38TH CONGRESS OF THE EUROPEAN REGIONAL SCIENCE ASSOCIATION

Candelaria Barrios González
Mª Angeles Martínez Navarro
Departament of General Economics.Faculty of Economics, University of Cádiz, Cádiz, Spain.
candelaria.barrios@uca.es
mariangeles.martinez@uca.es
Tfno: 956299706-956299703
Fax: 956299626

The demand for urban transport: An application of discrete choice model for Cadiz.

ABSTRACT

The study of the demand for transport has among others apllications, the valuation of travel time saving that is a very important question in cost-benefit analysis, and to adopt transport policy tools.Since MacFadden developed a discrete choice model for travel demand, it has usually been the application of this model to study the individual behaviour when he has to choice among transport modes. Citizens of big cities have to face traffic congestion; polution, wasted time in travels and fuel, noise, stress and accidents are the costs imposed by congestion to society, elements that reduce the quality of life in cities. Public transport is a real alternative to private transport that is socially less expensive, for this reason this paper tries to forecast travel demand for public transport in Cádiz when travelling have to choice between public or private transport, using a discrete choice model. The results of this analysis (travel demand, value of time, elasticities) can be used to desing transport policies that could reduce congestion.

The demand for urban transport: An application of discrete choice model for Cadiz.

1.- Introduction

Although Cadiz is a city of reduced extension, it has important traffic jam problems due to its geographic configuration, to the high density of inhabitants near 16.000 inhabitants per square kilometers and to be the administrative centre of the province, these facts take away life quality to its inhabitants. In this way the public iniciatives are centred in political movements that promote the use of colective transport to get a model and more equilibrated distribution, between urban and private transport.

In this context, with this essay, we have tried to make an estimation of demand of transport when the individuals must make a choice between two alternatives, urban and private transport, according to a discrete choice model like the probit model. This model is based on the theory of aleatory utility that means the existence of rational customers who take their consume decisions maximizing its utility, including like explicative variables the urban transport attributes and the individual socioeconomic caracteristics. This allows to calculate the elasticities of demand according to the price and the time of the travel that can help to the design of urban transport politics that decreases traffic jams improving social comfortable living.

This essay is centred in the estimation of the demand for private transport in Cadiz city for the displacements due to work where the individuals decide what kind of transport maximizes their utility, planning a binomial choice model between car and bus. For this reason in the second section we expose the methodology used for the estimation of the function of the demand for transport, in the third section it is made the treatment and the analysis of the sample esteeming the model in the fourth section; the exploitation of the results is made in the fifth section with the computation of direct and crossed elasticities, the essay is finished with the attainment of the main conclussions.

2.- Discrete choice model: probit model.

Discrete choice model allows us to study the individuals behaviour when this has to face discrete decisions like in this case, to choose between urban transport or private transport (Gallastegui, 1985). These models esteem demand functions from individual facts what allows us to foretell with more exactitude changes effects in the attributes of transport ways (González et al., 1995; Matas, 1991).

Qualitative answer models have been used in different areas of economical investigation (Amemiya, 1981) being in the transport economy field Mac Fadden (1974, 1981) who from a maximizing theory of the aleatory utility that means the existence of rational customers and basing on a marginal micro-economical analysis, he formulated a discrete choice model that makes possible the esteem of the function for demand of transport.

This methodology is based on the idea that each customer maximizes its utility according to a group of continuous well-living Z and a group of discrete alternatives,j, joined to a estimative restriction R. The maximization of the utility U(Z,j) means that first of all the individual maximizes U(Z,j) according to the well-living Z for each alternative and then he chooses the alternative j that maximizes the entire utility.

$$\max_{j}\left\{\max_{Z} U(Z, j) s.r. pZ \leq R\right\}$$

The indirect function of utility is got of the first maximization, for an individual i and for each alternative j we can represent it like:

$$U_{ij}(X) = V_{ij}(X^{*}) + \varepsilon_{ij}$$

Where X* gathers the prices, the rent and the relevant attributes of the alternatives and individuals V_{ij} represents the common utility to all the individuals only in its structure because X* is different depending on the alternatives and the individuals ε_{ij} is an aleatory variable with a function of given probability and being able to be interpreted like the effect of the caracteristics of non-measurable pleasures of the individual.

