LONG-TERM AND SHORT-TERM ASPECTS OF CAR ALLOCATION WITHIN THE HOUSEHOLD CONTEXT

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ABSTRACT

Decisions concerning household car ownership and the corresponding usage by the household members have significant implications on fuel consumption and vehicle emissions. In this context, long-term and short-term choices which are strongly interrelated with one another play an important role. The long-term aspects involve the number of vehicles and different types owned by a household as well as the assignment of a main driver for each vehicle. The short-term dimension is represented by the vehicle allocation within a household at a daily level.

In order to better understand the vehicle allocation process in the household context, the paper at hand investigates the importance of the longer-term and shorter-term components in this process and explores which one prevails. The study is based on data of the national household travel survey "Mobility in Germany" (MiD) of the year 2008, which collects behavioural travel data of entire households for all weekdays using a diary day concept. Initial analyses focus primarily on the long-term perspective. In this context, different discrete choice models which assign a principal driver to the available household cars are estimated. In order to study the interrelationship between the long-term and short-term aspects of the vehicle allocation process within a household, it is examined, whether the main driver of a car is, at the same time, the actual user on a trip. Attention is directed towards the trips where this is not the case, in order to understand what kind of trips (purpose, individual or joint travel, distance and duration, etc.) exhibit greater variability and in which cases households behave more flexible with respect to the allocation of vehicles.

The paper provides a brief introduction about the background of the vehicle allocation process within the household context, taking into account its long-term and short-term aspects. The main part then concentrates on the corresponding empirical analyses, showing insights of ongoing work. The data used is described, followed by statistical explorations and the results of various estimated discrete choice models for the identification of a main driver and the allocation of a car, and accompanied by examinations concerning the actual usage of the assigned car by the principal driver. In particular, attention focuses on the discrepancy between long-term and short-term decisions concerning the allocation of cars within a household. Finally, conclusions are presented.

INTRODUCTION

Decisions concerning household car ownership and the corresponding usage by the household members have significant implications on fuel consumption and vehicle emissions (Angueira, 2014; Golob, Kim and Ren, 1996). In this context, long-term and short-term choices which are strongly interrelated with one another play an important role (Angueira, 2014; Vovsha and Petersen, 2007). The long-term aspects involve the number of vehicles and different types owned by a household as well as the assignment of a main driver for each vehicle. The short-term dimension is represented by the vehicle allocation within a household at a daily level. This means that intra-household car allocation addresses the question, which driver uses which car for which trips (Nam, Lee, Aultman-Hall and Sears, 2013).

Vehicle allocation within a household is constrained by the number and types of vehicles in the fleet. Understanding the available fleet composition is, therefore, one step in explaining the car allocation process (Nam *et al.*, 2013). Households acquire vehicles to satisfy specific travel needs and desires as well as the preferences of the household members (Golob *et al.*, 1996). Therefore, car purchase decisions are associated with both household and individual driver characteristics (Nam *et al.*, 2013).

In order to allocate cars to drivers, different strategies may be applied within a household (Mannering, 1983). Firstly, the allocation may be based on individual members consistently using a specific vehicle, perhaps out of some notion of vehicle ownership within the household (Golob *et al.*, 1996; Vyas, Paleti, Bhat, Goulias, Pendyala, Hu, Adler and Bahreinian, 2012). Secondly, car assignment may be determined by a process in which household members bargain to obtain access to available vehicles for activities (Anggraini, Arentze and Timmermans, 2007; Anggraini, Arentze and Timmermans, 2008; Petersen and Vovsha, 2005). And thirdly, individual cars may be assigned to the trips that are most compatible with the vehicle attributes (e.g. fuel efficiency, seating and cargo capacity, as well as reliability in terms of possible breakdowns) (Anggraini *et al.*, 2007; Anggraini *et al.*, 2008; Petersen and Vovsha, 2006).

In order to better understand the vehicle allocation process in the household context, the paper at hand evaluates the various depicted approaches, by investigating the importance of the longer-term and shorter-term components in this process and exploring which one prevails. The principal, more or less exclusive use of one of the household's vehicles by each household driver due to personal preference, convenience, habit, and routine forms a long-term commitment to that car. In contrast, the use of different vehicles for different trip purposes represents a shorter-term element in the car allocation process, requiring more flexibility and willingness of household members to use a vehicle they may not normally drive or to accept the inconvenience of changing vehicles in the middle of a travel day.

