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## CAR OWNERSHIP AND ACCESS TO JOBS IN SPAIN

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### Abstract

This study analyses the impact that job accessibility in public transport has on car ownership. An ordered probit explaining the number of cars per household is estimated as a function of head of household characteristics, household characteristics and job accessibility. The data used in the analysis come from the Microcensus of year 2001 of the Spanish Institute of Statistics for the areas of Barcelona and Madrid. Our results show a significant effect of accessibility on car ownership. Additionally, we carried out simulation exercises in which the expected number of vehicles decreases as accessibility improves. For instance, in the case of households living outside the central city, an improvement of accessibility up to the average level of the central city would offset the effect of the number of working adults on the expected number of vehicles.

Keywords: car ownership, job accessibility, public transport.

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## **1. Introduction**

Urban decentralisation has long been a characteristic of US metropolitan areas. However, in recent decades, this phenomenon has also affected European cities. Most European cities have witnessed a process of population and employment decentralisation that has occurred with differences in intensity and timing (Cheshire, 1995). As a consequence, polycentric cities have emerged, but also low density developments (Kasanko et al., 2006). These changes in the urban form have affected travel patterns. In particular, a less dense urban area makes it difficult to provide a good quality public transport network and, hence, increases car dependence .

An extensive amount of literature has been devoted to the study of the relationship between land use and car dependence. Particular attention to the effect of urban form on car ownership is given in the works of Newman and Kenworthy, 1989; Giuliano and Small, 1993; Boarnet and Crane, 2001; Dargay, 2002; Bento et al., 2005; Giuliano and Dargay, 2006.

The purpose of this paper is to assess the effect of the decentralisation of economic activity on household car ownership. Decentralisation is measured in terms of residential accessibility to employment by public transport. We estimate an ordered probit model in which accessibility is included as an explanatory variable jointly with the usual household socioeconomic and demographic variables. The study is carried out for the two largest metropolitan areas in Spain: Barcelona and Madrid. The results show that job accessibility has a highly significant statistical effect on the number of cars owned by a household.

## **2. The study areas**

The study focuses on the metropolitan areas of Barcelona and Madrid. Barcelona has a relatively dense metropolitan area of 3,000 sq km and 4.4 million people, which implies a density of 1380 inhabitants per sq km. The central city comprises only 99 sq km of land and concentrates a little more than a third of the population, with a density of 15150 inhabitants per sq km. The Barcelona metropolitan area is polycentric, with a

central business district (the core of the area, made up of Barcelona city and eight surrounding municipalities) that concentrates 57% of the total employment and a significant number of secondary job centres.

The Madrid area hosts a population of 5.4 million in an area of 8000 sq km, with a density of 692 inhabitants per sq km. The central city covers an area of 600 sq km with a population of around 3 million, which implies a density of roughly 5000 inhabitants per sq km. In this case, the distribution of jobs defines a rather monocentric area with almost 70% of jobs located in the central business district, which is made up of Madrid city and three adjacent municipalities.

Over the last decades, a clear process of employment and residential decentralisation has taken place in both areas. As Tables 1 and 2 show, the central city lost both population and jobs as a percentage of the entire metropolitan area.

Table 1. Residential suburbanisation (% population in central city)

	<b>1981</b>	<b>1991</b>	<b>2001</b>	<b>2006</b>
Barcelona	41.3%	38.5%	34.3%	33.2%
Madrid	67.4%	60.8%	54.2%	52.1%

Table 2. Employment decentralisation (% jobs in central city)

	<b>1981</b>	<b>1991</b>	<b>1996</b>	<b>2001</b>
Barcelona	53.7%	48.1%	43.5%	42.0%
Madrid	n.a.	n.a.	67.0%	63.8%

Automobile ownership has also shown a significant change, with a very steep increase between 1981 and 2001, as illustrated in Table 3. Matas and Raymond (2008) prove that the main explanatory factors for such an increase are the growth in real income, the increase in employment ratio, the greater mobility needs derived from the process of suburbanisation and decentralisation, and the fall in the real hedonic prices of cars. Nonetheless, the relative importance of these factors varies according to municipality size.

As can be seen in Table 3, the increase in car ownership has been much lower in the central cities. In Barcelona, the percentage of households without a car is 31% in the central city and 14% in the rest of the area, whereas in Madrid the percentages are 26

and 14, respectively. On the other hand, the percentage of households with two or more cars is 13% in Barcelona city and 33% in other municipalities on average; figures for Madrid show a similar behaviour. In part, this may be explained by the higher cost of car use in central cities (mainly parking and congestion costs). A second explanation is that better accessibility by public transport for those living in the central city makes it possible to reduce the level of motorisation. That is the question that this paper addresses.

