied to different cities in the world (e.g. Hensher, 2001; Hensher and Reyes, 2000; Rose and Hensher, 2004; Ben-Akiva and Lerman, 1985; Brownstone and Small, 1989).

In the short run, changes in the variables explaining the decision to use different transport modes available will generate changes in the probability of use of different available transport modes. Moreover, changes in explanatory demand variables for public transport services may generate incentives for citizens to increase or decrease the number of private vehicles (cars or motorbikes) they own. Therefore, changes in transport systems services conditions determine private vehicle ownership decision. Thus, urban transport policy variables should be considered when analyzing the impact that they will have on private vehicle ownership and the decision to choose the transport mode to travel for different travel purposes in general and for journeys to work, in particular. Hence, there should be a simultaneous relationship between the decision of private vehicles ownership and the use of them for performing certain types of trips (e.g. journeys to work).

Thus, for example, an increase in public transport fares relative to the cost of travelling by private car or an increase in travel times (and/or waiting time) by public transport modes with travel times by car remaining constant, can generate in the short run an increase in the use of private cars for the trip, considering only those people who own a car. However, in a longer term, this policy can contribute to the decision to purchase the first car or motorcycle in a household that do not own it, or the decision to increase the number of cars or motorcycles owned, particularly for commuting. Thus, use of urban transport modes forecasts following policy changes will be biased by disregarding the decision process of private vehicle ownership related with urban mobility changing conditions from the implemented policies.

The city of Córdoba is one of the main cities of Argentina, where the problem of planning public transport systems (and especially buses) has been considered to date as one of the major social problems to be solved (Marconetti, 2008). There are no exclusive lanes for transit and the city has only two avenues in the city centre with selective lanes where taxis and buses share half of a lane in the road space. Bus headways are uncertain because of route congestion at the city centre, particularly at rush hours.

In recent years there has been a notable increase in the number of private vehicles in Argentina, both cars and motorcycles. The motorization rate in Argentina has grown a 30.3% in the period 2004-2009 and the average growth rate of new motorcycles sales has been about 58% for the period 2004-2011, reaching the annual sales record in 2011. The application of short-sighted policies that do not consider the effects that cause variables influencing the use of public transport services and the decision of private vehicle ownership can cause a worsening of urban mobility conditions. It is essential, therefore, to develop research of urban travel demand estimation and forecasting in the city of Córdoba, considering the two decisions set out: the ownership decision of private vehicle (car or motorcycle) and the use of transport mode, applied in this case, for journeys to work. So that, the motivation for this research has been to test the hypothesis that there is significant interdependence between mode choice and choice set decisions as a result of transport policy measures and to show the importance in some forecast scenarios. Also, it is important to recognize that the applied model is partial as the car/motorcycle ownership decision is related only to the journey to work, and vehicles acquired for the journey to work are likely to be used for other trip purposes, travel choices (like destination choice) and other choices as residential location, for example.

In this paper, we estimate the demand for journeys to work with data from a stated preference (SP) survey for the mode choice and the preference for vehicle ownership, conducted on a sample of workers in the City of Córdoba (Argentina), which has approximately 1.3 million inhabitants.

Different disaggregate approaches have been developed in the literature by dealing with car ownership and use estimation and forecast, but few studies have incorporated explicitly motorcycle ownership modelling and have considered directly transport mode levels of service as explanatory variables, or have jointly estimated behavioral models related with car ownership and mode choice. The importance of this type of study in considering the simultaneity of decisions of household car ownership models and mode of transport choice by workers has been highlighted by Ben-Akiva and Lerman (1974), Train (1980), and more recently by Srinivasan and Walker (2009) as a way of interrelating auto-ownership and mode choice decisions for "formulating and analyzing policies aimed at achieving sustainability in terms of transport capacity, fuel consumption, and environmental effects".

Ben-Akiva and Lerman (1974) presented one of the first studies modelling jointly automobile ownership and mode split to work, using a multinomial logit form and revealed preference (RP) data and describing the joint probability of a household selecting a given auto ownership level and a given mode to work for the breadwinner, with a choice set consisting of the cross-product of the entire set of modes and the entire set of possible auto ownership levels and using directly as explanatory variables representing mode level of services only in-vehicle travel time and out of vehicle travel time to work. In this connection, our research intended to incorporate several service level variables in a SP framework, as the single RP approach could mask problems of data aggregation and little variability in the level of service variables of the modes of transport to work. In addition, our research considers explicitly preferences for motorcycle ownership, a vehicle that has experienced high rates of selling in Córdoba city.

Also, there have been other researches relating transport mode choice and private vehicle ownership incorporating public and private modes of transport service levels as explanatory variables. Some car ownership models related in some way with the focus of our research were analyzed by De Jong, et. al. (2004). With the exception of Train (1980), other approaches do not consider explicitly the direct relationship between mode of transport choice for different purposes and several mode's service levels, relating generally car ownership and use with socio-demographic, socio-economic variables and in some cases a few modes' service level variables. In many studies RP data have long been used, describing the compromises households make in real economic conditions (Bhat and Pulugurta, 1998; Bhat, et. al. 2009; Whelan, 2001, 2007).

Following the same objective, Dissanayake and Morikawa (2010) estimated a nested logit model integrating household private vehicle ownership decisions and transport mode choice, considering a model combining revealed and stated preference data. The model was applied to Bangkok metropolitan region and recognized the existent relationship between private vehicle ownership (car ownership and motorcycle ownership treated separately), mode choice and car sharing decisions, by estimating two nested logit models, one with RP data and another with RP/SP data for commuting trips. Their results confirmed that combining RP and SP data is an effective technique to investigate trip behaviour and future transport services demand forecasting, despite the fact that the paper did not present forecasts.

The paper is organized as follows. Section 2 discusses the theoretical framework underlying the econometric estimates made. Section 3 presents the methodology used in the experimental design of transport mode choice and preference for owning private vehicle. Subsequently, we estimate the specified nested logit model in section 4, adding some forecasting scenarios related with plausible urban transport policies and estimating demand elasticities related to service level changes associated with those policy scenarios. Finally, section 5 presents final comments.

2. A NESTED LOGIT MODEL FOR PRIVATE VEHICLE OWNERSHIP AND MODE CHOICE FOR COMMUTING

In order to simultaneously estimate mode choice for commuting trips and the preference for private vehicle ownership (car or motorcycle), it is important to clearly specify the choice sets that workers currently face every day that they make their decision to commute. Therefore, we could identify basically four ownership categories. There is a first type which considers a person who owns both car and motorcycle at home and have both vehicles available for commuting. There is a second category, a person who does not own car or who does not have a car available[1]. The third category considers a person with car available but no motorcycle available for commuting. Finally, there is a fourth category referring to people without a car and motorcycle available. For those without any of the two classes of private vehicle available there could be a case for preferring to buy a car or a motorcycle for commuting as a function of the level of services of different transport modes. It is important to note that we consider all public transport modes as available for all consumers, as the objective of the research is to favour the analysis of improvements in public transport modes. Also, car and motorcycle modes are considered as potentially available because our SP study explicitly considered the preference of the interviewee for buying and using these private vehicles.