DATA

The study is based on data of the national household travel survey "Mobility in Germany" (MiD) of the year 2008, which is commissioned by the Federal Ministry of Transport, Building and Urban Development (Bundesministeriums für Verkehr, Bau und Stadtentwicklung, 2010a and 2010b). The MiD survey collects behavioural travel data of entire households for all weekdays using a diary day concept. The sample includes data of nearly 26'000 households with nearly 64'000 household members and approximately 185'000 reported trips. The detailed dataset includes variables on general household and individual characteristics, such as household size and structure, income as well as gender, age and occupation of all household members. With respect to the car ownership of the household,

information about the model, vintage, annual mileage, the owner and the main driver is available for the three most used vehicles. For the reported trips, the trip purpose, destination, number of companions, means of transport, including the car used, as well as distance and duration are known, amongst others.

The sample shows a wide structure of car ownership ranging from households with no available car (18%) to one car (53%), two cars (24%), three cars (4%) and more cars (1%). Regarding the ratio of the number of vehicles and the number of driving licence owners within a household, a balanced relationship with an equal number of drivers and cars is observed in 59% of the households. In contrast, the shares of households with fewer cars and more cars than drivers amount to 38% and 3%, respectively.

RESULTS OF THE DATA ANALYSES

Assignment of a main driver to a car

With the intention to evaluate the impact of the various vehicle allocation strategies within the household context, analyses focus primarily on the long-term perspective, following findings by Bolon, Keoleian and Kostyniuk (2013). They show that increases in car allocation optimality in terms of fuel use reduction does not appear to be the result of a greater prevalence of active, short-term vehicle assignment decisions, such as a driver's voluntary use of a non-preferred vehicle or switching vehicles mid-day. Rather these are accomplished by selecting a more efficient vehicle to be used on a regular basis by a certain driver.

In this context, different discrete choice models which assign a principal driver to the available household cars are calculated. Starting point for the analyses is a binomial logit model for the identification of a main driver, estimated at the person level of the data. Table 1 presents the corresponding results for a model with solely the significant parameters. The explanatory variables include individual and household characteristics as well as information regarding the location of residence. For male respondents, age shows an overall positive influence, whereas for females the opposite applies. After reaching the age of 25 years, men exhibit a higher probability of being the primary driver than women. This result points to the generally observed lower car ownership and use by females, especially for the elderly, due to a lower availability of driving licences in older age groups (Beckmann, 2013; Beige and Axhausen, 2008). Employment of a person has a positive effect, for part-time employees to a higher extent than for people working full-time. In comparison to the group of employees, infants, pupils and students are unsurprisingly less likely to be the assigned driver of a car. In contrast, retirees and domestic workers show a higher likelihood. The ownership of a driving licence has a strong positive influence, consistent with the expectations. Considering the household context, the numbers of male as well as of employed household members decrease the probability of being a main driver, revealing a certain competition within households. With the ratio of vehicles to drivers in a household, the likelihood also rises, while the number of car driving licence owners has a positive and the number of cars a negative effect. The variables describing the regional structure of the residential municipality are based on a classification of the Federal Institute for Research on Building, Urban Affairs and Spatial Development. In comparison to large towns, respondents living in other areas are more likely to be principal drivers of a vehicle. However, this influence is only significant for rural municipalities. As measure for the goodness of fit, the adjusted ρ^2 of the model is shown at the bottom of the table. With a value of 0.631, it is relatively high. This is mainly caused by the variables that relate to the ownership of car driving licences and cars. Removing these variables from the model reduces the adjusted ρ^2 to 0.442, while the influence of the other explanatory variables remains stable.

Table 1 Binomial logit model for being a main driver of a car (estimation at person level)

