Using built environment variables to explain car ownership for a medium size Chilean city

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Abstract

The aim of this work is to study the role of built environment attributes on car ownership in a medium size Chilean city. This work follows up a previous one, which showed that up to 50% of the total utility associated with having at least one car at home can be explained through household attributes, such as household income, family size and number of workers.

The studied city was Chillan, which has up to 200 thousands inhabitants. Built environment attributes corresponded to the proportion of land use devoted to economic and non-economic activities, public transport network density and others. Information was obtained from an OD survey, the Inland Revenue Office and the regional office of the Transport Ministry. These variables and household attributes were introduced in a binomial Logit model, with utility function specified linear in coefficients. The dependent variable corresponded to possession of at least one car at home, or not having a car at all.

Results show that the inclusion of built environment attributes certainly helps to improve the explanatory power of models. Interaction effects between variables were included to catch up and explain the relationship between location, income and car ownership. Empirical evidence shows that urban growth with poor public transport provision, supported by an income rising, is reinforcing the increase of car ownership indeed. This is a concerning situation for medium size cities, where there are not explicit urban and transport policies oriented to deal with car use, which is linked with car possession.

1 Introduction

Economic growth has generated a rising of car ownership in emerging economies. Evidence shows that this growth is faster in medium size cities, with respect to larger ones, since there are no restrictions on car use. Besides, environmental problems as well as requirements for the provision of more infrastructures devoted to car use are emerging.

The aim of this work is to study the role of built environment attributes on car ownership in a medium size Chilean city. This work follows up a previous one, which showed that up to 50% of the total utility associated with having at least one car at home can be explained through household attributes, such as household income, family size and number of workers (Merino, 2006).

The studied city was Chillan, which has up to 200 thousands inhabitants. This city is located in the central valley, with an economy based mainly upon agriculture and services. Information regarding the car ownership, as well as household socioeconomic information, was obtained from the OD survey carried out by the Transport Planning Agency.

Built environment attributes corresponded to the proportion of land use devoted to economic and non-economic activities, public transport network density and others. Data was gathered from the OD survey, the Inland Revenue Office and the regional office of the Transport Ministry.

The dependent variable was the possession of at least one car at home, or not having a car at all. This variable was modelled using a binomial Logit. Utility functions were specified linear in coefficients.

A descriptive analysis of the data before the model estimation allowed us to envisage some results. For instance, spatial distribution of households, stratified by income, showed that lower income people mostly live in the city periphery, where public transport supply is poorer than in central areas. These people, even though they live further away and have a poor access to public transport, do not have a car due to their socioeconomic condition. On the other hand, high-income people, which live away from central areas with a poor public transport, indeed have at least one car.

Results show that the inclusion of built environment variables certainly helps to improve the explanatory power of models. Interaction effects were included to catch up and explain the relationship between location, income and car ownership. Nevertheless, there is an important percentage of utility (20%), which cannot be explained through household and built environment attributes. Further work should look for a combination of car possession and car use, as a way of tackling the modelling and explain the observed levels of car ownership.

Empirical evidence shows that urban growth with poor public transport provision, supported by an income rising, is indeed reinforcing the increase of car ownership, which is strongly linked to car use, with its negative effects.

The following section contains a brief review on the literature dealing with car ownership, with emphasis on built environment attributes. A description of the data is provided in section 3, whereas modelling results are reported in section 4. Final section contains main conclusions and comments.

2 Car ownership modelling and built environment attributes

Car ownership models can be classified depending upon the nature of data being modelled and the expected use of the model. They can be classified in aggregate and disaggregate ones (De Jong *et al.*, 2004).

With respect to the disaggregated models, they are mainly based upon information associated with households, being postulated that the possession of a car implies an increase in household utility level. Indeed, there is a trade off between the cost of buying and operating a car, and the possible benefits related to its possession. The usage of households' information introduces more variability in explanatory variables, improving the predictive and explanatory nature of models. Disaggregate models can be used to model just car ownership or to model jointly use and possession.