Table 3. Household car ownership, share of households in each group

	Barcelona		Madrid	
	1981	2001	1981	2001
<b>Total area</b>				
No car	33.0	19.3	39.9	20.2
1 car	62.7	54.7	54.1	52.0
2 or more cars	4.3	25.9	6.0	27.9
<b>City centre</b>				
No car	34.7	30.6	38.6	26.3
1 car	60.7	56.3	54.0	52.2
2 or more cars	4.6	13.2	7.4	21.6
<b>Rest of the area</b>				
No car	31.3	13.6	44.0	13.5
1 car	64.8	53.9	54.5	51.7
2 or more cars	3.9	32.5	1.5	34.7

### 3. Measuring job accessibility

A key issue in this study is how to measure residential accessibility to job opportunities. Following Rogers (1997), this variable has to take into account the spatial distribution of jobs and the distance or access cost to reach them.

The variable used here is the employment potential for each residential zone computed for all municipalities in the metropolitan area. The job access formula is given by:

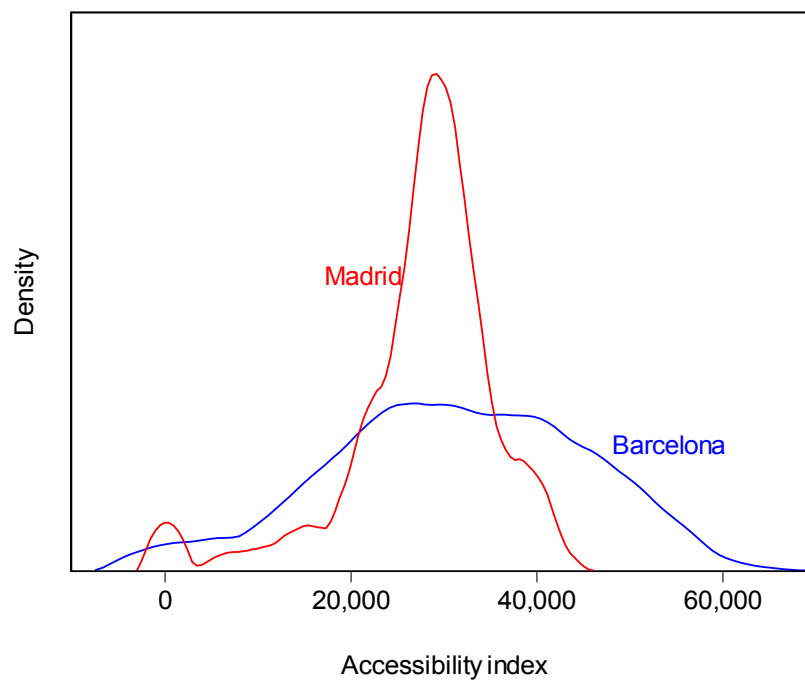
$$ACCEMP_i = \sum_j \frac{EMP_j}{t_{ij}} \quad (1)$$

where:  $EMP_j$  is the number of jobs in municipality/district  $j$   
 $t_{ij}$  is the travel time by public transport between  $i$  and  $j$   
 $i$ , is the household zone of residence  
 $j$ , is the destination zone

In other words, job accessibility for a household living in zone  $i$  is computed as the sum of employment opportunities in each municipality  $j$  inversely weighted by travel time between  $i$  and  $j$ . For the residential zones, the geographic unit of analysis is transport zones, which are a subdivision of municipalities used to calculate the matrices of travel time<sup>1</sup>. Regarding the destination zone, the municipality is the smallest spatial unit for which the number of jobs is available. However, in order to improve the accuracy of the accessibility measure in the cities of Barcelona and Madrid, jobs are computed at the level of districts<sup>2</sup>. The index is computed using job locations from the 2001 Census of Population and the commuting times by public transport are obtained from the official travel time matrices.

The computed index provides an accessibility value for each residential zone that, in the case of Barcelona, for instance, goes from 10 to 60000. Figure 1 shows very clearly that the distribution of the accessibility index is more concentrated for the Madrid area, with the result that nearly 65% of jobs are located in the central city.

Figure 1. Accessibility to employment index



<sup>1</sup> Roughly, each metropolitan area is divided into 600 zones.

