Car ownership and access to jobs in Spain

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1. Introduction

Urban decentralization has long been a characteristic for US metropolitan areas. However, over the last decades, this phenomenon has also affected European cities. Most of the European cities have seen a process of population and employment decentralization 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. Particularly, a less dense urban area makes it difficult to provide a good quality public transport network and, hence, increases auto dependence.

An extensive amount of literature has been devoted to the study of the relationship between land use and auto 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 asses the effect of decentralization of activities on household car ownership. Decentralization 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. The area of Barcelona is a relatively dense metropolitan area with 3000 km^2 and 4.4 million people, which implies a density of 1380 inhabitants per km^2. The central city comprises only 99 km^2 of land and concentrates a little more than a third of the population, with a density of 15150 inhabitants per km^2. Barcelona metropolitan area is polycentric, with a central business district that (the core of the area - formed by Barcelona city and eight surrounding municipalities) concentrates 57% of total employment and a significant number of secondary job centres.

The Madrid area hosts a population of 5.4 million in 8000 km^2 area, with a density of 692 inhabitants per square kilometre. The central city covers an area of 600 km^2 with a population around 3 million, which implies a density of 5000 inhabitants per km^2. In this case, the distribution of jobs defines a rather monocentric area with almost 70% of employments located in the CBD – Madrid city and three adjacent municipalities.

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

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

	1981	**1991**	**2001**	**2006**
Barcelona	41.3%	38.5%	34.3%	33.2%
Madrid	67.4%	60.8%	54.2%	52.1%

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

	1981	**1991**	**1996**	**2001**
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 fast 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

suburbanization and decentralization and the fall of the real hedonic prices of cars. Nonetheless, the relative importance of these factors varies according to municipality size.

As it 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 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% on average in other municipalities; figures for Madrid show a similar trend. In part, this may be explained by higher cost of car use in central cities (mainly parking and congestion costs). A second explanation is that a better accessibility by public transport for those living in the central city makes it possible to reduce its level of motorization. This is the question that the paper addresses.

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

	Barcelona		**Madrid**	
	1981	**2001**	**1981**	**2001**
Total area				
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
Central city				
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
Rest of the area				
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 of 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 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

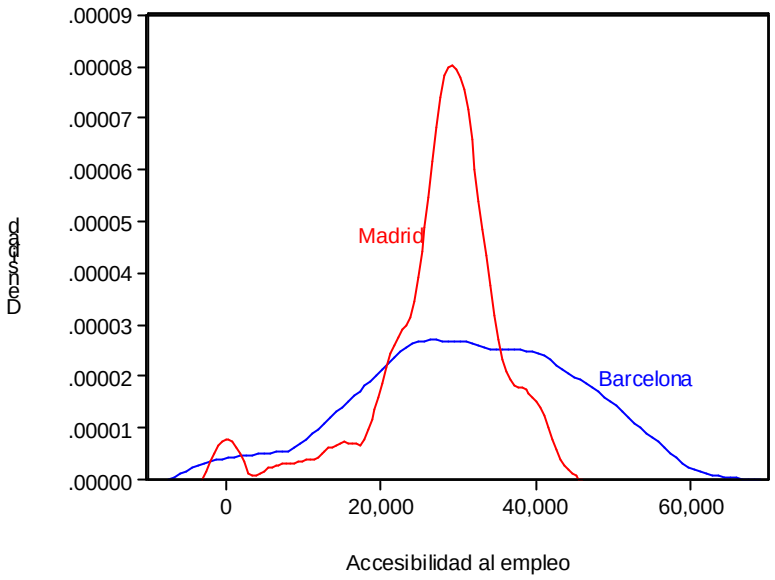
That is, job accessibility for a household living in zone i is computed as the sum of employment opportunities in each municipality j inversely weighted by travel time between i and j. For the residential zones the geographic unit of analysis is transport zones, which are a subdivision of municipalities used to calculate the matrices of travel time[1]. 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[2]. 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, as a result that nearly 65% of jobs are located in the central city.

[1] Roughly, each metropolitan area is divided into 600 zones.

[2] The cities of Barcelona and Madrid are divided into 12 and 21 districts, respectively.

Figure 1. Accessibility index to employment



4. The data

The study relies on cross-section data from the 2001 Spanish Micro-census. This data set corresponds to a 5% sample of 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[3], gender, civil status, socio-economic 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 by the economic status of the head of the household, housing size, availability of a second residence and housing tenure.

[3] A variable of years of education was generated according to the required number of years to complete each degree.

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 a dummy variable that takes value 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 statistic of the explanatory variables

	Barcelona	**Madrid**
	Mean	Mean
Head of household characteristics		
Age	43	43
Years of education	10.1	10.8
Male	62.2%	63.8%
Married	69.2%	69.1%
Socio-economic status		
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%
Skilled and semi-skilled workers	24.3%	18.1%
Unskilled workers	14.2%	16.4%
Other	1.0%	1.8%
Citizenship		
UE–15 other than Spanish	1.1%	1.0%
Other	3.9%	5.7%
Household characteristics		
Adults	2.5	2.6
Working-adults	1.7	1.7
Housing size (m^2)	87.6	90.6
Second residence (%)	15.6%	20.4%
Housing tenure (% rented)	17.0%	14.8%
Neighbourhood characteristics		
Unemployment rate	10.9%	12.1%
Job accessibility	32220	27363
Dummy for central city	0.34	0.53

5. Model estimation

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

As it 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:

$$y^* = Xb + e \qquad e \sim N(0,1) \qquad (2)$$

Where y^* is the standardized latent variable, X is the set of explanatory variables and e is the random term.