Explanatory variables	Parameter	Significance
Person related variables		
Age in years	– 0.071	0.000
Age in years natural logarithm	+ 1.740	0.000
Gender: Male	– 1.060	0.000
Age in years * Gender: Male	+ 0.042	0.000
Employment:		
Employed	+ 0.388	0.010
Full-time employed	+ 0.667	0.000
Part-time employed	+ 1.240	0.000
Phase of life:		
Infant	– 6.770	0.070
Pupil	– 1.120	0.000
Student	– 0.187	0.210
Domestic duties	+ 0.440	0.000
Retired	+ 0.572	0.000
Car driving licence ownership	+ 10.400	0.000
Household related variables		
Number of male household members	– 0.088	0.000
Number of employed household members:		
Employed	– 0.071	0.130
Full-time employed	– 0.309	0.000
Part-time employed	– 0.518	0.000
Number of car driving licence owners	+ 1.090	0.000
Number of cars	– 1.600	0.000
Ratio of the number of cars to the number of car driving licence owners	+ 10.300	0.000
Variables describing the regional structure of the residential municipality		
Classification of the Federal Institute for Research on Building, Urban Affairs and Spatial Development: Large towns as referential category		
Medium-sized towns	+ 0.039	0.380
Small towns	+ 0.056	0.330
Rural municipalities	+ 0.094	0.040
Further variables		
Constant	– 20.000	0.000
Number of observations		37617.000
L(0)		– 25817.390
L(max)		– 9508.726
ρ^2 (adjusted)		0.631

In order to further study the assignment of a primary driver to a specific car, a nested logit model is estimated. Figure 1 shows the structure of the model. On the first level, the main drivers are identified, while on the second level, conditionally on being a main driver, one of the available household vehicles, ranging from one to three cars, is chosen.

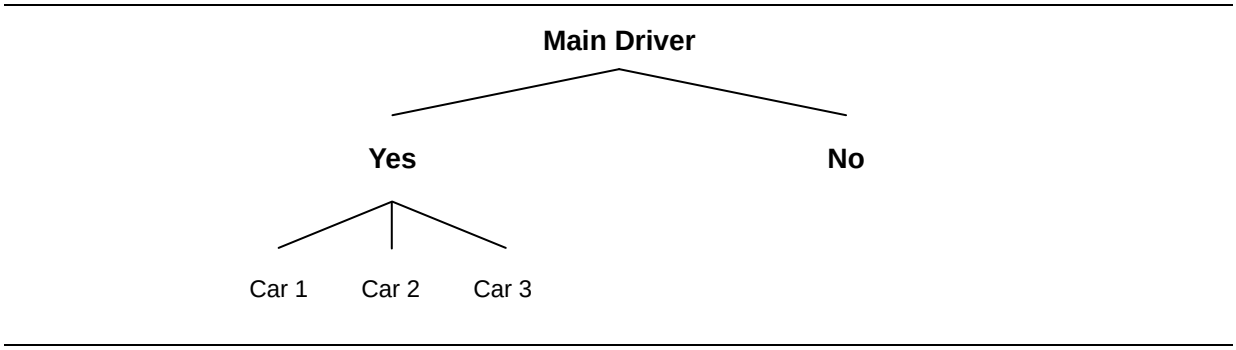

Figure 1 Structure of the nested logit model for assigning a main driver to a car

Table 2 presents the corresponding results of the nested logit model. Overall, similar variables with respect to individual and household characteristics are significant and show the same effects as in the binomial logit model in Table 1. Again, the influence of age is generally positive for men and negative for women. With increasing age, the utility of the male respondents exceeds the one of the females. Employment promotes the assignment as a main driver to a car. This also applies to the ownership of a driving licence. With an increasing number of household members, and especially male household members, the probability of being a primary driver decreases. As expected, the number of driving licences in the household has also a negative influence, whereas the allocation of a vehicle benefits from a higher number of available cars. In the choice of the car, vehicle size has a negative effect. At the same time, principal drivers have a preference for older cars. In this context, the forming of habits and routines over time might play an important role. The variables describing the regional structure of the residential municipality are no longer significant. The model parameters describing the two nests of being and not being a primary driver of a car indicate significant correlations among the alternatives of the first nest.

Table 2 Nested logit model for assigning a main driver to a car (estimation at person level)

Explanatory variables	Parameter	Significance
Person related variables		
Age in years	– 0.065	0.000
Age in years natural logarithm	+ 1.680	0.000
Gender: Male	– 0.912	0.000
Age in years * Gender: Male	+ 0.037	0.000
Employment:		
Full-time employed	+ 0.829	0.000
Part-time employed	+ 1.410	0.000
Phase of life:		
Pupil	– 1.660	0.000
Student	– 0.605	0.000
Retired	+ 0.196	0.020
Car driving licence ownership	+ 6.430	0.000
Household related variables		
Number of household members	– 0.060	0.150
Number of male household members	– 0.153	0.000
Number of employed household members:		
Full-time employed	– 0.457	0.000
Part-time employed	– 0.660	0.000
Number of car driving licence owners	– 1.940	0.000
Number of cars	+ 0.446	0.010
Car related variables		
Size of the car:		
Small cars as referential category		
Medium-sized cars	– 0.190	0.000
Large cars	– 0.344	0.000
Age in years of the car	+ 0.008	0.000
Further variables		
Constant	– 5.870	0.000
Model parameters for the two nests		
Nest ”Main driver: Yes”	0.223	0.000
Nest ”Main driver: No”	1.000	*fixed*
Number of observations		26908.000
L(0)		– 22599.147
L(max)		– 13151.890
ρ^2 (adjusted)		0.417