<sup>2</sup> The cities of Barcelona and Madrid are divided into 12 and 21 districts, respectively.

#### 4. The data

The study relies on cross-section data from the 2001 Spanish Micro-census. This dataset corresponds to a 5% sample of the census population. Its main advantage, besides the sample size, is the level of spatial disaggregation of the information, which makes it possible to define the variables using very small spatial units (census tract level).

The dataset provides the main individual characteristics, including age, educational attainment<sup>3</sup>, gender, marital status, socioeconomic status and citizenship. The survey also provides household characteristics that are included as explanatory variables: the number of adults, the number of working adults, housing size, second residence property and housing tenure. One drawback of census data is that no information is available about the level of household income. Given that income is a crucial determinant of car ownership, we have approximated it using the economic status of the head of household, housing size, availability of a second residence and housing tenure.

Finally, we have considered three variables defined at census tract level. The first one is job accessibility as defined in the previous section; the second is the unemployment rate, as a proxy for residential segregation; and the third is a dummy variable that takes the value of 1 for those households located at the central city and 0 otherwise.

The mean values for all variables used in the model are given in Table 4.

**Table 4. Descriptive statistics of the explanatory variables**

	<b>Barcelona</b>	<b>Madrid</b>
	Mean	Mean
<b>Head of household characteristics</b>		
Age	43.0	43
Years of education	10.1	10.8
Male	62.2%	63.8%
Married	69.2%	69.1%
<i>Socioeconomic status</i>		
Employers	6.2%	5.2%
Managerial occupations	5.2%	6.1%
Own account workers	7.0%	5.9%
Professional occupations	23.2%	27.2%
Clerical	18.9%	19.3%

<sup>3</sup> A variable of years of education was generated based on the required number of years to complete each degree.

Skilled and semi-skilled workers	24.3%	18.1%
Unskilled workers	14.2%	16.4%
Other	1.0%	1.8%
<i>Citizenship</i>		
UE-15 other than Spanish	1.1%	1.0%
Other	3.9%	5.7%
<b>Household characteristics</b>		
Adults	2.5	2.6
Working adults	1.7	1.7
Housing size (sq m)	87.6	90.6
Second residence (%)	15.6%	20.4%
Housing tenure (% rented )	17.0%	14.8%
<b>Neighbourhood characteristics</b>		
Unemployment rate	10.9%	12.1%
Job accessibility	32220	27363
Dummy for central city	0.34	0.53

## 5. Model estimation

The car ownership decision has been modelled at the household level according to an ordered probit model<sup>4</sup>. The alternatives faced by a household are no car, one car, two cars and three or more cars. Data on car ownership also come from the 2001 Census and the mean values are shown in Table 3.

As is well known, the ordered probit model can be derived from a latent variable model. The latent variable measures the underlying desire for car ownership and can be expressed as:

$$y^* = X\beta + \varepsilon \quad \varepsilon \sim N(0,1) \quad (2)$$

where  $y^*$  is the standardised latent variable,  $X$  is the set of explanatory variables and  $\varepsilon$  is the random term.

The observed values for car ownership,  $y$ , are determined from  $y^*$  using the following relation:

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<sup>4</sup> In Matas and Raymond (2008), an ordered approximation for modelling car ownership is justified over non-ordered alternatives.



$$\begin{aligned}
y = 0 & && \text{if } y^* \leq \mu_1 \\
y = 1 & && \text{if } \mu_1 < y^* \leq \mu_2 \\
y = 2 & && \text{if } \mu_2 < y^* \leq \mu_3 \\
y = 3 & && \text{if } y^* > \mu_3
\end{aligned} \tag{2}$$

where  $\mu_1$ ,  $\mu_2$ , and  $\mu_3$  are unknown threshold parameters to be estimated.

Given that our interest lies in the relationship between access to jobs and numbers of cars, our analysis is based on those families in which at least one of their members belongs to the labour force. The explanatory variables of the model are those defined in the previous section and include individual, household and neighbourhood characteristics. The number of observations for Barcelona and Madrid are 52375 and 63903, respectively.

The number of household members who are in work is a variable that appears as highly significant in the literature explaining car ownership. We design a specification of equation (2) that allows this variable to interact with job accessibility. In this way we can test whether, for a given number of employed members in the household, a higher or lower job accessibility affects car ownership probabilities. In equation (2) the number of vehicles (*numveh*) appears as a function of the number of working adults in the household (*workingadults*) in the following way:

$$numveh = \beta \cdot workingadults \tag{3}$$

Different specifications for the coefficient  $\beta$  in equation (3) were tried with similar results. Finally, we selected the following linear relation because of its simplicity. Hence,  $\beta$  behaves as follows:

$$\beta = \gamma_0 - \gamma_1 accessibility \tag{4}$$

This specification assumes that  $\beta$  decreases as accessibility improves, attaining the maximum value when accessibility is zero.