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

$$\begin{aligned} y &= 0 && \text{if } y^* \le \mu_1 \\ y &= 1 && \text{if } \mu_1 < y^* \le m_2 \\ y &= 2 && \text{if } \mu_2 < y^* \le m_3 \\ y &= 3 && \text{if } y^* > \mu_3 \end{aligned} \qquad (2)$$

Where μ_1, μ_2, and μ_3 are unkown 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 that at least one of its 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.

[4] Matas and Raymond (2008) provide a reasoning of using an ordered approximation to model car ownership in front non-ordered alternatives.

The number of employed members in the household is a variable that appears as highly significant in the literature explaining car ownership. We design a specification of equation (2) that allows that 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 of the household (workingadults) in the following way:

$$numveh = b \cdot workingadults \quad (3)$$

We assume that b behaves as follows: $b = g_0 - g_1 accessibility$ (4)

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

$$numveh = g_0 workingadults - g_1 workingadults * accessibility \quad (5)$$

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. Besides, coefficients are very similar between the two metropolitan areas.

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

Table 5. Estimation results of the ordered probit model

	Barcelona		Madrid	
	Coefficient	z-statistic	Coefficient	z-statistic
Head of household characteristics				
Age	0.012858	3.290932	0.012303	3.405974
Age square	-0.000185	-4.119643	-0.000168	-4.055592
Years of education	0.027094	19.64925	0.033734	27.19557
Male	0.111173	10.30809	0.112322	11.21939
Married	0.433257	34.4193	0.468127	41.05834
Employers	0.23173	10.62454	0.282679	13.27996
Managerial occupations	0.12908	5.37656	0.158331	7.959716
Own account workers	0.088363	4.264577	0.174095	8.595002
Unskilled worker	-0.195704	-12.27899	-0.199528	-14.57124
Citizenship				
UE-15 other than Spain	-0.230368	-4.669598	-0.106111	-2.299668
Other countries	-0.897041	-29.47278	-1.008346	-41.87036
Household characteristics				
Adults	0.135607	20.97198	0.103733	19.22871
Working-adults	0.487458	38.54246	0.40312	36.35434
Housing size (m^2)	0.004527	31.88581	0.004389	40.74483
Second residence (%)	0.229956	16.14494	0.248325	21.64818
Housing tenure (% rented)	-0.384604	-25.70573	-0.387627	-26.65796
Neighbourhood characteristics				
Unemployment rate	-2.283744	-14.2101	-2.932174	-19.22956
Working adults *access	-9.41E-06	-29.02417	-7.76E-06	-23.48541
Dummy for central city	-0.278311	-18.20894	-0.189509	-17.84348
Limit points				
m_1	0.392604	4.627998	0.393563	4.922807
m_2	2.275008	26.6878	2.166448	26.99181
m_3	3.615248	41.96464	3.542596	43.71711
Observations	52375		63903	
Pseudo R-2	0.161122		0.16106	
Schwarz criterion	1.869289		1.919315	
Log likelihood	-48832.49		-61203.28	

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

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

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 don't 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 its 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 related with the fact these cities suffer the worst congestion problems and the highest parking prices.

6. Elasticities and simulations with respect to job accessibility

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

The estimated elasticity for average car ownership level is -0.25 in Barcelona and -0.19 in Madrid. Although these values are low it should be reminded its statistical significance. Besides, 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 the second or third car and that significantly increases the number of households with zero cars.

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 fixing the level of job accessibility for all the individuals in the sample equal, at least, to the average value of this variable for the highest zone 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, whereas the third gives the difference between them[6].

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

	Barcelona			Madrid		
	Observed value	**Simulated value**	**Difference**	**Observed value**	**Simulated value**	**Difference**
Total area						
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
Central city						
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
Rest of the area						
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
Average car ownership						
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 it can be observed, increasing job accessibility would achieve a significant reduction in the level of motorization. For those families living out of the city of Barcelona the percentage of households with 2 or more cars would descend from 32.5% to 19.3%, with an increase of 7.6 points of non car owner households. As expected, the impact for those living in the central city would be lower given the higher accessibility level they

[6] 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 Table 7 and 8 are restricted to household with at least one member of the labour force.

already enjoy. It could be noted the average number of cars per household for the total area would fall below unity.

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

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

7. Conclusions

The aim of this paper has been to assess the effect of job decentralization on car ownership in the metropolitan areas of Barcelona and Madrid. For this purpose we build an employment potential index that makes it possible to measure job accessibility in public transport. This index controls for urban structure so that we can compare two areas of such a different structure as those we are focussing one.

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 car ownership probability.

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

A simulation exercise of 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 Barcelona area out of the central city accessibility increase translates into a reduction

of households with 2 or more cars from 32.5% to 19.3%. Such a change would counterbalance the effect of the number of working adults in the sample.

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