The maximization of the utility about the alternatives means the that the individual i will choose the alternative j if $U_{ij} \geq U_{ik}$ $\forall$ k $\neq$ j, and then.

$$\begin{aligned}
&\Pr(i, j) = P_{ij} = \Pr(U_{ij} \geq U_{ik}) \\
&= \Pr(\varepsilon_{ik} - \varepsilon_{ij} \leq V_{ij} - V_{ik}) \\
&= F(V_{ij} - V_{ik}) = F[H(X^*, \theta)]
\end{aligned}$$

where F represents the distributive function of (ε_{ik} - ε_{ij}) and H represents the functional form of the relation ($V_{ij} - V_{ik}$). H is lineal one. In a binarial case with transport alternatives 1 and 2 are expressed like:

$$\begin{aligned}
U_{i1} &= X_i \beta_1 + Z_{i1}\alpha + \varepsilon_{i1} \\
U_{i2} &= X_i \beta_2 + Z_{i2}\alpha + \varepsilon_{i2}
\end{aligned}$$

where X_i are the variables that correspond to the individual caracteristics and Z_{ij} are the attributes of the considered alternatives.

The individual i chooses the alternative j (Yi = 1) if $U_{il} > U_{i2}$ it means,

$$\begin{aligned}
&Y_i = 1 \quad si \quad X_i{}' \beta + (Z_{i1} - Z_{i2})' \alpha + \varepsilon_i > 0 \\
&Y_i = 0 \quad on\, the\, contrary \\
&where\ \beta = (\beta_1 - \beta_2) \quad y \quad \varepsilon_i = (\varepsilon_{i1} - \varepsilon_{i2})
\end{aligned}$$

According to this planning, the choice of a decided alternative according to the attributes associated to each one of them (Z_{ij}) does not depends on their absolute values but on their differences.

An economical model of discrete choice means the necesity to choose a distribution of probability of the model (F). When the individual faces to binary alternatives, the most usual functions are the ones that give place to logit and probit models, in this case the chosen model is binomial probit that is based on the supposition that the function F is distributed according to a rule, being the probability of choosing the alternative 1:

$$P(Y_i = 1) = \Phi(X^* ' \Gamma)$$

Where Φ is the value of the function of a rule (0, 1), Γ is the standard value of the coefficients that we have to esteem that include the coefficients β and α, X* is the matrix of explicative variables where are present as the attributes of the urban transport as the socioeconomic caracteristics of each individual.

3.- Analysis of the sample.

The estimation of the function of demand for transport by discrete choice model requires knowing the individual behaviours in front of the choice of transport used, being posible, in general, to apply well the declared preferencies or the revealed preferences (The MVA Consultancy, 1994). In this essay real facts have been used, we start with a domiciliary inquiry about movility in work days in the Bay of Cadiz, made by EPYPSA (1993) and financed by MOTPMA and "Junta de Andalucia". The number of inquiries made for the area of study was 2.200 being distributed in a proportional way to a number of families in each zone adapted previously in Rota, Puerto de Santa Maria, Cadiz, Puerto Real, San Fernando and Chiclana. In Cadiz 786 inquiries were made and these families were asked about the socioeconomic caracteristics and the urban travels made for every member older than 5 years, being made with these facts three classifications, one about families, other about people and the last one about urban travels.

The original sample consists on 5.565 observations that means the total of urban travels made by the asked individuals in Cadiz. The first step consisted on determining the users of urban and private transport in Cadiz, for this reason we chose all the urban travels that have as origin and end the studied area, could be given the case of individuals that to travel to other towns use in the first part of the way a car or the urban bus, and for this ought to be included in the sample, however we verified that this situation was not usual. Then, we proceeded to avoid in the sample the travels made on foot, that although are alot, they are not an object of study, because we want to analyse only motorised travels; we avoided travels made in laboral and scholar transport and by taxi too, for being non-representative and being in need of the homogeneity needed to include them in some of the ways of study, for this reason we only chose travels made in private car as driver or attendant and by bus.