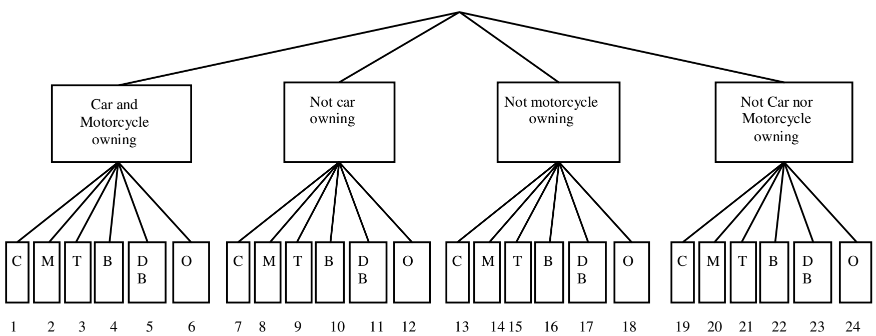
Hence, we specified a multidimensional model of private vehicle ownership (car and/or motorcycle) and mode choice for commuting trips. Considering a tree diagram, the top level of the tree represents the current availability of transport alternatives related with the private vehicle ownership situation of the person and the lower level represents all mode alternatives for commuting on each nest.

Figure I presents the tree diagram, where the elemental transport mode alternatives are designed as C: car, M: motorcycle, T: taxi, B: bus, DB: differential bus and O: other (no

[1] This is also the case for people who specifically reported the car alternative as not available due to the fact that, even though owning a car, the car is always used by another person in the household and also there is no opportunity of sharing that car to commute.

choice option). Therefore, we have six transport modes for each of the four SP design models defined in relation with the individual current ownership of private vehicle to commute, leaving us with 24 elemental alternatives of which the six transport modes belong to each nest. The first nest refers to an individual owning car and motorcycle, which also have the six transport modes available to choose. The second nest corresponds to an individual currently owning a motorcycle and not owning a car, mode which is considered as potentially available and could be chosen if the interviewee states her preferences for buying a car to commute in the SP scenario. The third nest refers to an individual who own a car but not a motorcycle, with motorcycle potentially available through motorcycle buying. Finally, the fourth nest refers to an individual who do not own a car nor a motorcycle and who have four modes currently available to commute (taxi, bus, differential bus and other) and two modes potentially available (car and motorcycle). Therefore, the first hierarchical level of the decision tree represents the revealed preference choice of household vehicle ownership currently available for use by the interviewed worker to commute.

Figure I. Tree Diagram for the Joint Estimation of Preference for Vehicle Ownership and Mode Choice for the Journey to Work. Nested Logit Model.



The nested logit model is specifically designed to recognize the possibility of the existence of different variances between the alternatives and some correlation between subsets of alternatives. This is equivalent to relaxing the IID/IIA[2] assumption from the logit model.

Following Ben-Akiva and Lerman (1985) it is possible to specify a multidimensional choice model as a nested logit model for estimating the mode choice and the preferences for vehicle ownership for commuting, considering different ownership categories defined by the current availability of car and/or motorcycle to commute. Specifying the utility of mode m in private vehicle availability category o as: $U_m = V_m + \varepsilon_m$; where V_m is the systematic component of mode m utility in ownership category o ; ε_m is the random utility component associated with mode choice m in ownership category o and that is IID extreme value distributed.

The specified model assumes that each the person have all mode alternatives available, at least potentially, as for example, if a person has no car available at present then he or she will be willing to buy a car in the near future (a new car or a used car) as a response to the perceived levels of services of the current and potential modes of transport.

[2] IID: Identically and independently distributed. IIA: independence of irrelevant alternatives.

Considering this combined vehicle ownership and mode choice model, leading to four current choice set types, the marginal probability of belonging to ownership category "a" is:

$$P_n(a) = \frac{e^{\lambda_a (V'_a)}}{\sum_{a'=1}^{4} e^{\lambda_a (V'_{a'})}}$$

with a' = 1,…, 4 corresponding to private vehicle ownership category 1 to 4; $\lambda_a = 1$ and the systematic component of the maximum utility of the alternatives included in ownership category "a" is:

$$V'_a = V_a + \left(\frac{1}{\lambda_m}\right) \cdot \log \sum_{j=1}^{6} \exp(\lambda_m .\ V_{j/a})\text{, with } \log \sum_{j=1}^{6} \exp(\lambda_m .\ V_{j/a}) = EMU_a$$

with *j*=1 for car, *j*=2 for motorcycle, *j*=3 for taxi, *j*=4 for bus, *j*=5 for differential bus and *j*=6 for other mode (no choice option), $V_{j/a}$: the systematic utility of mode *j* in ownership category "a" and V_a : the systematic utility of the nest related with ownership category "a". *EMU* is the expected maximum utility or inclusive value variable.
The conditional choice probability of an alternative belonging to a private vehicle ownership nest is:

$$P_n(m/a) = \frac{e^{V_m \cdot \lambda_m}}{\sum_{m'=1}^{6} e^{V_{m'} \cdot \lambda_m}}$$

Thus, the joint probability of mode choice "*m*" and private vehicle ownership "a", with utility of mode *m* as V_m, is given by:

$$P_n(m, a) = \frac{e^{\lambda_a (V'_a)}}{\sum_{a'=1}^{4} e^{\lambda_{a'} (V'_{a'})}} \cdot \frac{e^{V_m \cdot \lambda_m}}{\sum_{m'=1}^{6} e^{V_{m'} \cdot \lambda_m}}$$

Moreover, by consecutively numbering the joint probabilities from 1 to 24, we have P(1,1) = P(car, category 1) = P(1), P(2,1) = P(motorcycle, category 1) = P(2), P(3,1) = P(taxi, category 1) = P(3), P(4,1) = P(bus, category 1) = P(4), P(5,1) = P(diff, category 1) = P(5), P(6,1) = P(other, category 1) = P(6), P(1,2) = P(car, category 2) = P(7), and so on, up to P (6,4) = P(other, category 4) = P(24)[3]. In this context, very important probabilities for unravelling preferences for vehicle ownership are: P(7) which is the probability of buying and using a car to commute for those who do not currently have a car; *P(13)* which is the probability of buying and using a motorcycle to commute for those who do not currently have a motorcycle;

[3] It is important to note here that the taxi and other mode alternatives for ownership category 1 were not chosen in the sample and consequently they were not considered in estimation and forecasting.

P(19) and *P(20)* which are respectively the probability of buying and using a car to commute and the probability of buying and using a motorcycle to commute, for those who do not have currently a car or a motorcycle.
Also it is important to note that in order to comply with global utility maximization, the scale parameters must be $\lambda_o \leq \lambda_m$[4]. Moreover, assuming all $\lambda_m = 1$ makes the model collapse to the multidimensional multinomial logit model.