Discrete choice models used in car ownership modelling are based on the Random Utility Theory (Domencich and McFadden, 1975). Applications consider either ordered responses, multinomial or hierarchical models. Initial applications considering this approach were developed by Train (1986), whilst Bhat and Pulugurta (1998), using ordered and multinomial specifications, found that the second approach proved to have better results.

With respect to the urban environment, it has been pointed out that an appropriate urban design might allow a higher people's social interaction, reducing motorised trips, distances to be travelled, increasing the use of non motorised modes and occupation rates (Cervero and Kockelman, 1997; Ewing and Cervero, 2001; Hess and Ong, 2002).

The relationship between the built environment and transport demand is multidimensional, being not easy to identify how people perceive the space and how they process the information to make decisions regarding their mobility and related issues (Bhat and Guo, 2007). Factors of density, diversity and design might affect car ownership and use and, therefore, should be include into the analysis (Cervero and Kockelman, 1997).

Land use structure and diversity might affect car ownership. It has been suggested that more dense neighbourhoods reduce car ownership due to the lack of space for parking. Besides, mode diverse areas might help to decrease the need to travel long distances, promoting walking and diminishing the possession of cars (Cervero and Kockelman, 1997).

Two indicators have been used in the literature to measure land use diversity: diversity index and entropy index.

Land use diversity index (ID) is given by equation 1:

$$ID_j = 1 - \left\{ \frac{\sum_{K}^{n} \left| \frac{a_K}{A} - \frac{1}{n} \right|}{\frac{2(n-1)}{n}} \right\}, \ n \geq 2 \quad (1)$$

where a_K is the surface being used by the *k-th* category of land (housing, industry, *etc*.). $A = \sum a_K$ corresponds to the total area associated with all the categories and n is the total number of land use categories. ID varies between 0 and 1. If ID equals to 0, it means there is just one use for the land, whilst if ID equals to 1, it implies all categories have the same participation. This index has been used by Rajamani *et al.*, (2004), Potoglou and Kanaroglou (2007) and Zegras (2007) when studying the role of the built environment on car ownership.

The entropy index is also a measure of the land use diversity, being bigger than the ID index. Its expression is shown in equation 2.

$$IE = -\sum_{i=1}^{K} \frac{p_i \cdot \ln(p_i)}{\ln(K)}. \quad (2)$$

p_i corresponds to the proportion of land devoted in the specific use i-th, for a walking distance from a certain point. K is the total type of land uses. This index varies between 0 and 1. An index equals to 0 implies no diversity, whereas an index equals to 1 implies total variety. This index has been used by Kockelman (1996), Chu (2002), Zhang (2006), and Potoglou and Kanaroglou (2007).

The location of the household with respect to the whole city has been considered into the analysis. For instance, the distance from the house to CBD (Zegras, 2007) or from the working place to the household (Bhat and Guo, 2007), the number of people in a household travelling a long distance (Potoglou and Kanaroglou, 2007) or the spatial location of the house modelled through dummy variables (Whelan, 2005; Potoglou and Susilo, 2008) have been found to help to explain car ownership.

Accessibility has been deemed as a relevant factor to explain car ownership. It has been argued that if people in a household have a good accessibility to reach different places, *ceteris paribus*, then it is very likely that that household might not need a car, or having a car, might use it less (Zegras, 2007). The Hanson gravitational index to measure accessibility is given by equation 3.

$$A_i^m = \sum_{j \in L} w_j \cdot f_{ij} \cdot 100 \quad (3)$$

A_i^m is the accessibility for zone i in mode m. L is the total number of zones in the study area. w_j is the proportion of land for a specific use in zone j, whereas W is the total surface in the study area devoted to a specific use. $f_{ij} = \exp\left(-b \cdot TT_{ij}^m\right)$ is a deterrence function, depending on the travel time in mode m between zones i and j, $TT^m{}_{ij}$, and the parameter b, representing people's sensibility to travel time. This index has been used by Kockelman (1996), Cervero and Kockelman (1997), Zegras (2007), and Bhat and Guo (2007).