Actual use of a car by its main driver

In the following, the interrelationship between the long-term and short-term aspects of the vehicle allocation process within a household is analysed. It is examined, whether the main driver of a car is, at the same time, the actual user on a car trip. First analyses show that for a normal weekday, the main driver corresponds to the actual user of the vehicle in nearly 70% of the trips. Differentiating with respect to the usage of the car as driver or passenger, the actual driver is even in 83% of all vehicle trips the primary driver of the car. For car passengers, this share amounts to only 21%.

A binomial logit model is estimated at the trip level of the data, analysing the concurrence of being the main driver and the actual car user. Considering all vehicle trips in the sample, Table 3 shows the corresponding results in the form of the significant explanatory variables. For men, the probability for actual usage of a car by its principal driver rises with increasing age. For female respondents, the opposite applies, leading to a lower correspondency especially for older women. Employment, domestic duties as well as retirement have a positive effect, whereas being a pupil or a student points in the reverse direction. As expected, the ownership of a driving licence is associated with a higher likelihood of being the primary driver and the actual car user. Considering the household context, vehicle usage varies more in smaller households, households with less employees and a lower monthly equivalent net income. In contrast, households with older as well as more male members exhibit a tendency towards car usage by the main driver. This also applies for households with a higher ratio of vehicles to drivers, consistent with the expectations. The number of operable bicycles existing in a household has a negative influence, as bicycles represent an alternative mode to motorised means of transport. Regarding the characteristics of the car, privately registered vehicles are more often used by the principal driver. The size of the vehicle shows a negative effect, i. e. large cars are less frequently used by their corresponding primary driver. The age of the car increases the probability for the usage by its main driver, while the time since the acquisition of the car decreases it. Diesel vehicles are less likely to be used by the primary driver, and thus, more flexibly scheduled. The main purpose of the car trip also shows a significant effect, which is, compared to accompanying someone as referential category, positive for obligatory activities, such as work, business and education, and negative for shopping, private business and leisure. This indicates that the last group of so-called discretionary activities allows for more flexibility in car allocation. With a rising number of persons participating on the vehicle trip, the user is less likely to be the main driver of the car. Being a passenger instead of the driver has obviously a negative influence. The opposite is true for all the explanatory variables describing the diary day. When the reported day is a weekday or a normal day for the respondent, then the likelihood for usage of a car by its primary driver rises. These results imply a generally stable vehicle assignment within households. More mobile persons, i. e., with a higher number of trips carried out during the diary day and with overall longer distances travelled, tend to be the main drivers while using a vehicle. Interestingly, the distance of the single car trip has no significant effect in the model, while a variance analysis shows substantial differences between the two groups of being and not being the primary driver of the used vehicle on a car trip.

Table 3 Binomial logit model for the actual use of a car by its main driver (estimation at trip level)

Explanatory variables	Parameter	Significance
Person related variables		
Age in years	– 0.027	0.000
Age in years natural logarithm	+ 0.464	0.008
Gender: Male	– 1.176	0.000
Age in years * Gender: Male	+ 0.028	0.000
Employment:		
Full-time employed	+ 0.435	0.000
Part-time employed	+ 0.795	0.000
Phase of life:		
Pupil	– 1.071	0.000
Student	– 0.464	0.000
Domestic duties	+ 0.228	0.003
Retired	+ 0.247	0.003
Car driving licence ownership	+ 3.293	0.000
Household related variables		
Number of household members	– 0.115	0.000
Age in years of the oldest household member	+ 0.007	0.000
Number of male household members	+ 0.123	0.000
Number of employed household members:		
Full-time employed	– 0.102	0.000
Part-time employed	– 0.290	0.000
Monthly equivalent net income in 1'000 € squared	– 0.009	0.035
Ratio of the number of cars to the number of car driving licence owners	+ 1.276	0.000
Number of operable bicycles	– 0.046	0.000
Variables describing the car		
Registration of the car: Private	+ 0.231	0.000
Size of the car:		0.007
Small cars as referential category		
Medium-sized cars	– 0.024	0.208
Large cars	– 0.056	0.030
Age in years of the car	+ 0.014	0.000
Time in years since the acquisition of the car	– 0.026	0.000
Fuel type of the car: Diesel	– 0.139	0.000