3. DESIGN OF THE STATED CHOICE EXPERIMENT

In this research, the mode choice experimental design considered six choice alternatives: car, motorcycle, taxi, urban bus, differential bus (a high quality urban bus) and the “no-choice/other mode”. The attributes of the alternatives are: travel time, travel cost, waiting time for the public transport alternatives (taxi, urban bus and high quality urban bus), parking cost (for car and motorcycle) and walking distance on origin and destination (for bus alternatives). The design of the choice experiment considers all attributes as alternative specific.
The survey was carried out in two stages. A first stage involved a home interview about the current way of travelling to work for the workers at home, complemented with socio-demographic variables, e.g.: number of persons at home, numbers of workers at home, number and type of vehicles owned (cars and motorcycles), internet connection available at home, e-mail address and telephone number. The travel part of this survey was similar to an origin-destination survey. Also we asked the workers for her/his willing to participate in the stated preference experiment by internet or by a computer assisted personal interview (CAPI) if they do not have internet connection or email available.
Once the email addresses were gathered, e-mails were launched inviting participation in the web based SP survey part.
The attribute levels were chosen considering current conditions experienced by the population of Córdoba[5]. The range of variation in attributes levels was designed in relation to the experience of interviewed people, trying to be expanded as much as possible without losing sight of its reasonableness. For the purpose of making the choice experiment more realistic for each of the interviewees, five experimental designs were made for trips of different lengths, namely: 2.5 km, 5 km, 10 km, 15 km, 20 km and 25 km.
Thus, the choice scenarios presented to each respondent are closely related to the length of their usual journey to work. Then, each respondent was assigned to one of the design lengths according to the travel time from home to work reported and sensible average speeds for the habitual mode used.
Also considered was the current availability of alternatives faced by each respondent. Table I shows the different possibilities of availability of alternatives considered.
As can be seen, it was considered that there is full availability of public transport modes.
A *D-p* efficient average design of the four models presented in Table I was developed for each trip length and for the multinomial logit model specification considering as weights the

[4] Hensher, et. al. (2005).
[5] Sartori and Robledo (2011) present the attributes and levels used in the choice experiment design.

share of each model collected once completed a quarter of the first stage home interviews. Some prior parameter values used were estimated from a pilot study carried out in 2010 (Sartori, 2010; Sartori and Robledo, 2011) and other prior values were assumed considering sensible figures for the valuation of travel time and waiting time.

Table I. Designs Based on Availability of Alternatives.

Design	Available alternatives				
Model 1 – All alternatives available (Owning car and motorcycle)	Car	Motorcycle	Taxi	Bus	Differential Bus
Model 2 (not owning car)		Motorcycle	Taxi	Bus	Differential Bus
Model 3 (not owning motorcycle)	Car		Taxi	Bus	Differential Bus
Model 4 (not owning car nor motorcycle)			Taxi	Bus	Differential Bus

Note: The final design used in the survey was a model averaging of the four above designs.

The utility functions specified for the design with all specific parameters are as follows:

$$U(Car) = ASC_{car} + \beta_{TT\_car} \cdot TT_{car} + \beta_{TC\_car} \cdot TC_{car} + \beta_{PC\_car} \cdot PC_{car}$$
$$U(Motorcycle) = ASC_{moto} + \beta_{TT\_moto} \cdot TT_{moto} + \beta_{TC\_moto} \cdot TC_{moto} + \beta_{PC\_moto} \cdot PC_{moto}$$
$$U(Taxi) = ASC_{taxi} + \beta_{TT\_taxi} \cdot TT_{taxi} + \beta_{TC\_taxi} \cdot TC_{taxi} + \beta_{WT\_taxi} \cdot WT_{taxi}$$
$$U(Bus) = \beta_{TT\_bus} \cdot TT_{bus} + \beta_{TC\_bus} \cdot TC_{bus} + \beta_{WT\_bus} \cdot WT_{bus} + \beta_{WD\_bus} \cdot WD_{bus}$$
$$U(Dif) = ASC_{Dif} + \beta_{TT\_Dif} \cdot TT_{dif} + \beta_{TC\_Dif} \cdot TC_{dif} + \beta_{WT\_Dif} \cdot WT_{dif} + \beta_{WD\_Dif} \cdot WD_{dif}$$
$$U(Nochoice) = ASC_{no\_choice}$$

where: *TT*: travel time; *TC*: travel cost; *PC*: parking cost; *WT*: waiting time; *WD*: walking distance.

The sample design applied a two stage home based sample methodology, stratifying the population into 74 geographic zones corresponding to the population census urban geographic areas called ‘fractions’, and randomly selecting first a geographic ‘radio’ of each population fraction and then one block into the selected radio. For selecting homes to be interviewed we followed a systematic sampling, trying to complete five interviews per block.

The total minimum sample size calculated for this sample was 100 respondents with 6 choice scenarios per respondent, a total of 600 cases, considering a 3.8% sampling error for the market share of bus commuters[6] and a 95% confidence level.

It is convenient to comment here that, at the implementation level we could not collect all of the expected surveys in the 74 geographic zones due to time and money restrictions so that we further aggregated some neighbouring zones into a total of 42 wider zones and recalculated the weight factors for each zone for calculating market shares using the sample enumeration method.

In order to inter-relate the preferences for vehicle ownership (car or motorcycle) and mode choice decisions for commuting purposes, one model averaging D-efficient design was generated (Choicemetrics, 2009; Rose et. al., 2009) considering the four models described in Table I and using as weights the sample shares of each type of model based on the home interview. In this way, it is possible to use the same design for those people travelling the same distance and who own some type of private vehicle, both or who do not own any. The

[6] Commuting mode market shares from origin-destination surveys done in year 2000 were: car (30.71%), motorcycle (5.06%), taxi (5.95%), bus (34.22%) and other (24.06%).

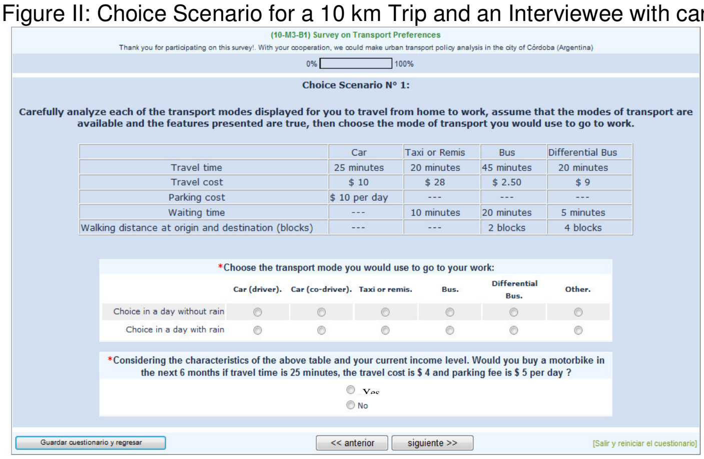
reason for using an averaging design is that it allows us to collect responses about the mode choice short run decision considering the current availability of private vehicle and, with the same experimental design, to collect responses about preference for buying and using vehicles not owned at the moment of the interview and that would be bought in the near future due to changes in transport modes' levels of services.

Additionally, in the experimental design stage we have checked the S-optimality measure, proposed by Bliemer and Rose (2005), derived from the experimental design. With the specified parameter priors, realistic ranges of attribute levels and all specific parameters, the Sp measures (at a 5 percent significance level) were always higher than the minimum sample size derived from the exogenous stratified random sample and we have restricted the number of levels for some attributes and broaden the range of levels in order to minimize the theoretical minimum sample size required for efficient estimation of the parameters, given the priors. Also the Sp estimates were evaluated for the MNL model design with all generic coefficients and as expected, the Sp figures reduce significantly in relation to the specific parameters model, although never reaching the lower levels of the stratified exogenous sample size. Anyway, some parameters Sp estimates were lower than the stratified exogenous sample size, both at the specific and the generic parameters designs and we finally kept the design model with specific parameters which allow us to estimate the model with generic parameters as well.

Figure II presents an example of the scenario showed to a respondent with a job that is a distance of 10 km from home. As it can be seen, each choice scenario first presented the mode choice to work question by showing the available alternatives to the respondent and asking for choosing the choice of mode in a day without rain and in a rainy day[7].

