SOCIO-ECONOMIC AND SPACIAL DETERMINANTS OF CAR OWNERSHIP IN GERMANY

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ABSTRACT

Drawing on disaggregate household data from Germany, this study analyzes the determinants of automobile ownership, focusing specifically on the role of the spatial configuration and socio-economic attributes of the neighborhood in which the household resides. To this end, we employ an unordered multinomial logit model, which, following Baht and Pulugurta *(1)*, is consistent with global utility maximization on behalf of the individual household. The estimated model explores several determinants of car ownership over which policy makers have direct leverage, including the price for fuel, the price of fare and the supply of public transit.

1. INTRODUCTION

In Germany, as elsewhere in the industrialized world, the demand for car ownership has grown substantially in the last decades, with the number of registered cars per resident increasing by over 25% between 1990 and 2005 *(2)*. Understanding the determinants of this trend has emerged as a major priority within the scientific and policy arenas given the range of externalities associated with the automobile, including air and noise pollution as well as congestion and accidents on the public roadways. One potentially important factor impacting a household's car ownership decision is the spatial configuration and socio-economic attributes of the neighborhood in which it resides. The hypothesis of a link between neighborhood attributes and car ownership has far-reaching implications for transport and land-use policy, as its verification would avail a broad palette of options that encourage households to reassess their dependence on the automobile.

Much of the recent empirical work on automobile ownership has drawn on disaggregate data to focus on the role of household characteristics, including income and demographic composition. Whelan *(3)*, for example, undertakes a detailed analysis of both household income and demographic structure, finding both factors to be important predictors of the number of cars owned. Other issues covered in this research include the impact of employment status *(4-6)*, the costs of car acquisition *(7)*, the influence of car-sharing *(8)*, and the number of household members with a driver's license *(2)*. A relatively smaller body of work has addressed the impact of urban form on car ownership. Studies in this vein include Potoglou's *(9)* analysis of the effect of neighborhood characteristics on the type of vehicle owned, and Bento et al.'s investigation *(10)* of city shape, the supply of public transit, and other aspects of urban spatial structure. As with the larger body of work examining the link between urban form and mobility more generally, this research tends to draw on data from North America, and there have been few investigations of this issue in the European context.

The German pattern of car ownership is of particular interest because, as Europe's largest car market, the country is a major source of transport emissions, accounting for some 19% of the EU-15 total in 2005 *(11)*. Moreover, the German government has for many years pursued policies that combine high fuel taxes with land use planning measures to reduce automobile dependency. In 1993, the government legally codified the concept of "decentralized concentration" into its regional planning guidelines *(12)*, and since that, several German cities have adopted urban planning models predicated on "compact" development *(13)*.

Nevertheless, the efficacy of particular measures associated with such development has rarely been subjected to empirical scrutiny. Drawing on household level data, the present study aims to fill this void with a multinomial logit analysis of car ownership in Germany. The estimated model highlights several determinants of car ownership over which policy makers have direct leverage, including the price for fuel, the price of fare and the supply of public transit.

2. DATA

The household data used in this research is drawn from the German Mobility Panel *(14)*, an ongoing travel survey that was initiated in 1994. The panel is organized in overlapping waves, each comprising a group of households surveyed for a period of up to three consecutive years. All households that participate in the survey are requested to fill out a questionnaire eliciting general household information, person-related characteristics, and relevant aspects of everyday travel behavior. We augmented this dataset with information on population density measured at the county level, which was obtained from the German Federal Statistical Office's public online database *(15)* and merged in using a county-identifier.

The data used in this paper cover thirteen years, spanning 1996 through 2008. The resulting sample includes 5,675 households, 1,856 of which appear one year in the data, 1,281 of which appear two years and 2,538 of which appear three consecutive years. Altogether, the data contains 12,032 observations.

Table 1: descriptive statistics

# cars	number of cars in household	1.118	0.719
# of retired	number of retired in household	0.493	0.705
# of full time workers	number of full time workers in household	0.678	0.704
# of part time workers	number of part time workers in household	0.259	0.458
# of children	number of children in household	0.437	0.827
# of licenses	household members with driving licenses	1.560	0.843
monthly net income	monthly net income in 1000 Euro of 2000	2.095	0.788
population density	population density in 1000 people / km^2	0.959	1.098
minutes	walking distance in minutes to nearest public transport stop	5.690	4.818
tram / subway / train station	1 if nearest public transport station is tram / subway or train station	0.224	0.417
company car: business trips only	1 if household has company car restricted to business trips	0.009	0.096
company car: private use allowed	1 if household has company car not restricted to business trips	0.047	0.212
fuel price	fuel price in Euro per liter of 2000	1.024	0.122
fare price	monthly fare price in Euro of 2000	32.585	5.647

The suite of variables selected for inclusion in the model measure the socio-economic attributes and the spatial characteristics that are hypothesized to influence the number of cars owned. These capture the number of fulltime and part time employed, the retired and the number of children in the household, its income and the number of driving licenses. In addition, we control for the surrounding population density, for company cars as well as fuel and fare prices. Table 1 contains the definitions and descriptive statistics of all the variables used in the modeling. Note that since there are very few households owning more than three cars, we analyze only four cases of car ownership: no car, one car, two cars and three or more cars.