Table 3 is continued …

Table 3 continued …

Explanatory variables	Parameter	Significance
Variables describing the car trip		
Main purpose of the trip: Accompanying someone as referential category		0.000
Work	+ 0.292	0.000
Business	+ 0.189	0.059
Education	+ 0.494	0.000
Shopping	– 0.222	0.000
Private business	– 0.241	0.000
Leisure	– 0.224	0.000
Number of persons participating on the trip	– 0.125	0.000
Passenger instead of driver on the trip	– 2.273	0.000
Variables describing the diary day		
Diary day: Monday to Friday	+ 0.200	0.000
Diary day: Normal day	+ 0.160	0.000
Number of all trips carried out during the diary day	+ 0.019	0.001
Overall distance travelled during the diary day	+ 0.001	0.005
Further variables		
Constant	– 3.724	0.000
Number of observations		45038.025
L(0)		– 29597.831
L(max)		– 17773.119
ρ^2 (adjusted)		0.398

Furthermore, the discrepancy between long-term and short-term decisions concerning the allocation of vehicles within a household is explored by analysing the everyday attachment of a primary driver to his or her car. In this context, the share of all vehicle trips on which the main driver uses the assigned car are examined. This portion represents a measure for the occurring variability in car allocation. Figure 2 shows the distribution of these shares. 63% of the persons driving during the diary day are the sole users of the vehicle primarily allocated to them. Two further, however, smaller peaks with about 10% appear at the ranges of 0-10% and 50-60% of car use by the main driver. In the first case, the assigned car is almost completely used by others, while, in the second case, the vehicle is more or less equally shared with other household members. A similar picture unfolds for the corresponding shares of the distances travelled and durations spent travelling during the diary day.

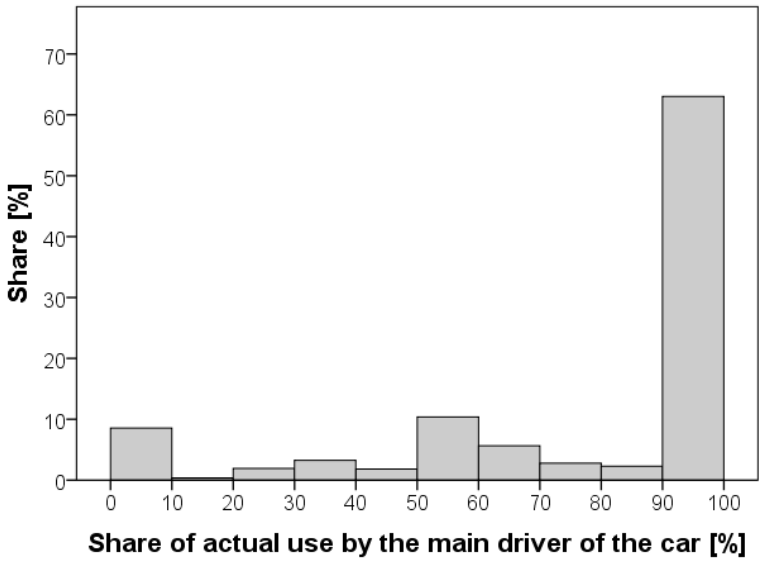

Figure 2 Distribution of the shares of all car trips on which the main driver of a car corresponds to the actual user