For example, for those who do not own a car, the mode choice scenarios do not present the car option (as driver) in the mode choice part of the survey. Also, for those who do not own a motorcycle, it was not presented as an option for commuting at present. And, for those who do not own any of the two types of private vehicles, they do not appear in the mode choice scenario.

Figure II: Choice Scenario for a 10 km Trip and an Interviewee with car and public transport available


(10-M3-B1) Survey on Transport Preferences

Thank you for participating on this survey!. With your cooperation, we could make urban transport policy analysis in the city of Córdoba (Argentina)

0% 100%

Choice Scenario N° 1:

Carefully analyze each of the transport modes displayed for you to travel from home to work, assume that the modes of transport are available and the features presented are true, then choose the mode of transport you would use to go to work.

	Car	Taxi or Remis	Bus	Differential Bus
Travel time	25 minutes	20 minutes	45 minutes	20 minutes
Travel cost	$ 10	$ 28	$ 2.50	$ 9
Parking cost	$ 10 per day	---	---	---
Waiting time	---	10 minutes	20 minutes	5 minutes
Walking distance at origin and destination (blocks)	---	---	2 blocks	4 blocks

*Choose the transport mode you would use to go to your work:

	Car (driver).	Car (co-driver).	Taxi or remis.	Bus.	Differential Bus.	Other.
Choice in a day without rain						
Choice in a day with rain						

*Considering the characteristics of the above table and your current income level. Would you buy a motorbike in the next 6 months if travel time is 25 minutes, the travel cost is $ 4 and parking fee is $ 5 per day ?

Yes
No

Guardar cuestionario y regresar | << anterior | siguiente >> | [Salir y reiniciar el cuestionario]

[7] The purpose of including this double choice question is related with the possibility of capturing changes in demand for rainy days as for these days the demand for taxi services increases and the supply of taxis on the streets decreases. Sartori (2006) analyzed this problem and proposed differential fares for dealing with it.

Then it was questioned whether or not the person would like to buy the private vehicle which they do not possess within the next 6 months, considering their current income level and the attribute levels of this alternative not available at that moment jointly with the levels of the alternatives available. That is to say, with the same experimental average design we try to capture the present mode choice preference for the travel to work which is conditioned by their alternatives available and the preference for private vehicle ownership related directly with the transport mode levels of services. Anyway, in this paper the only answer considered was that of the day without rain and the mode choice that considered all modes available for all respondents, that is to say including the preference for private vehicle ownership.

Also, the experimental design considered a total of 18 choice situations with three blocks, in order to present six choice situations to each respondent.

The questionnaire was designed using the University of Córdoba web platform based on the Limesurvey software. A total of 227 home interviews were collected with members of 92 homes answering the stated preference interviews and 95 usable SP interviews that were collected in 2011, meaning to accept a 3.90 percent sampling error for the market share of bus users and a 95 percent confidence level. It is important to note that just six CAPI surveys (with 3G mobile internet access) were collected at homes without internet access and there were some cases where we have found illiterate people who asked the interviewers to help them to read the scenarios in order to make their choice in each one. This latter aspect is an important feature of the CAPI interview, allowing us to capture responses from people that could not possibly be included with only the web based interview. Finally, we had a data base integrated by 78 SP cases belonging to model 1 (owning car and motorcycle), 78 cases of model 2 (not owning car), 360 cases belonging to model 3 (not owning motorcycle) and 156 cases of model 4 (not owning a car nor a motorcycle).

Our data base showed a car per household ratio equal to 0.8804 and a motorcycle per household ratio of 0.3043 and consequently a ratio of motorcycles per car in the sample equal to 0.3456, figure that seems reasonable considering that this ratio was equal to 0.2948 in the last 2009 origin-destination survey for the city of Córdoba, and also according to Marconetti (2009) the market ratio of motorcycles per car was 0.393 for December 2009.

Furthermore, it has to be recognized that market share forecasting must involve the use of SP data to enrich RP data, one of our future research objectives. Nevertheless, in this paper we present only the modelling results with SP data.

4. SIMULTANEOUS ESTIMATION OF COMMUTING MODE CHOICE AND PREFERENCES FOR VEHICLE OWNERSHIP MODELLING RESULTS

The estimated utility functions related with the elemental alternatives of the nested logit model were the same for each respondent belonging to any of the four different choice designs related to private vehicle availability. So that, we could number the utility functions from one to twenty four, expressing the mode choice decision conditional to current private vehicle ownership and availability. Thus, for people without a car, for example, the probability of using a car for commuting trips will show the probability of buying a car and its use in the near future.

The estimation considered the current private vehicle alternatives available to each respondent and her/his preferences for owning a private vehicle (car or motorcycle) as a response to other transport modes service levels. The car mode considered the use of a car “as a driver” or as a “co-driver”. Also it was done by jointly specifying a nested logit model for commuting mode choice and vehicle ownership, allowing disaggregating the preferences for vehicle buying.

As the mode choice design allows us to ask people if they will buy a car or a motorcycle, if confronted with the choice experiment considering full availability of modes, the utility functions system is composed here of 24 utility functions in four categories of six alternatives each.

Utilities one to six are for the category of people with car and motorcycle available (model design 1). Utilities seven to twelve are for the category without car available (model design 2). Utilities thirteen to eighteen are for the category indicating an individual without motorcycle available (model design 3). Utilities nineteen to twenty four are for an individual without car and motorcycle (model design 4). So, for a worker who has not a car available, it was asked if she/he would be willing to buy a car considering the full mode choice design. Also, for a worker without motorcycle it was asked if she/he will buy a motorcycle in the next six months considering the full design that showed all the attributes of all the alternatives: car, motorcycle, taxi, bus, differential bus and other (e.g. the no choice alternative).

The systematic part of the linear in the parameters utility functions specified and estimated for each of the four nests of the nested logit model were as follows:

$$V(car)=V(1) = V(7) = V(13) =V(19) = ASC_{car} + \beta_{TT} . TT_{car} + \beta_{TC} . TC_{car} + \beta_{PC\_car} . PC_{car} + \beta_{2.5} . D_{2.5} + \beta_{5} . D_{5} + \beta_{activ3} . Activ3 + B_{activ4} . Activ4 + B_{activ5} . Activ5$$

$$V(moto) = V(2) = V(8) = V(14)=V(20)= ASC_{Moto} + \beta_{TT} . TT_{moto} + \beta_{TC} . TC_{moto} + \beta_{PC\_moto} . PC_{moto} + \beta_{2.5} . D_{2.5} + \beta_{5} . D_{5}$$

$$V(taxi)=V(9)=V(15)=V(21)= ASC_{Taxi} + \beta_{TT} . TT_{taxi} + \beta_{WT} . WT_{taxi} + \beta_{TC} . TC_{taxi} + \beta_{2.5} . D_{2.5} + \beta_{5} . D_{5}$$

$$V(bus)=V(4)=V10)=V(16)=V(22)= ASC_{Bus} + \beta_{TT} . TT_{bus} + \beta_{WT} . WT_{bus} + \beta_{TC} . TC_{bus} + \beta_{WD} . WD_{bus} + \beta_{2.5} . D_{2.5} + \beta_{5} . D_{5}$$

$$V(dif) =V(5)=V(11)=V(17)=V(23)= \beta_{TT} . TT_{dif} + \beta_{WT} . WT_{dif} + \beta_{TC} . TC_{dif} + \beta_{WD} . WD_{dif} + \beta_{2.5} . D_{2.5} + \beta_{5} . D_{5}$$