Special interest has the access to public transport, since these modes are relevant in the Chilean context; public transport corresponds to 50-60% of modal split in the largest cities, whereas in medium and small cities, it counts for 20-30% of modal split. Possible indicators of the level of access are the distance or walking time to bus stops (or public transport network), number of bus stops to a certain distance from the household, bus operation frequency, public transport lines density, streets density and others (Cervero and Kockelman, 1997; Hess y Ong, 2002; Kim and Kim, 2004; Zhang, 2006; Bhat and Guo, 2007; Potoglou y Kanaroglou, 2007; Zegras , 2007; Chen *et al.*, 2008).

3 Data description

The information for this study comes from an Origin Destination trip survey, collected by the Chilean transport planning authority in the city of Chillan (MIDEPLAN, 2004). This survey is applied to a random sample of households, containing information related to the household members, vehicles, trips and house. More than 1.400 household records were available for Chillan city.

Table 1 contains city socio-economic information. Household information was obtained from the OD survey, whereas population data was obtained from the National Statistics Office. Education 1 corresponds to percentage of people having primary and secondary education level, whilst education 2 refers to higher education. A full description of data can be found in Benavente (2010).

Table 1: Socio-economic information

Population (inhabitants)	184.037
Density (h/km^2)	4.034
Sample size (HH)	1.573
HH Income^{2003} (USD/month)	306
Car Ownership (Veh/HH)	0,36
Education 1 (%)	71
Education 2 (%)	20

Source: MIDEPLAN (2004)

When studying household (HH) income information through a spatial analysis, it was found that population is segregated spatially by income, a common issue in large Chilean cities. Lower income households are located in the east part of the city, whilst the wealthiest ones are located near the CBD and the northeast of the city. Medium income HH are located in the south, west and northwest of Chillán city.

The crossed analysis of car ownership rate (CO) with HH income allowed us to find that poorest households have a CO rate of 0,08 cars/HH, the medium income HH have a CO of 0,32 cars/HH, whereas the high income group has a CO of 0,95 cars/HH. Indeed, 71% of households have no car, 25% hold one car, and just a 4% have two or more cars. This car ownership distribution limits the modelling approach, reducing it to a binary election model: having no car at all or having at least one car.

During a working day, there are 450 thousand trips in Chillan, all purposes and modes. Non motorised trips are 50% of the total, whereas trips on public transport are 25%. Trips based on cars are 18%. For working purposes, the car use rises to almost a 30% of trips.

For those households without a car, most of trips are made on non motorised modes (walking and cycling, with 60% of trips), whereas for HH with at least one car, car use rises up to 40% of trips. Low income people uses mostly non motorised and public transport modes (up to 80% of trips), whilst high income people use car to travel (up to 40%) either as a driver or passenger.

The higher the income, more trips related to the working and studying purposes; trips rates vary from 1,5 to 2,0 trips/person. For recreation, errands and other reasons, there are no differences among socioeconomic groups.

Related to the public transport supply, there are two modes serving the demand: buses and shared taxis. All of them go through the CBD, serving the rest of the city. At the time of the OD survey, there were 11 bus routes, with an average operation frequency of 5 buses per hour; and a capacity of 20 seated passengers. With respect to the shared taxis, there were 22 routes, with an operational frequency of 20 vehicles per hour, with a capacity of 4 passengers per vehicle.

With respect to land use information, 70% of the surface is dedicated to housing and 10% to retail. Education, services, warehouses and industry occupy 3,5% of the land each. The rest of the land is devoted to health, parking and other services. Most of housing is located in the east, south and northwest of the city, whereas the lowest housing happens in the CBD.

Land use structure, public transport availability and people spatial distribution, with a strong socioeconomic segregation, impose some restrictions on mobility and accessibility. Actually, lower income households have less access to transport facilities (private and public), either because they do not have enough money to afford a car, or because the public transport network is scarce, operating with low frequencies. A sort of implicit social exclusion arises due to the spatial location of activities and transport facilities. With respect to higher income groups, they face more dense public transport networks, due to the household spatial location, and having access to at least one car since they can pay for it.

These accessibility issues affect mobility, with lower income groups having lower mobility rates than higher income households. The synergy between accessibility and mobility is clear for these city inhabitants.