In a next step, the shares of all vehicle trips on which the principal driver uses the corresponding car are modelled, applying the method of linear regression. Table 4 presents the related results. Besides the non-standardised regression coefficients, the ones standardised according to their value range are given, which specify the importance of the several parameters. As can be seen in the table, age has a negative influence on the portion of vehicle usage by the primary driver, which is stronger for men than for women. Part-time employment, domestic duties and retirement are also associated with lower shares, while ownership of a driving licence promotes these shares. Persons living in smaller as well as in older households show a higher attachment. With an increasing number of employed household members, vehicle usage becomes less flexible, whereas the monthly net income of the whole household has the opposite effect. The three variables describing the ownership of driving licences and cars within a household exhibit a composite interrelationship. This is shown in Figure 3, in the form of the summarised utility for these three parameters for varying numbers of drivers and vehicles. Overall, the parameter regarding the driving licences points towards a positive relation, while an increasing quantity of cars leads to a lower utility. A turning point, i. e., where the different graphs intersect, is observed around households with two driving licence owners. From that point onwards, the positive influence prevails. A higher number of bicycles corresponds with a more variable use of cars. With respect to the vehicle characteristics, size has a negative influence, as does the time passed since the acquisition of the car, meaning that the longer a car is owned the less it is used by its main driver. With rising average mileage per year, the vehicle is more frequently driven by the household member primarily assigned to it, and less by others.

Table 4 Linear regression for the shares of all car trips on which the main driver of a car corresponds to the actual user (estimation at person level)

Explanatory variables	Non-standardised regression coefficient	Standardised regression coefficient	Significance
Person related variables			
Age in years natural logarithm	– 0.054	– 0.058	0.000
Gender: Male	+ 0.143	+ 0.219	0.000
Age in years * Gender: Male	– 0.003	– 0.227	0.000
Employment:			
Part-time employed	– 0.041	– 0.047	0.000
Phase of life:			
Domestic duties	– 0.120	– 0.092	0.000
Retired	– 0.066	– 0.074	0.000
Car driving licence ownership	+ 0.260	+ 0.026	0.000
Household related variables			
Number of household members	– 0.043	– 0.161	0.000
Age in years of the oldest household member	+ 0.004	+ 0.191	0.000
Number of employed household members	+ 0.031	+ 0.088	0.000
Monthly net income in 1'000 €	– 0.151	– 0.661	0.000
Monthly net income in 1'000 € squared	+ 0.012	+ 0.398	0.000
Monthly equivalent net income in 1'000 €	+ 0.154	+ 0.386	0.000
Monthly equivalent net income in 1'000 € squared	– 0.017	– 0.224	0.000
Number of car driving licence owners	+ 0.033	+ 0.082	0.000
Number of cars	– 0.063	– 0.138	0.000
Ratio of the number of cars to the number of car driving licence owners	+ 0.133	+ 0.118	0.000
Number of operable bicycles	– 0.005	– 0.028	0.003
Variables describing the car			
Size of the car:			
Small cars as referential category			
Medium-sized cars	– 0.020	– 0.030	0.000
Large cars	– 0.015	– 0.017	0.048
Time in years since the acquisition of the car	– 0.002	– 0.023	0.001
Average mileage in 100'000 kilometres per year of the car	+ 0.045	+ 0.023	0.001
Further variables			
Constant	+ 0.646		0.000
Number of observations			17655.000
ρ^2 (adjusted)			0.161