$$V(Other)=V(12)=V(18)=V(24) = ASC_{Other}$$

and the utility functions for each of the four nests representing ownership category are as follows:

$$V(\alpha_1) = \lambda_{\alpha} [ASC\alpha_1 + \beta_{Ing\_4000\_1} . INC\_4000 + \beta_{Qwork\_1\&3} . Qwork + 1/\lambda_{m1} . EMU\alpha_1]$$

with $EMU\alpha_1 = ln [exp(\lambda_{m1}.Vcar) + exp(\lambda_{m1}.Vmoto) + exp(\lambda_{m1}.Vtaxi) + exp(\lambda_{m1}.Vbus) + exp(\lambda_{m1}.Vdif) + exp(\lambda_{m1}.Vother)]$

$$V(\alpha_2) = \lambda_{\alpha} . [ASC\alpha_2 + 1/\lambda_{m2} . EMU\alpha_2]$$

with $EMU\alpha_2 = ln [exp(\lambda_{m2}.Vcar)+exp(\lambda_{m2}.Vmoto) + exp(\lambda_{m2}.Vtaxi)+exp(\lambda_{m2}.Vbus) + exp(\lambda_{m2}.Vdif) + exp(\lambda_{m2}.Vother)]$

$$V(\alpha_3) = \lambda_{\alpha} . [ASC\alpha_3 + \beta_{Ing\_4000\_3} . INC\_4000 + \beta_{Qwork\_1\&3} . Qwork + 1/\lambda_{m3} . EMU\alpha_3]$$

with $EMU\alpha_3 = ln [exp(\lambda_{m3}.Vcar)+exp(\lambda_{m3}.Vmoto)+ exp(\lambda_{m3}.Vtaxi)+ exp(\lambda_{m3}.Vbus) + exp(\lambda_{m3}.Vdif) + exp(\lambda_{m3}.Vother)]$

$$V(\alpha_4) = \lambda_{\alpha} . [ASC\alpha_4 + \beta_{Ing\_2500\_4} . INC\_2500 + 1/\lambda_{m4} . EMU\alpha_4]$$

with $EMU\alpha_4 = ln [exp(\lambda_{m4}.Vcar)+exp(\lambda_{m4}.Vmoto + exp(\lambda_{m4}.Vtaxi)+ exp(\lambda_{m4}.Vbus) + exp(\lambda_{m4}.Vdif) + exp(\lambda_{m4}.Vother)]$

The explanatory variables for these elemental alternatives are as follows:

TT: travel time; *TC*: travel cost; *PC*: parking cost (per day); $D_{2.5}$: dummy variable for 2.5 kms trips from home to work; D_5: dummy variable for 5 kms trips from home to work; *WT*: waiting time; *WD*: walking distance on origin and destination (blocks); Activ3: dummy variable assuming the value of 1 if the person is chief or manager of a firm, and zero otherwise; Activ4: dummy variable assuming the value of 1 if the person is a private firm owner with 1 to

4 workers, and zero otherwise; and Activ5: dummy variable assuming the value of 1 if the person is a private firm owner with 5 to 20 workers, and zero otherwise[8].

The acronym *Dif* corresponds to "differential bus, ASC refers to "alternative specific constant". EMU: refers to expected maximum utility or inclusive value variable.

The explanatory variables for the utility functions of the ownership nests are:

INC_4000: dummy variable assuming the value of 1 if monthly household income is higher than AR$ 4000 and zero otherwise[9].

INC_2500: dummy variable assuming the value of 1 if monthly household income is smaller than AR$ 2500 and zero otherwise.

Qwork: number of household workers.

There are also ASC parameter constants for the nests.

This model incorporates specific parameters related with car and motorcycle ownership associated with different private vehicle ownership categories. Thus, $\beta_{Inc\_4000\_1}$ is the parameter associated with the *INC_4000* variable for ownership category 1 (with car and motorcycle available), $\beta_{Inc\_4000\_3}$ is the parameter associated with the *INC_4000* dummy variable for ownership category 3 (with car available), $\beta_{Inc\_2500\_4}$ is the parameter associated with the *INC_2500* variable for ownership category 4 (without car and motorcycle available), $\beta_{Qwork\_1\&3}$ is the parameter associated with the *Qwork* variable for ownership categories 1 and 3 (with car available).

Also, considering that we are dealing with an SP experiment and therefore there could be interdependent or serially correlated repeated choices, the model was estimated as a static (error component model) with random effect discrete panel data model and estimated as a mixture of logit in order to capture the intrinsic correlation among the choices made by each respondent due to the six stated choice responses given per individual in the survey. We have added individual specific error terms (normalizing the "no choice/other" alternative), so that we can reformulate the i^{th} utility as $U_{int} = V_{int} + \varepsilon_{int}$, where the unobserved part of the utility for alternative *i*, individual *n* and choice situation *t* is specified as $\varepsilon_{int} = \alpha_{in} + \varepsilon'_{int}$ with $\alpha_{in} \sim N(0,\Sigma)$, also it was assumed that ε'_{int} are independent across *t* (Bates and Terzis, 1997; Brownstone and Train, 1999; Train, 2009).

The estimation was carried out using BIOGEME software (Bierlaire, 2003 and 2009). Table II presents the estimation results.

The cases without reporting the monthly household income were excluded for estimation, so that the number of observations is 570. The goodness of fit of the model ($\bar{\rho}^2$) is found to be reasonably good (0.183).

All the estimated parameters have the expected sign, and all are significantly different from zero at 5 percent confidence level. All the estimated parameters have the expected sign, and almost all are significantly different from zero at 5 percent confidence level. The only parameter which is significant at 10 percent confidence level is the parameter associated to the variable "waiting time".

---

[8] Work activities were classified into nine categories: private sector employee, public sector employee, chief executive officer of a private firm, owner of a private firm with 1 to 4 workers, owner of a private firm with 5 to 20 workers, owner of a private firm with more than 21 workers, freelancer, unpaid family worker and other.

[9] AR$ refers to the Argentinean peso. The average currency exchange between the two moments the survey was collected (March 2011 and November 2011) was € 1 = AR$5.62 and US$ 1 = AR$ 4.15.

Table II: Nested logit model for simultaneous estimation of preference for vehicle ownership and mode choice for the journey to work

Variable description	Alternative	Coefficient estimate	Robust t-test
Explanatory variables for elemental alternatives			
Car constant	Car	0.743	4.32
Bus constant	Bus	0.549	3.06
Other constant	Other	-4.25	-7.65
Travel distance = 2.5 km dummy	All excl other	-3.03	-5.32
Travel distance = 5 km dummy	All excl other	-2.62	-4.75
Walking distance	Bus, Differential Bus	-0.0824	-2.66
Parking cost (per day)	Car	-0.0957	-7.03
Parking cost (per day)	Motorcycle	-0.122	-4.93
Travel cost	All excl other	-0.122	-8.46
Waiting time	Bus, Differential Bus, Taxi	-0.0158	-1.65
Travel time	All excl other	-0.0330	-4.19
Work activity 3: CEO of a private firm	Car	1.68	2.57
Work activity 4: owner of a private firm with 1 to 4 workers	Car	2.28	3.70
Work activity 5: owner of a private firm with 5 to 20 workers	Car	2.80	3.97
Explanatory variables for the nests			
Constant Motorcycle ownership	Nest 2	-0.593	-2.97
Household income > AR$ 4000, Car and motorcycle ownership	Nest 1	0.92	2.85
Household Income > AR$ 4000, Car ownership	Nest 3	2.27	8.88
Number of household workers	Nests 1 & 3	0.180	2.18
Household Income < AR$ 2500, No vehicle ownership	Nest 4	0.923	3.89
Scale parameters			
Car & Motorcycle ownership	Nest 1	1.56	2.16
Motorcycle ownership	Nest 2	1.00	Fixed
Car ownership	Nest 3	1.00	Fixed
No vehicle ownership	Nest 4	1.00	Fixed
Summary statistics			
Number of observations		570	
ρ^2		0.194	
$\bar{\rho}^2$		0.183	
L($\hat{\beta}$)		-1419.881	
L(0)		-1761.894	
LR Test		679.08	
VoTT (AR$ / hour)		16.22	
VoWT (AR$ / hour)		7.77	
VOWD (AR$/block)		0.6754	