Finally, by substituting (4) into (3) we obtain:

$$numveh = \gamma_0 workingadults - \gamma_1 workingadults * accessibility \quad (5)$$

In (5) we allow the effect of working adults on the number of vehicles to be mediated by accessibility.

Estimation results of the ordered probit model are presented in Table 5. All the estimated coefficients take the expected sign and are highly significant. In addition, coefficients are very similar between the two metropolitan areas.

The relationship between the number of cars and age is not linear and reaches a maximum at around 35 years of age. As expected, the probability of the highest car ownership level rises with the education of the head of household. *Ceteris paribus*, the probability of owning at least one car is higher when the head of household is a man, married, employer, own account worker or employed in managerial occupations. By contrast, the probability is lower when the head of household is an unskilled worker or was born abroad.

**Table 5. Estimation results of the ordered probit model**

	Barcelona		Madrid	
	Coefficient	z-statistic	Coefficient	z-statistic
<b>Head of household characteristics</b>				
Age	0.01286	3.29	0.01230	3.41
Age squared	-0.00019	-4.12	-0.00017	-4.06
Years of education	0.02709	19.65	0.03373	27.20
Male	0.11117	10.31	0.11232	11.22
Married	0.43326	34.42	0.46813	41.06
Employers	0.23173	10.62	0.28268	13.28
Managerial occupations	0.12908	5.38	0.15833	7.96
Own account workers	0.08836	4.26	0.17410	8.60
Unskilled workers	-0.19570	-12.28	-0.19953	-14.57
<b>Citizenship</b>				
UE-15 other than Spain	-0.23037	-4.67	-0.10611	-2.30
Other countries	-0.89704	-29.47	-1.00835	-41.87
<b>Household characteristics</b>				
Adults	0.13561	20.97	0.10373	19.23
Working adults	0.48746	38.54	0.40312	36.35
Housing size (sq m)	0.00453	31.89	0.00439	40.74
Second residence (%)	0.22996	16.14	0.24833	21.65
Housing tenure (% rented )	-0.38460	-25.71	-0.38763	-26.66

**Neighbourhood characteristics**

Unemployment rate	-2.28374	-14.21	-2.93217	-19.23
Working adults *access	-9.41E-06	-29.02	-7.76E-06	-23.49
Dummy for central city	-0.27831	-18.21	-0.18951	-17.84
<i>Limit points</i>				
$\mu_1$	0.39260	4.63	0.39356	4.92
$\mu_2$	2.27501	26.69	2.16645	26.99
$\mu_3$	3.61525	41.96	3.54260	43.72
Observations	52375		63903	
Pseudo R <sup>2</sup>	0.161		0.161	
Schwarz criterion	1.8693		1.9193	
Log likelihood	-48832.5		-61203.3	

Regarding household characteristics, the number of household adult members increases the probability of owning a car, and a higher effect appears for working adults. This result is in accordance with results obtained in previous studies<sup>5</sup>, and reflects the greater mobility needs of working people. The three variables included as proxies for income—housing size, second residence and housing tenure—are of the expected sign.

Finally, neighbourhood characteristics also prove to have an effect on car ownership. The probability of owning at least one car is lower for those families living in zones with high unemployment rates. Taking into account that we do not have a proper measure of household income, unemployment can capture part of its effect.

The other two variables that account for the effect of residential location are highly significant. The results make it possible to confirm that time costs to access jobs by public transport is a determinant of car ownership. The magnitude of the impact will be analysed in the next section. After controlling for public transport accessibility, living in the central city lowers the probability of owning at least one car. This conclusion has to be viewed in relation to the fact that these cities suffer the worst congestion problems and the highest parking prices.

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<sup>5</sup> This is a well known result in the literature. See Bath and Pulugurta (1999), and for the Spanish case Matas and Raymond (2008).

## 6. Elasticities and simulations with respect to job accessibility

As stated in the introduction, the purpose of this paper is to quantify the effect of job accessibility on car ownership. With this objective in mind, we have computed demand elasticities with respect to job accessibility by public transport. Elasticity values—presented in Table 6—correspond to aggregate values for the whole sample and are computed by simulating a unit percentage increase in the explanatory variable.