4 Models estimation and results

Binary Logit models were estimated, given the discrete nature of the dependent variable: having at least one car at home; it must be remembered that less than 5% of households have two or more cars. A complete description of models, generation of explanatory variables and estimations can be found in Benavente (2010). Utility functions were specified linear in coefficients, considering interaction between variables when plausible, according to the available data. Maximum likelihood technique was used for the estimation of coefficients.

After screening the data, a final sample size of 1497 records was available for calculations. A base model was estimated, to compare it with alternative ones. The base model was specified as a function of socioeconomic attributes of the household. Table 2 shows the list of variables considered during the modelling, for the best models.

Information of land use and distances were processed and obtained using GIS software. Household location was geo-referenced, allowing further calculations.

Table 2: Variables description

Variable	Description
INGRESO	Household monthly income (CL$)
JHSEXO	Dummy variable. 0 if HH head is male. 1 if the HH head is female
HACLC	Number of adult males with driving license
MACLC	Number of adult females with driving license
HASLC	Number of adult males without driving license
VIVIENDA	Dummy variable. 0 if the house is rented. 1 otherwise
DPLAZA	Distance from the house to main square (m)
DENSHOG	Household density (HH/Hectare)
DESPTOT	Mean distance travelled per household members (m/person)
TVNOB	Non compulsory trips per person (trips/person)
TVTRABJ	Working purpose trips (trips/person)
TVESTUD	Studying purpose trips (trips/person)
TVRECR	Recreation purpose trips (trips/person)
TVOTRO	Other purposes trips (trips/person)
ID1	Index of diversity, considering all types of land use
IE2	Index of entropy, excluding land use devoted to housing
DISTBUS	Distance to the nearest bus route (m)
NRTXC300	Number of shared taxis in a buffer distance of 300 m

Best models, and the base model, are reported in table 3. Model 1 considers attributes associated with the people mobility and the availability of shared taxis around the household. Model 2 takes into account the land use level of diversity, as well as information associated with access to public transport and trips structure. Model 3 is similar two model 2, but using a different specification for attributes.

Signs of coefficients are according to what was expected in the Chilean context. Higher the income, it is more likely to have at least one car at home. Being a male as household head, more adults holding a driving license and owing your own house increases the probability of having a car. More mobility and more trips for purposes different to work and study also increase the chance of holding a car. For this data, information associated with land use diversity does not prove to be relevant for the possibility of having a car.

Two other models were estimated to take into account the fact that low income people live further away from the city centre, they do not have access to the car, but also have a poorer access to public transport. Interaction models were estimated, using the following specifications when combining the household income and the distance to the main square:

Model 4: $$\beta \cdot \text{DPLAZA} \equiv \left(\beta_1 + \beta_2 \cdot I_2 + \beta_3 \cdot I_3 + \beta_4 \cdot I_4 + \beta_5 \cdot I_5\right) \cdot \text{DPLAZA}, \quad (4)$$

β_1: lowest income β_5: highest income

Model 5: $$\beta \cdot \text{INGRESO} \equiv \left(\beta_1 + \beta_2 \cdot D_2 + \beta_3 \cdot D_3 + \beta_4 \cdot D_4\right) \cdot \text{INGRESO}. \quad (5)$$

β_1: shortest distance to square β_5: longest distance to square

Model 4 would tell us how the impact of the distance from the household to the main square changes according there is a variation in the household income, and how this would affect the possibility of having a car; five levels were considered for the income segmentation. Model 5 would say how changes the role of income with respect to having a car when the distance to the main square varies; four possible distances were considered for the segmentation. Table 4 shows the estimation results.

When comparing models 4 and 5 with the previous ones, it can be seen that the consideration of interaction provides a better model, either for economical and statistical fit. When analyzing model 4, it can be seen that for a fixed distance, the higher the income, more likely to have a car. The negative sign for β_1 is telling us that belonging to a low income sector implies a lower probability of having a car, without minding where the household is located. With respect to model 5, figures tell us that, for a fixed income, the further is located the house from the main square, more likely to have at least one car. These models are able to capture what was observed during the descriptive examination of data, when analysing the spatial distribution of population, their income and the existence of transport facilities.