The estimated coefficients associated with short distance trips (2.5 km and 5 km) are negative indicating that the utilities of using other modes like bicycle or making the trip on foot are a little higher for this trip length in comparison with greater travel distances. Furthermore, the panel effect coefficient was not significant, so that it was eliminated for carrying the estimation presented here.

The estimation presents fixed structural parameters for nests 2, 3 and 4 because they were not significantly different from the value of one. The estimated value of the Nest 1 scale parameter is according to theory, higher than one because the estimated model is normalized from the top, indicating the existence of a higher correlation between the preferences of individuals belonging to ownership category 1 (with car and motorcycle available).

The explanatory variables for the nests indicate that there is a higher probability of owning car or motorcycle and using them to commute if the household income is higher than AR$4,000; also there is a greater probability of owning car as the number of household workers increase and a greater probability of no car or motorcycle ownership if household income is lower than AR$2,500.

The subjective value of travel time savings (VoTT) and waiting time savings (VoWT) were calculated using the estimated coefficients of travel time, waiting time and travel cost. The subjective value of travel time savings is AR$ 16.22 per hour and the subjective value of waiting time is AR$ 7.77 per hour. It is important to note here that international experience indicates the value of waiting time is higher than the value of travel time (Wardman, 2004). In our results, the smaller subjective value of waiting time could be explained for the commuter's productive use of the waiting time related to reading, phoning or listening to music while waiting the public transport, activities that are very difficult to do once travelling on the bus services in Cordoba city, as it was expressed by users in Marconetti (2012). Further, we have estimated the model incorporating random parameters for travel time and waiting time variables, resulting in no evidence of heterogeneity of preferences related with these variables.

Furthermore, the specified NL model allows us to estimate jointly the mode choice for commuting purposes and the preferences for vehicle ownership as a function of the level of services of urban transport options.

Following, a scenario analysis is presented, which is designed to forecast the stated use of the urban transport modes for commuting and preference for vehicle ownership and for deriving demand elasticities. However, we have to recognise that only RP data should be used for prediction as it represents the real consumer behaviour. Nevertheless, our scenario analysis based on the estimated model with SP data allows us to estimate the sensitivity of mode choice commuters' preferences along with the sensitivity of preferences for buying car or motorcycle to changes in travel conditions. It is important to state here that further research could be done expressly considering the joint estimation with RP and SP data (as in Dissanayake and Morikawa, 2010) using the applied multidimensional modelling presented here and allowing the SP data to enrich the RP data collected in the first stage of the survey.

In our results, the forecasted mode market shares were calculated applying the sample enumeration method and weighting each response from a geographic zone by the share of workers in that zone by the total city workers. This is in line with the applied exogenous stratified sampling by geographic zone carried out at the sample design stage.

The base scenario was designed considering the following attribute levels: an average speed of 30 km/h for car, motorcycle and taxi trips (this speed determines travel times); an average speed of 18 km/h for bus and 20 km/h for differential bus; car and motorcycle parking costs equal to AR$10 a day; waiting times for bus, differential bus and taxi equal to 10 minutes on average; a bus fare equal to the current level of AR$2.5; a differential bus fare equal to the current level of AR$5; car costs were calculated as AR$0.50 per kilometer and motorcycle costs were AR$0.25 per kilometer.

Table III presents the results for the base scenario and other six scenarios. The base scenario column shows the market shares (probability) of use of the different transport modes for commuting as well as the market share of buying car and motorcycle in the short run. The following scenarios present the same figures resulting as a response to service level changes, and the derived demand elasticities. The analysis considers no change in ownership nests explanatory variables (i.e., income level and number of household workers). All the results were obtained applying the sample enumeration method.

Scenario 1 considers a 20 percent decrease in bus travel times as a consequence of a 25 percent increase of average speed. This scenario could be reached if the municipality implements exclusive lanes for buses and differential buses in the city centre and its vicinity.

Scenario 2 looks at the results caused by a 30 percent increment in car parking costs.

Scenario 3 takes into account a 25 percent decrease in differential bus waiting time.

Scenario 4 considers a 25 percent decrease in bus waiting time.

Scenario 5 presents market shares considering a 50 percent increase in bus fares.

Scenario 6 looks at the market shares derived from a 50 percent increase in differential bus fares.

Scenario 7 contemplates a 10% increase in car travel time.

First rows of the table present the mode market shares. Following, are the car and motorcycle market share that are explained by car and motorcycle buying. So that, for example, in the base scenario, a 47.82 percent car market share is composed of a category of users owning a car at present and another category of people who do not currently have a car but they would be willing to buy a car in the next six months if the transport modes service levels were as the ones in this scenario. A 24.88% of the 47.82% is willing to buy a car in this scenario[10]. Motorcycle figures have the same interpretation.

Scenarios 1 to 6 show different market shares as a consequence of some change in a level of service variable, each scenario considering a single change.

Demand elasticities are presented at the bottom of the table, direct demand elasticities are presented in grey shadowed cells and the other are cross elasticities of demand. Therefore, it could be stated from scenario 1 that a 20 percent decrease in bus travel time could cause a 5.20 percent decrease in the probability of buying cars and using them to commute as the elasticity of car buying with respect to bus travel time is equal to 0.26. Also, the total elasticity of car use is 0.288. The elasticity of motorcycle buying is 0.311 and the elasticity of motorcycle use is 0.333. The direct elasticity of bus demand with respect to bus travel time is -0.879, the cross elasticity of differential bus use with respect to bus travel time is 0.331 and the cross elasticity of taxi use with respect to bus travel time is 0.131. So that, there is scope to further research, evaluation and implementation of policies like “guided buses” or

[10] The market share of car use buying new car (24.88%) is calculated as the sum of P(7) and P(19), in terms of the syntax presented in section II.

"exclusive lanes for transit services" in order to reduce transit travel times and ensuring headways, promoting the use of public transport alternatives.

Scenario 2 shows that there is an important sensitivity of car use and car buying with respect to parking costs. It is important to note that nowadays parking costs exist only in the city centre and its vicinity and a large amount of current car users have parking costs lower than assumed in this scenario. The elasticity of car buying and the elasticity of car use with respect to car parking costs are -0.482 and -0.521, respectively. These elasticities might be rather high, result that could be related with the experience reported in car type choice models pointing out that pure SP models could give some implausible forecasts. Also, the cross elasticity of bus demand with respect to car parking costs is 0.493, indicating that a 10 percent increase in car parking costs will cause a 4.93 percent of bus commuting use market share.

From scenario 3, the waiting time elasticity of differential bus is -0.152, implying that a 25 percent decrease in differential bus average waiting time causes an increase of 3.80 percent in differential bus market share.