3. THE ECONOMETRIC MODEL

As a categorial variable, car ownership is usually analyzed using discrete choice models. Bhat and Pulugurta *(1)* argue in favor of multinomial models since these are consistent with global utility maximization on behalf of the household compared to ordered-response mechanisms, e.g. the ordered probit or ordered logit. The basic idea of employing multinomial models is that a household associates a certain level of utility with each car owned and chooses the number of cars accordingly. It comes with the advantage that the parameters can vary unrestricted over the categories at the expense of having to estimate more parameters compared to the ordered case.

The empirical methodology proceeds by specifying a structural model describing the probability of car ownership:

$$U_{ij} = x_i^{'}\beta_{ij} + \varepsilon_{ij}\,, \qquad (1)$$

where x is a vector of exogenous variables containing the socio-economic characteristics of household i and the spatial information on the area the household is situated in (see Table 1). Subscript j denotes the number of cars and β is the vector holding the parameters for each level of car ownership to be estimated. ε is an error term. The variable U measures the utility associated with household i's level of car ownership j, and is therefore unobservable. We do, however, observe the outcome with the highest level of utility in terms of the number of cars j household i owns, which we denote by y_j.

The probability that we observe a car ownership level j for household i, conditional on the regressors is then:

$$p_{ij} = P(y_i = j) = \frac{\exp(x_i^{'}\beta j)}{\sum_{l=0}^{m} \exp(x_i^{'}\beta_l)}, n = 0,2,3, i = 1,...,N.\,, \qquad (2)$$

where P denotes probability. Multinomial logit models require a base case as a reference for interpretation, which in our case is the single-car household. This approach makes sense, given that the majority of German households are single-car households and it is most interesting to know what makes households deviate from this level of car ownership. We obtain the marginal effects (ME) by differentiating with respect to the variable of interest k:

$$ME_{ijk} = \frac{\partial P(y_i = j)}{\partial x_{ik}}. \qquad (3)$$

4. RESULTS

Table 2 gives the results from the multinomial logit regression performed for the case of 0, 2 or 3 or more cars against the base case of a single-car household. Multinomial logit models always reference the results with respect to a base group. In our study, for example, if the number of retired in a given household rises by one unit, then the probability of observing 2 cars is reduced by 0.437 log-odds.

To obtain more readily interpretable results, we calculated the marginal effects at the means of the variables using Equation 3 and present these in Table 3. In the following, all results are interpreted with respect to the base case of a single-car household.

First and most important, all coefficients have the right sign with the minor exception that an increase in the number of full time workers significantly increases the probability of non-car households.

The quality of the estimated results confirmed, we proceed directly to the interpretation of the policy variables. In this regard, the dataset allows for the inclusion of controls for very distinct policy tools with strikingly different impacts as Table 3 highlights. The results confirm the expectation that the further away the nearest public transport station, the smaller the probability of having no car and the larger the probability of having more than one car. Furthermore, if the nearest station is a tram, subway or train station, the probability of having no car increases by an additional 2.3%, while at the same time the probability of owning 2 cars decreases by 5.6%. This likely reflects the fact that the average rail mounted transport station is serviced more often compared to bus stops.

On the other hand, the results suggest limited scope for exerting direct influence on car ownership via fuel or fare prices. Neither a rise in fuel nor a decrease in fare prices leads to a change in car ownership levels. But it introduces further research questions that link car ownership levels to acceptance and continued use of public transport given that fare prices are increased for the sake of financing public transport infrastructure.

The final policy variables in our model concern company cars. Company cars that households are allowed to use at their discretion have an even more pronounced negative impact on car ownership levels than those reserved exclusively for business trips. Table 3 shows that the probability of possessing no car increases by nearly 52% given that a company car for business and private use is provided, while at the same time the probability of having 2 cars decreases by 16%. On the other hand, company cars restricted to business trips do not increase the probability of not owning a car, but lower the probability of a household owning 2 cars by about 12%. Therefore, policy measures such as tax laws or insurance regulation regarding company cars seem to be potentially effective tools for influencing household car ownership levels.

Apart from policy variables, we controlled for household characteristics such as the number of full and part time employed, the number of licensed drivers, income and population density of the area the household is situated. Turning first to an increase the number of part time workers, we find that the probability to observe 2 cars increases significantly by 4.2%, while it is insignificant for the other two cases. Children, on average, seem to restrict the car ownership level. For the 2 car case the impact is negative with an impact of about 1.7% per additional child, while in the 3 car case the number of children is significant from a statistical point of view but not from an economic one. The coefficient is negligibly small. In contrast, the number of licensed drivers is a strong correlate of car ownership. Each additional license in a household decreases the probability that the household owns no car by nearly 11%, while the probability of observing 2 or 3 cars increases by 17.0% and 0.4%.