The final sample was divided depending on the travel motive, getting three sub-samples, because the behaviour changes in each case, being necesary the estimation of a function of demand for motive; the first sub-sample includes travels made by job motive, the second, the travels made by study motives and the third one the displacements by shopping and leisure, the rest of motives were rejected because they do not present homogeneous behaviour.

Then with these facts we built the first sample called “non-restricted 1”, which includes 331 observations of which the modal distribution is of 37-63 between bus and car. Then we chose the first of the travels for each person, to be only included once in the sample independiently of the number of travels made by the same motive, because it means that everyone has the same information, in this way, we built the sample called “non-restricted 2”, in this second sample, the sample size is of 262 observations, being the modal distribution similar to the before one. From a theoretical point of view, to apply the model, is necessary that all the individuals have access to all the alternatives, to make maxim his utility in the choice of transport for this, we avoided all the individuals who had not driving-licence and for this reason, they depended on the urban transport to get the “restricted” sample that is formed by 192 observation of which 81% corresponds to travles made in private transport and 19% to urban transport. This final sample, although is the most correct theoretically, presents the inconvinient of the slant in the information about urban transport, for this reason we decided to apply the model to the three samples.

4.- The model and its explicatives variables.

The explicative variables chosen to esteem the function of demand and that picks up as attributes of the ways of transport as the individual socioeconomic caracteristics are these:

1.- OFFER VARIABLES

Cost. We consider that the individual chooses the transport looking at the relative price and not the absolute price, for this reason, this variable is calculated by the difference of price or cost between private and bus. To calculate this variable we esteemed firstly the whole cost of each alternative, then for the car we included, facts like fuel, lubricants, tyre

(MOPTMA, 1993) and the parking cost, for the bus we use a pondered average bond-bus and the usual ticket and then we calculated the difference.

Time of travel. This variable is calculated like the difference of total time spent in the travel by car and by bus expressed in minutes, we needed esteem the time of the non-chosen alternative for each individual to be able to calculate the differences, because like we have commented, the way of transport is chosen depending on the difference in time between urban and private transport.

2.- SOCIOECONOMIC VARIABLES

Relation with the head of the family. This variable can be interpreted like a proxy of the availability of vehicle, although it is not determinant of the chosen way of transport. It will take value 1 for the head of the family and 0 for the rest of the cases.

Sex. Like the previous one it is a proxy of the possibility to have a vehicle that takes 0 value for women and 1 for men.

Age. It will give us information if there are rules of different behaviours for the choice of the way of transport, depending on the individual´s age. This variable was divided in two groups choosing like a reference the group of younger than 35.

Professional situation. This is a proxy variable of the rent level, because we do not have this variable, was divided in three groups; bosses and superior workers (Profession 1) the other workers with a boss (Profession 2) and own workers (Profession 3), taken the this like reference.

Defined the variables we esteemed the function of private transport demand along the probit model, getting the results in charts 1, 2 and 3.

In the trhee models, all the variables as the offer ones as the socioeconomic ones appear with the expected sign although not every ones are important. The variables that gather the transport caracteristics are in every case important to 5% but, the influence of a variation in the difference in time over the probability to choose private transport, is always over the same variation of the difference in prices. These results make us think that a reconstruction of the buses net, that would suppose a bigger adequacy between offer and demand and an increasing of the frequency and the speed, joined to an appropiate rate, will increase the probability to choose urban transport.

Chart 1.**Esteem of demand of transport in Cadiz. Dependent variable: Probability to travel in private transport.**

Variable	Coefficient	Statistic t	Probability
C	2,8705	2,770	0,0056
Difference in time	-0,0711	-4,125	0,0000
Difference in price	-0,0283	-3,670	0,0002
Head of family	0,5924	2,723	0,0065
Sex	0,3348	1,511	0,1306
Profession 1	-0,3426	-1,195	0,2319
Profession 2	-0,3889	-1,869	0,0615
Age >35 years	0,2751	1,588	0,1121
N	331	LR Statistic	74,9948
Log (L)	-180,8972	Probab. (LR Stat.)	0,0000
Rest. Log (L)	-218,3946	MacFadden R-Squa.	0,1717

Source: Own Elaboration.