Table III. Policy Scenario Forecasting and Derived Demand Elasticities

Mode	Market Shares Scenarios Base	1 (-20% bus travel time)	2 (+30% car parking cost)	3 (-25% differential bus waiting time)	4 (-25% bus waiting time)	5 (+50% bus travel cost)	6 (+50% in differential bus travel cost)	7 (+10% car travel time)
Car	47.82%	45.06%	40.35%	47.60%	47.30%	48.89%	46.64%	46.12%
Motorcycle	9.08%	8.48%	10.36%	9.04%	8.98%	9.29%	9.60%	9.40%
Taxi	2.47%	2.41%	2.80%	2.46%	2.45%	2.52%	1.33%	2.51%
Bus	24.70%	29.04%	28.35%	24.58%	25.50%	23.02%	26.22%	25.56%
Differential Bus	11.00%	10.27%	12.57%	11.42%	10.88%	11.25%	10.69%	11.39%
Other (no choice option)	4.93%	4.74%	5.56%	4.90%	4.88%	5.02%	5.52%	5.03%
Car use buying new car	24.88%	23.59%	21.29%	24.78%	24.64%	25.38%	25.60%	24.07%
Motorcycle use buying new motorcycle	5.40%	5.06%	6.10%	5.37%	5.34%	5.51%	5.56%	5.57%
				Derived elasticities				
Elasticity of car buying		0.26	- 0.482	0.017	0.038	0.072	0.058	-0.329
Elasticity of car use		0.288	- 0.521	0.019	0.043	0.080	0.062	-0.356
Elasticity of motorcycle buying		0.311	0.434	0.019	0.041	0.076	0.062	0.323
Elasticity of motorcycle use		0.333	0.471	0.019	0.044	0.081	0.065	0.351
Elasticity of bus use		- 0.879	0.493	0.020	- 0.130	- 0.243	0.065	0.347
Elasticity of differential bus use		0.331	0.474	- 0,152	0.044	0.081	- 0.507	0.350
Elasticity of taxi use		0.131	0.441	0.016	0.038	0.070	0.053	0.161

Scenario 4 allows us to calculate the mode demand elasticities related to bus waiting time. The direct waiting time elasticity of bus demand is -0.130, indicating that a 10 percent decrease in average bus waiting time will increase the bus market share in 1.30 percent. Also, the elasticity of car buying with respect to bus waiting time is 0.038 and the elasticity of car use with respect to bus waiting time is 0.043, showing a very small sensitivity of car ownership and use to bus waiting time changes. The elasticity of motorcycle use to changes in bus waiting time is 0.044 and other demand elasticities related to bus waiting time in this scenario are also smaller than 0.1 (i.e. motorcycle buying, differential bus use and taxi use).

Fare elasticity of bus demand is -0.243 (see Scenario 5) and fare elasticity of differential bus is -0.507 (see Scenario 6). These figures seem reasonable, considering other research done in the city of Córdoba in Argentina (Sartori, 2003; Sartori, 2006a). In addition, it is important to note that the elasticity of car buying with respect to bus fare is only 0.072 and the same elasticity with respect to differential bus is 0.058 (from scenario 6). It should be noted that currently in Argentina there is an important amount of national subsidy going towards urban bus public transport firms importing nearly 30 percent of total costs into some urban bus firms. Subsidy declines and corresponding bus fare increases could cause urban bus users loss but it will not generate an important new demand for cars to commute. Scenario 5 also shows that the elasticity of car use with respect to bus travel cost is 0.08, indicating that a 10 percent increase in bus fares will cause a 0.8 percent increase in car use. In addition, elasticity of motorcycle buying related with bus fare is 0.058 and elasticity of motorcycle use with respect to bus fare is 0.155; the elasticity of differential bus use to changes in bus fares is also 0.081 and the elasticity of taxi use o changes in bus fares is 0.070. From scenario 6, it can be stated that apart from the direct fare elasticity of differential bus, all the demand elasticities related with differential bus fare changes are smaller than 0.1, a result that could be related with the current minor urban network coverage of differential bus transport lines and its effect on travel demand preferences for commuting and private vehicle ownership. Scenario 7 shows car use elasticity related with car travel time of -0.329 and an elasticity of car buying of -0.356, indicating the high car demand sensitivity to travel time. Cross demand elasticities of other modes with respect to car travel time are in the range of 0.3 – 0.4 except to the taxi elasticity that is 0.161.

The estimated model allows comparing the effect of different policies, for example, changing car and motorcycle travel cost versus acting directly over traffic conditions and travel times. For example, if new exclusive bus and differential lanes were implemented in Córdoba city implying an increase in bus and differential bus speeds reflecting a 10% decrease in travel time and a 10% increase in car and motorcycle travel time, the probability of using car will decrease by 6.44% and the probability of using motorcycle by 7.44%, increasing the probability of using bus by a 10.84% and differential bus by a 9.77%. Correspondingly, a policy increasing car and motorcycle travel cost with the aim of raising the combined bus and differential bus market shares by the same joint amount found with the exclusive bus and differential lanes, we will need a 32% increment in car and motorcycle travel costs. So that, the model could be used to forecast the effects of different policies aimed to improve urban mobility, contemplating car and motorcycle ownership conditions, preferences for buying car and motorcycle and use of different modes of transport for commuting.

According with all this evidence, if we want to cope with urban traffic congestion promoting the use of public transport alternatives for a sustainable urban mobility policy it is not sufficient action with maintaining the "status quo"; there is a need for improving urban public transport service levels in order to improve urban mobility. Our results show that there are users waiting for better public transport travel conditions that have a potential new demand for cars and motorcycles and are ready to leave public transport use for commuting if public transport service levels worse. Nevertheless, it is important to state that a bigger sample could be needed for being aware of the relationship between sample size, model complexity and forecasting power of the model. Hence, some of the valuations and elasticities are debatable or at least they have to be taken as the first values for an Argentinean city to start the debate.

5. FINAL COMMENTS

This paper has confirmed the hypothesis of interdependence between urban travel mode choice for commuting based on transport modes service levels and the car and motorcycle ownership decision.

We have specified a discrete choice multidimensional nested logit model considering the private vehicle ownership state of four different population categories and the mode choice decision for commuting trips based on a stated preference survey allowing us to capture the preferences for car and motorcycle owning for people not owning car or motorcycle at present.

The estimation results showed significant generic parameters for the level of services variables included in the utility functions (i.e. travel time, travel cost, waiting time, walking distance on origin and destination for commuting trips) and also allowed to estimate specific parameters for the car and motorcycle parking costs.

Also, we have estimated the value of travel time savings as AR$ 16.22 per hour, the value of waiting time as AR$ 7.77 per hour and the value of walking distance as AR$0.6754 per block.

A scenario analysis was conducted as a way of calculating elasticities of different modes of transport and for preferences for buying car or motorcycle. We have presented seven policy scenarios showing that there would be significant sensitivity of car buying preferences to parking costs. Also, worse bus travel times could encourage car and motorcycle buying decisions and as a consequence could aggravate the current urban traffic congestion conditions at rush hours.

Bus waiting times are viewed as not so important in order to impel private vehicle buying decisions and we recognise this is a fact requiring additional research as some people probably do not believe in the exact waiting times presented in the SP experiment as they confront high variability in bus waiting times in the market, a situation we have proved in past research (Sartori, 2006a). Differential bus service levels do not produce high changes in the shares of buying car and motorcycles. Furthermore, direct demand elasticities of bus use to bus travel time, demand elasticities of bus and differential bus use to its own waiting time, bus and differential bus price elasticities, appeared with reasonable calculations.