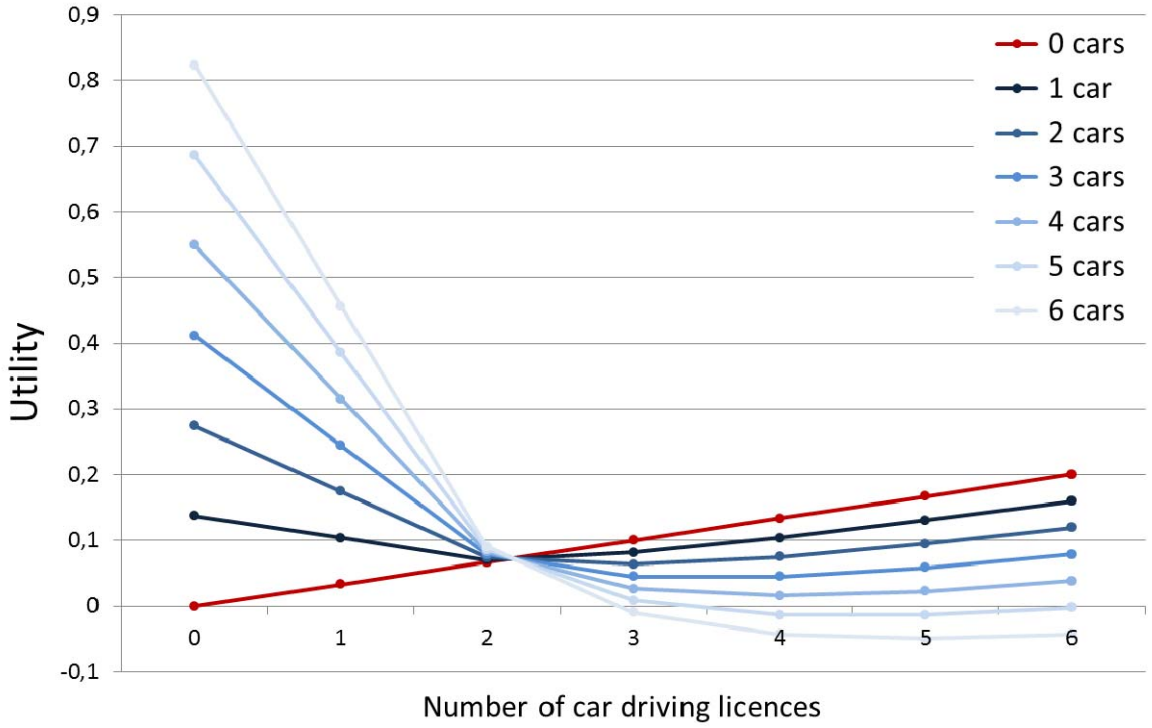

Figure 3 Utility for the numbers of car driving licence owners and cars as well as the ratio of cars to car driving licence owners within a household

CONCLUSIONS AND OUTLOOK

The paper at hand focuses on the long-term and short-term aspects of car allocation within the household context and investigates the corresponding interrelationship between these two dimensions. The long-term component includes the identification of a main driver and the assignment of a corresponding car. The analyses show that primary drivers tend to be male, especially in older age groups, as well as employed or retired. This confirms findings by other authors, e. g. Mannering (1983) as well as Golob et al. (1996). Considering the household context, the numbers of male as well as of employed household members decrease the probability of being a main driver, revealing a certain competition within households. In the choice of the car, vehicle size has a negative effect. At the same time, principal drivers have a preference for older cars. In this context, the forming of habits and routines over time might play an important role.

Overall, the long-term approach of assigning a principal driver to a vehicle, followed by a more or less exclusive use of that vehicle prevails. With 63%, a relatively high portion of persons are the sole users of the car primarily allocated to them. In contrast, only about 10% of the main drivers do not use their assigned vehicle. Instead this vehicle is completely used by others. However, variations occur with respect to different individual and household characteristics. Age has a negative influence on the share of vehicle usage by the primary driver, which is stronger for men than for women. Persons living in smaller as well as in older households show a higher attachment. With an increasing number of employed household members, vehicle usage becomes less flexible, whereas the monthly net income of the whole household has the opposite effect. For households with higher income, it is easier to meet occurring conflicts with respect to car allocation.

At the same time, an interrelationship between the long-term and short-term dimensions of the vehicle allocation process is observed on the trip level. In nearly 70% of all car trips on a normal weekday, the main driver corresponds to the actual user of the vehicle. For men, the probability for actual usage of a car by its principal driver rises with increasing age. For female respondents, the opposite applies, leading to a lower correspondency especially for older women. Employment and retirement have a positive effect. As expected, the ownership of a driving licence is associated with a higher likelihood of being the primary driver and the actual car user. Considering the household context, vehicle usage varies more in smaller households, households with less employees and a lower monthly equivalent net income. In contrast, households with older as well as more male members exhibit a tendency towards car usage by the main driver. Consistent with the expectations, this also applies for households with a higher ratio of vehicles to drivers, as less competition exists. The number of operable bicycles existing in a household has a negative influence, as bicycles represent an alternative mode to motorised means of transport. The main purpose of a car trip also shows a significant effect, which is, compared to accompanying someone as referential category, positive for obligatory activities, such as work, business and education, and negative for shopping, private business and leisure. This indicates that the last group of so-called discretionary activities allows for more flexibility in car allocation. For a weekday or a normal day, the likelihood for usage of a car by its primary driver rises. These results also imply a generally stable vehicle assignment within households. More mobile persons, i. e., with a higher number of trips carried out during the diary day and with overall longer distances travelled, tend to be the main drivers while using a vehicle.

In a next step, the modelling results are implemented in the microscopic transport model TAPAS (Travel and Activity Patterns Simulation), which is developed at the DLR Institute of Transport Research. The aim is to better represent car allocation and usage within the household context.

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Keywords

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