Although the socioeconomic variables seen in the models, have a sign hoped, not all of them were important. Although the head of the family variable is not important in the restricted model, its positive sign says us that there is a bigger possibility of choosing private transport for travels to work if he is the head of the family, something similar happens with sex variable, men have bigger possibility to travel in private transport in front of women although none of these variables are important for the chosen way of transport. According to the job, we take as a reference the workers for their own, negative signs in the coeficients of the other two professional categories reflect that the possibility of choosing private transport minimizes according to the reference if we are part of one of these groups, and is that the group of own workers includes individuals with high rents and others whose job needs the use of a private vehicle. Although the age variable reflects that is bigger the possibility of using private transport when we are older than 35 years, it was not important as an explicative variable.

Chart 2**. Esteem of demand of transport in Cadiz. Dependet variable: Probabolity to travel in private transport.**

Variable	Coefficient	Statistic t	Probability
C	2,3933	2,078	0,0376
Difference in time	-0,0687	-3,588	0,0003
Difference in price	-0,0260	-3,036	0,0024
Head of family	0,4807	1,938	0,0525
Sex	0,4664	1,856	0,0634
Profession 1	-0,3406	-1,080	0,2799
Profession 2	-0,1968	-0,855	0,3922
Age >35 years	0,2868	1,464	0,1431
N	262	LR Statistic	58,4806
Log (L)	-146,3331	Probab. (LR Stat.)	0,0000
Rest. Log (L)	-175,5734	MacFadden R-Squa.	0,1665

Source: Own Elaboration.

Chart 3. **Esteem of demand of transport in Cadiz. Dependent variable: Probability to travel in private transport.**

Variable	Coefficient	Statistic t	Probability
C	4,0619	2,642	0,0082
Difference in time	-0,0939	-3,362	0,0008
Difference in price	-0,0299	-2,689	0,0072
Head of family	0,3505	1,125	0,2605
Sex	0,1978	0,555	0,5782
Profession 1	-0,2808	-0,584	0,5591
Profession 2	-0,6477	-1,736	0,0826
Age >35 years	0,0115	0,045	0,9634
N	192	LR Statistic	31,30829
Log (L)	-77,00075	Probab. (LR Stat.)	0,0000
Rest. Log (L)	-92,65489	MacFadden R-Squa.	0,1689

Source:Own Elaboration.

5.- Elasticity in price and time of the function of demand for private transport.

The coefficients that have been got with the models for the different explicative variables, say to us the relative importance of each one of them about the choice between urban and private transport for the displacement to work, but what is really useful to establish a politic of transport that will guarantee an optimal modal distribution, is the knowledge of elasticities. These offer information about the effects aggregated of variations in the attributes being able to foretell then the impacts what changes in velocity, the frequency and in the prices have about the modal distribution, for this reason, they are a proper instrument to design the global offer of urban transport or to establish punctual changes in the existent one.

The elasticities have been calculated for discrete changes between 10% and 50% as in the variable price as time and in the three samples, the results obtained have been similars in both cases and are gathered in Chart 4.

The obtained elasticities are similar in the 2 non-restricted samples, with exception of the crossed elasticities of urban transport according to the price of private transport that is sensibly superior in the largest sample, this similarity is because the difference in both samples are in the cause that the most reduced includes an only travel per person and then the caracteristics of the model must not be very different.