As a result, we have stated that if we want to cope with urban traffic congestion and to promote public transport alternatives for a sustainable urban mobility policy it is not sufficient action with maintaining the “status quo”, so that, there is scope for further evaluating and implementing policies such as guided buses or exclusive lanes for bus and differential bus services. There is a need for improving urban public transport service levels in order to get better urban mobility, as there is an important potential demand for buying cars and motorcycles for commuting as a result of worsening traffic conditions.

Further research based on the developed model is related with the possibility of applying an RP/SP estimation with the collected data or the development of a data panel applying the same interview in at least three years in order to validate stated preferences for vehicle buying decisions and to analyse changes in preferences for ownership and use as transport level of services change in time. Also, it must be recognized that expanding the research to other journey motives could be beneficial in terms of policy implementation.

ACKNOWLEDGEMENTS

This research was supported by Secretaría de Ciencia y Tecnología (Secyt) - Universidad Nacional de Córdoba (Argentina).

The authors wish to thank Luis Ignacio Rizzi (Pontificia Universidad Católica de Chile) for their valuable support and guidance, the reviewers of the 2nd International Choice Modelling Conference 2011 and two reviewers from the Journal of Choice Modelling for their valuable comments that helped to improve the model specification and results.

REFERENCES

Bates, J. J. and G. Terzis, 1997. Stated Preference and the "Ecological Fallacy", PTRC European Transport Forum, Transportation Planning Methods, vol. II.

Bhat, C. and V. Pulugurta, 1998. A comparison of two alternative behavioural choice mechanisms for household auto ownership decisions, Transportation Research Part B, 32 (1), 61-75.

Bhat, C., S. Sen and N. Eluru, 2009. The impact of demographics, built environment attributes, vehicle characteristics, and gasoline prices on household vehicle holdings and use, Transportation Research Part B, 43 (1), 1-18.

Ben-Akiva, M. E. and S. R. Lerman, 1974. Some estimation results of a simultaneous model of auto ownership and mode choice to work, Transportation, 3 (4), 357-376.

Ben-Akiva, M. E. and S. R. Lerman, 1985. Discrete Choice Analysis: Theory and Application to Travel Demand. MIT Press.

Bierlaire, M., 2003. BIOGEME: A free package for the estimation of discrete choice models, Proceedings of the 3rd Swiss Transportation Research Conference, Ascona, Switzerland.

Bierlaire, M., 2009. Estimation of discrete choice models with BIOGEME 1.8, http://transp-or2.epfl.ch/biogeme/doc/tutorial.pdf .

Bliemer, M. C. J. and J. M. Rose, 2005. Efficient designs for alternative specific choice experiments, Working Paper ITLS-WP-05-04, Institute of Transport Studies, The University of Sydney.

Brownstone, D. and K. Small, 1989. Efficient estimation of nested logit models, Journal of Business and Economic Statistics, 7 (1), 67-74.

Brownstone, D. and K. Train, 1999. Forecasting new product penetration with flexible substitution patterns, Journal of Econometrics, 89, 109-129.

Choicemetrics, 2009. NGene 1.0. User Manual & Reference Guide. The cutting edge in experimental design.

De Jong, G., J. Fox, A. Daly, M. Pieters and R. Smit, 2004. Comparison of car ownership models, Transport Review, 24 (4), 379-408.

Dissanayake, D. and T. Morikawa, 2010. Investigating household vehicle ownership, mode choice and trip sharing decisions using a combined revealed preference/stated preference Nested Logit model: case study in Bangkok Metropolitan Region, Journal of Transport Geography, 18 (3), 402-410.

Hensher, D. and A. J. Reyes, 2000. Trip chaining as a barrier to the propensity to use public transport, Transportation, 27 (4), 341-361.

Hensher, D., 2001. The valuation of commuter travel time savings for car drivers: evaluating alternative model specifications, Transportation, 28 (2), 101-118.

Hensher, D.; J. M. Rose and W. H. Greene, 2005. Applied Choice Analysis. A Primer. Cambridge University Press. Cambridge. UK.

Louviere, J. J., D. Hensher and J. Swait, 2000. Stated Choice Methods. Analysis and Application. Ed. Cambridge University Press.

Marconetti, D., 2008. Limpieza, tránsito y transporte con mala nota. La voz del interior, 7 de diciembre de 2008.

Marconetti, Diego, 2009. Las mismas calles, 66% más de vehículos. La voz del interior, 7 de diciembre.

Marconetti, Diego (2012). El ómnibus se usaría más si fuera más rápido. La voz del interior, 6 de octubre.

Rose, J. M., R. Scarpa and M. C. J. Bliemer, 2009. Incorporating model uncertainty into the generation of efficient stated choice experiments: A model averaging approach, International Choice Modelling Conference, March 30-April 1, Yorkshire U.K.

Rose, J. M. and D. A. Hensher, 2004. Handling individual specific availability of alternatives in stated choice experiments. Seventh International Conference on Travel Survey Methods. Costa Rica, 1st – 6th August.

Sartori, J. J. P., 2003. Estimación de elasticidades de demanda para el transporte urbano de pasajeros de la ciudad de Córdoba (Argentina), XXXVIII Reunión Anual de la Asociación Argentina de Economía Política, Mendoza – Argentina – Noviembre.

Sartori, J. J. P., 2006. Regulación de los servicios de taxi y remis: una contribución al análisis de la problemática de la falta de servicios en días feriados y de lluvia en la Ciudad de Córdoba (Argentina), Documento de trabajo N° 26, Departamento de Economía y Finanzas, Facultad de Ciencias Económicas, Universidad Nacional de Córdoba.

Sartori, J. J. P., 2006a. Diseño de un experimento de preferencias declaradas para la elección de modo de transporte urbano de pasajeros, Revista de Economía y Estadística, Facultad de Ciencias Económicas, Universidad Nacional de Córdoba.

Sartori, J. J. P., 2010. Estimación de la demanda de viajes al trabajo y la tenencia de vehículo particular utilizando encuestas de preferencias declaradas en la Ciudad de Córdoba – Argentina, XLV Reunión Anual de la Asociación Argentina de Economía Política, Universidad Nacional de Buenos Aires, Buenos Aires, Argentina, Noviembre.

Sartori, J. J. P. and C. W. Robledo, 2011. Simultaneous estimation of mode choice for commuting trips and preference for vehicle ownership in an urban area: the case of Córdoba city in Argentina, International Choice Modelling Conference 2011, Leeds, United Kingdom.

Srinivasan, S. and J. L. Walker, 2009. Vehicle ownership and mode use: the challenge of sustainability, Transportation, 36 (4), 367-370.

Train, K., 1980. A structured logit model of auto ownership and mode choice. Review of Economic Studies, XLVII, 357-370.

Train, K., 2009. Discrete Choice Methods with Simulation, Cambridge University Press, Cambridge, UK.

Wardman, Mark, 2004. Public transport values of time. Transport Policy 11, pp. 363-377.

Whelan, G., 2001. Methodological advances in modelling and forecasting car ownership in Great Britain, European Transport Conference 2001, PTRC, Cambridge, UK.

Whelan, G., 2007. Modelling car ownership in Great Britain, Transportation Research Part A, 41 (3), 205-219.