It is interesting the sign for the variable DISTBUS. A negative sign would mean that the largest the distance to the public transport routes, it is less likely to have one car. This apparent contradiction has to do with the public transport network structure and car ownership spatial distribution. People having at least one car live in the central area of the city and the northeast, areas which are better served by public transport since most of the routes go through the central zone. On the other hand, people who do not have a car live mostly in the periphery, where public transport network is, in comparative terms, less dense than in the central area. This result suggests that another interaction might need to be considered to catch up this spatial effect.

5 Conclusions and comments

Consideration of socioeconomic as well as built environment and location attributes do indeed help to explain better the possession of at least one car, for the sample being studied. Nevertheless, income is still one of the most relevant factors affecting the ownership of a car, as well as the fact of having a male household head.

Interaction effects might be relevant as shown inhere, particularly when there are variables which have spatial variability and might be interacting between them. This is the case of household income and location with respect to CBD, and the effect upon car ownership.

There is an endogenity issue associated with car possession and car use, which has not been addressed here: people use a car because they have it, or people decide to buy car, since the need to use it? Further work need to be carried on in this direction, since might help to improve the explanatory power of the model.

The magnitude of the constant term is suggesting that there are other factors, apart from the studied here, which would be influencing the possession of a car. Since having a car might be considered a status sign, it seems that symbolic factors should be taken into account. Social psychology might provide us with the tools to understand people's decision to acquire a vehicle, apart from the instrumental ones. Unfortunately, OD surveys do not have this information, implying that a specific experimental tool should be designed.

In urban planning terms, models estimated show that the low density increasing city is promoting the acquisition of at least once car, which will be used once bought, affecting the city traffic and environmental conditions. Unfortunately emphasis has been put on large cities when dealing with car use and its impacts, forgetting that land use planning is also required for small ones to prevent what is observed in larger ones.

Acknowledgments

This work has been partially funded by Universidad de Concepcion, and the Complex Engineering Systems Institute, through grant FBO 16.

References

Benavente, R. (2010) M**odelación de la tasa de motorización en la ciudad de Chillán considerando aspectos de localización y accesibilidad**. Civil Engineer Final Dissertation. Civil Engineering Department. Universidad de Concepcion. Chile. (in Spanish).

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

Bhat, C. and Guo, J. (2007) A comprehensive analysis of built environment characteristics on household residential choice and auto ownership levels. **Transportation Research B 41.** 506-526.

Cervero, R. and Kockelman, K. (1997) Travel demand and the 3Ds: Density, diversity, and design. **Transportation Research D. 2.** 199-219.

Chen, C., Gong, H. and Paaswell, R. (2008) Role of the built environment on mode choice decisions: additional evidence on the impact of density. **Transportation 35**. 285-299.

Chu, Y. (2002) Automobile Ownership Analysis Using Ordered Probit Models. **Transportation Research Record 1805.** 60-67.

De Jong, G., Fox, J., Daly, A., Pieters, M., and Smit, R. (2004) Comparison of Car Ownership Models. **Transport Reviews. 24**. 379-408.

Domencich, T., and McFadden, D. (1975) **Urban travel demand: a behavioural analysis**. North Holland. Amsterdam.

Ewing, R. and Cervero, R. (2001) Travel and the Built Environment: A Synthesis. **Transportation Research Record 1780.** 87-114.

Hess, D.B and Ong, P.M (2002) Traditional Neighborhoods and Auto Ownership. **Transportation Research Record 1805.** 35-44.

Kim, H. and Kim, E. (2004) Effects on public transit on automobile ownership and use in households of the USA. **Review of Urban and Regional Developments Studies 16.** 245-262.

Kockelman, K. (1996) **Travel behavior as a function of accessibility, land use mixing and land use balance: Evidence from the San Francisco Bay Area.** Master of City Planning Thesis. University of California, Berkeley.

Merino, L. (2006) **Modelación de la tasa de motorización en ciudades de tamaño medio**. Civil Engineer Final Dissertation. Civil Engineering Department. Universidad de Concepcion. Chile. (in Spanish).

MIDEPLAN (2004) **Actualización de Encuestas Origen Destino de Viajes, IV Etapa. Informe Final Chillan**. Ministerio de Planificación y Cooperación. Chile. Made by DICTUC. (in Spanish).