In general the elasticities according to the price are superior than according to the time, although it does not happen in the restricted sample in the case of urban transport, where the elasticity of price in this way of transport is similar to the time one. In this sample we can emphasize the high values that the urban transport elasticity have got, and this makes us think that a proper reestructuration of lines and an efficient politic of prices in this way of transport could help to a modal distribution more balanced than the actual. The elasticities in the same sample, but according to private transport is more rigid and consistent with the results of other studies made with similar methodologies (Matas, 1990) except with the elasticity, price of private transport that is superior to the unity what means a high sensibility of users of private transport according to the costs of this way, for this reason, it could de effective to introduce a politic of urban toll to reduce the congestion, although the

effects would always be lower than an increasing in the service of urban transport like is confirmed by the highest elasticities that shows this way of transport.

Chart 4. **Private and urban transport elasticities.**

Elasticities	*N=331*	*N=262*	*N=192*
Private Transport			
Time	-0,46	-0,48	-0,44
Price	-2,81	-2,71	-1,83
E. crossed time	0,73	0,76	0,32
E. crossed price	0,89	0,87	0,35
Public Transport			
Time	-1,25	-1,19	-3,38
Price	-1,52	-1,36	-3,03
E. crossed time	0,79	0,75	1,93
E. crossed price	4,79	1,12	7,92

Source:Own Elaboration

6.- Conclusions

In this essay we have esteemed the function of demand for private transport in Cadiz with the objective of knowing the varibles that determine the individual behaviours in the modal choice when they make motorized displacements, moreover we have determined the added effects that discrete changes in these variables price and time, have over the modal distribution between urban and private transport.

The esteem of the demand for private transport in Cadiz through a model of discrete choice proves that the possibility for the displacements, private transport increases with the difference in cost and time between private and urban transport, although the urban transport has a bigger influence what is consistent with similar studies. On the other hand, although the socioeconomic variables resulted with a hoped sign, they are not determinant for the choice between the alternatives. The calculated elasticities for the private transport

are inferior to the urban transport, moreover in the first case demand is shown more sensitive to changes in price than in time and for this the restricted measurements to use the car could help to a more balanced modal distribution. Demand for urban transport, is shown more sensitive as in a variation in price as in time what shows that a politic that followed a reduction of congestion in Cadiz must not forget a reestructuration of urban transport that looked at smaller times for displacements and a politic of proper prices to get an effective movement of users between ways. The biggest elasticities obtained for urban transport in Cadiz in comparisson with other studies induce us to think that in this city there is nowadays a big control margin to act over the variables that determine the modal choice.

References

Amemiya, T. (1981): "Qualitative Response Models" *Journal of Economic Literature.* Vol. XIX , págs. 1483-1536.

EPYPSA (1993): *Movilidad en día laborable en la Bahía de Cádiz.* MOPTMA y Junta de Andalucía.

Gallastegui, I. (1985): "Aspectos básicos de los modelos de elección discreta en economía". *Revista Española de Economía,* vol. 2, nº 2, págs 187-202.

González, R. M. et al (1995): "Modelos logit y probit binomiales. La estimación del valor del tiempo en la línea Gran Canaria-Tenerife". V Congreso Nacional de Economía. Las Palmas de Gran Canaria.

MacFadden, D. (1974): "The Measurement of Urban Travel Demand", *Journal of Public Economics.* Vol. 3, nº 4, págs 303-328.

MacFadden, D. (1981): "Econometric Models of Probabilistic Choice", en Structural Analysis of Discrete Data. Manski, C. F. y MacFadden, D. eds..Cambrige: MIT Press, págs. 198-272.

Matas, A. (1990): *El transporte urbano: análisis de la eficiencia y factores condicionantes de la demanda.* Tesis Doctoral, Facultad de Ciencias Económicas y Empresariales, Bellaterra, Barcelona.

Matas, A. (1991): “La demanda de transporte urbano: un análisis de las elasticidades y valoraciones del tiempo” *Investigaciones Económicas (Segunda época),* vol. XV nº 2, págs. 249-267.

MOPTMA (1993): *Recomendaciones para la Evaluación Económica, Coste-Beneficio deEstudios y Proyectos de Carreteras.* Ministerio de Obras Públicas y Transportes. Madrid.

The MVA Consultancy (1994): “Time savings: Research into the value of time”, en Cost-Benefit Analysis. (Second edition) Layard R. and Glaister S. eds.. Cambrige University Press.