The estimated elasticity for average car ownership is -0.25 in Barcelona and -0.19 in Madrid. Although these values are low, their statistical significance should be borne in mind. In addition, when computing the elasticities for the four discrete alternatives, it can be observed that reducing the travel time to jobs has a larger impact on the decision to buy a second or third car and it significantly increases the number of households with no car.

Table 6. Elasticity of car ownership with respect to job accessibility

	Barcelona	Madrid
Average car ownership	-0.253	-0.185
No car	0.557	0.369
1 car	0.049	0.054
2 cars	-0.450	-0.313
3 or more cars	-0.883	-0.664

Additionally, the impact of job accessibility on car ownership is illustrated through a simulation exercise consisting of setting the level of job accessibility for all the individuals in the sample at least equal to the average value of this variable for the zones in the highest decile. On average this simulation implies increasing job accessibility by 61% in Barcelona and 43% in Madrid. The reason for the lower percentage in Madrid is the lower variance of accessibility distribution in that area.

The results are given in Table 7. For each area, the first column corresponds to the predicted share of households in each car group, the second column is the predicted share after increasing accessibility, and the third gives the difference between them<sup>6</sup>.

Table 7. Household car ownership, share of households in each group

	Barcelona			Madrid		
	Observed value	Simulated value	Difference	Observed value	Simulated value	Difference
<b>Total area</b>						
No cars	19.3	25.4	6.1	20.2	23.2	3.0
1 car	54.7	57.9	3.2	52.0	53.8	1.8
2 or more cars	25.9	16.7	-9.2	27.9	23.1	-4.8
<b>Central city</b>						
No cars	30.6	33.8	3.2	26.3	28.1	1.8
1 car	56.3	54.8	-1.5	52.2	53.2	1.0
2 or more cars	13.2	11.4	-1.8	21.6	18.7	-2.9
<b>Rest of the area</b>						
No cars	13.6	21.2	7.6	13.5	17.8	4.3
1 car	53.9	59.5	5.6	51.7	54.4	2.7
2 or more cars	32.5	19.3	-13.2	34.7	27.9	-6.8
<b>Average car ownership</b>						
Total area	1.11	0.93	-0.18	1.12	1.03	-0.09
Central city	0.84	0.78	-0.06	0.99	0.93	-0.06
Rest of area	1.24	1.00	-0.24	1.27	1.14	-0.13

As can be observed, increasing job accessibility would achieve a significant reduction in the level of motorisation. For those families living outside the city of Barcelona, the percentage of households with two or more cars would fall from 32.5% to 19.3%, with an increase of 7.6 points in households without a car. As expected, the impact for those living in the central city would be lower given the higher accessibility level they already enjoy. It should be noted that the average number of cars per household for the total area would fall below unity.

In the Madrid area the predicted effects work in the same direction; however, the impacts are less pronounced given the lower increase in the simulated accessibility index.

<sup>6</sup> It should be noted that the observed values of household car ownership are not the same as those presented in Table 3. The reason is that values in Table 3 correspond to total population, whereas values in Tables 7 and 8 are restricted to households with at least one member in the workforce.

It is interesting to note that the effect on car ownership of increasing job accessibility to the average value of the highest decile is equivalent to having no working adults in the population.

## **7. Conclusions**

The aim of this paper has been to assess the effect of job decentralisation on car ownership in the metropolitan areas of Barcelona and Madrid. For this purpose we have built an employment potential index that makes it possible to measure job accessibility in terms of public transport. This index controls for urban structure so that we can compare areas of such differing structure as the two under study here.

In order to carry out the analysis, an ordered probit model has been estimated including individual, household and spatial variables. All the estimated coefficients are significant and correctly signed. The results show that, after controlling for individual and household variables, the spatial variables play a significant role in explaining the probability of car ownership.

The results confirm that time costs to access jobs by public transport is a determinant of car ownership. The elasticity values for average car ownership are -0.25 for Barcelona and -0.19 for Madrid. Although these values might seem low when computing the elasticities for the four discrete alternatives, we should note that the estimated elasticity for the alternatives of two or more cars ranges from -0.31 to -0.88.

A simulation exercise increasing accessibility to jobs for all residential areas results in a noticeable impact on the probability of owning a car. For instance, for those living in the Barcelona area but outside the central city increased accessibility translates into a reduction of 32.5% to 19.3% in the share of households with two or more cars. Such a change would offset the effect of the number of working adults in the sample.

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