Potoglou, D. and Kanaroglou, P. (2007) Modelling car ownership in urban areas: a case study of Hamilton, Canada. **Journal of Transport Geography**. **16**. 42-54.

Potoglou, D. and Susilo, Y. (2008) Comparison of Vehicle-Ownership Models. **Transportation Research Record 2076**. 97-105.

Rajamani, J., Bhat, C. R., Handy, S., Knaap, G. and Song, Y. (2004) Assessing the impact of urban form measures on nonwork trip mode choice after controlling for demographic and level-of-service effects. **Transportation Research Record 1831.** 158 – 165.

Train, K.E (1986) **Qualitative Choice Analysis: Theory, Econometrics and an Application to Automobile Demand.** The MIT Press. Cambridge, Massachusetts.

Whelan, G. (2005) Modelling car ownership in Great Britain. **Transportation Research A. 41.** 205-219.

Zegras, C. (2007) The Built Environment and Motor Vehicle Ownership and Use: Evidence from Santiago de Chile. **Transport Research Board 86th Annual Meeting.** Washington DC.

Zhang, M. (2006) Travel choice with no alternative: Can land use reduce Automobile Dependence?. **Journal of Planning Education and Research. 25.** 311-326.

Table 3: Best estimated models

Variables	Base model	Model 1	Model 2	Model 3
Constant	-3.09 (-12.44)	-4.08 (-12.71)	-3.59 (-11.60)	-2.66 (-4.37)
INGRESO	1.54E-06 (4.95)	1.36E-06 (4.19)	1.44E-06 (4.54)	1.50E-06 (4.68)
JHSEXO	-0.69 (-3.19)	-0.79 (-3.60)	-0.83 (-3.68)	-0.72 (-3.29)
HACLC	1.68 (10.54)	1.72 (10.57)	1.73 (10.56)	1.73 (10.68)
MACLC	1.50 (7.78)	1.38 (7.10)	1.45 (7.38)	1.46 (7.57)
HASLC	-0.65 (-5.47)	-0.65 (-5.37)	-0.67 (-5.52)	-0.63 (-5.32)
VIVIENDA	0.77 (4.07)	0.89 (4.56)	1.00 (5.01)	0.84 (4.38)
DESPTOT		7.81E-05 (3.02)		
TVNOB		0.14 (2.32)		
NRTXC300		0.02 (3.43)		
ID1			0.97 (2.22)	
DISTBUS			-9.29E-04 (-2.36)	
TVOTRO			0.45 (4.28)	
TVRECR			0.31 (2.26)	
DPLAZA				-2.33E-04 (-2.18)
DENSHOG				-0.01 (-0.89)
IE2				0.14 (0.27)
TVTRABJ				-9.63E-02 (-1.00)
TVESTUD				0.12 (1.03)
Sample size LL(*) ρ^2	1497 -541.9 0.385	1497 -527.1 0.402	1497 -521.8 0.408	1497 -537.8 0.389

Table 4: Models with interaction between income and distance

Variable	Model 4	Model 5
β_1	-4.53E-04 (-2.4)	9.21E-07 (1.5)
β_2	4.85E-04 (3.7)	1.54E-07 (0.3)
β_3	6.22E-04 (4.0)	7.48E-07 (1.1)
β_4	8.04E-04 (4.1)	1.23E-06 (1.6)
β_5	8.67E-04 (4.3)	-
JHSEXO	-0.82 (-3.6)	-0.83 (-3.7)
HACLC	1.74 (10.7)	1.73 (10.5)
MACLC	1.47 (7.6)	1.46 (7.5)
HASLC	-0.66 (-5.5)	-0.67 (-5.6)
VIVIENDA	1.02 (5.1)	0.99 (5.0)
ID1	1.24 (2.3)	1.43 (2.8)
DISTBUS	-8.77E-04 (-2.1)	-1.04E-03 (-2.6)
TVOTRO	0.47 (4.4)	0.45 (4.3)
TVRECR	0.35 (2.5)	0.31 (2.3)
Constant	-3.25 (-7.5)	-3.66 (-11.6)
Sample size LL(*) ρ^2	1497 -518.3 0.412	1497 -519.4 0.410