We also controlled for the real net household income and its square, but found that there are no diminishing returns so that each increase in monthly net income worth 1,000 Euro reduces the probability of a non car household by 13.3%, while it increases the probability to observe 2 cars by approximately 15.6%. Its impact is insignificant for the 3 car case.

Population density, which we employ as a proxy measure for local working, shopping or recreational opportunities, is a significant correlate, as well. An increase in the population density by 1,000 people per square kilometer increases the probability of non-car households by 1.8%, while it decreases the probability of two car households by about 4.1%.

Altogether, the majority of variables included in the model are statistically highly significant for all variables and cases. But given that only very few German households possess 3 or more cars, the coefficients for the marginal effects for this case are all relatively small.

Table 2: Results from Multinomial Logit Model

	number of cars		
	0	2	3+
# of retired	0.141	**-0.437	**-0.464
	(0.090)	(0.084)	(0.172)
# of full time workers	**0.311	**0.221	**0.424
	(0.119)	(0.082)	(0.151)
# of part time workers	0.121	**0.340	*0.373
	(0.136)	(0.085)	(0.169)
# of children	-0.024	**-0.140	**-0.563
	(0.088)	(0.045)	(0.110)
# of licenses	**-2.354	**1.234	**2.455
	(0.109)	(0.077)	(0.146)
monthly income	**-2.974	**1.089	-1.018
	(0.304)	(0.353)	(0.671)
monthly income squared	**0.000	0.000	**0.000
	(0.000)	(0.000)	(0.000)
population density	**0.373	**-0.307	**-0.536
	(0.046)	(0.045)	(0.155)
minutes	**-0.058	**0.028	**0.055
	(0.012)	(0.007)	(0.013)
tram / subway / trainstation	**0.410	**-0.466	**-0.589
	(0.105)	(0.102)	(0.227)
company car: business trips only	0.702	**-1.751	**-18.087
	(0.478)	(0.338)	(0.515)
company car: private use allowed	**3.282	**-2.929	**-21.945
	(0.220)	(0.218)	(0.800)
fuel price	0.735	-0.584	-1.023
	(1.273)	(1.070)	(2.993)
fare price	-0.002	0.000	-0.029
	(0.009)	(0.008)	(0.019)
constant	**3.322	**-5.454	**-8.141
	(1.183)	(1.035)	(2.892)

Standard errors in brackets. ** denotes significance at the 1%-level, * at the 5%-level.

Table 3: Marginal Effects

	number of cars		
	0	2	3+
# of retired	*0.009	**-0.056	*-0.001
	(0.004)	(0.010)	(0.000)
# of full time workers	*0.012	*0.026	*0.001
	(0.005)	(0.010)	(0.000)
# of part time workers	0.003	**0.042	0.001
	(0.006)	(0.011)	(0.000)
# of children	0.000	**-0.017	**-0.001
	(0.004)	(0.006)	(0.000)
# of licenses	**-0.108	**0.170	**0.004
	(0.008)	(0.010)	(0.001)
monthly income	**-0.133	**0.156	-0.002
	(0.020)	(0.040)	(0.000)
monthly income squared	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
population density	**0.018	**-0.041	**-0.001
	(0.000)	(0.010)	(0.000)
minutes	**-0.003	**0.004	**0.000
	(0.001)	(0.001)	(0.000)
tram / subway / trainstation	**0.023	**-0.056	*-0.001
	(0.006)	(0.010)	(0.000)
company car: business trips only	0.053	**-0.121	**-0.002
	(0.041)	(0.011)	(0.000)
company car: private use allowed	**0.517	**-0.161	**-0.005
	(0.043)	(0.007)	(0.001)
fuel price	0.035	-0.078	-0.002
	(0.055)	(0.134)	(0.005)
fare price	0.000	0.000	0.000
	(0.000)	(0.001)	(0.000)

Standard errors in brackets. ** denotes significance at the 1%-level, * at the 5%-level.

5. CONCLUSION

This article investigates the impact of socio-economic and spatial household characteristics on the level of household car ownership in Germany, with special respect to variables that are policy driven. We find evidence that the number of cars a household owns increases with the number of licensed drivers in the household, the income and the prevalence of company cars for private use.

Apart from socio-economic variables, we examined different policy measures concerning infrastructure and travel cost that are hypothesized to have impact on car ownership levels. The results are clear cut. Providing public transportation infrastructure reduces car ownership levels significantly while increases in fuel or decreases in fare prices exhibit no impact. We believe that future research on transportation especially with respect to car ownership levels should draw heavily on spatial variables and should include transfer times and prices for different travel modes. With these kinds of data it would be possible to advance to the core of mobility concerns: to bridge distances between locations of activity under time and money constraints.

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