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Motor Vehicle Use and Travel Behaviour in Germany - Determinants of Car Mileage

Berlin, June 2006

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Abstract

In contrast to other countries where official odometer readings are collected when cars are being inspected or whenever there is a change in the registration data, no such information is available in Germany. The published annual figures on mileage of German vehicles result from model calculations, based on different data sources. The last two large surveys on car use were carried out in 1993 and 2002. These data are analyzed to find determinants of car mileage traveled and to check if there was a significant change of average mileage within 10 years. The method used to find determinants of car mileage is a log-linear analysis of variance.

In general, average annual mileage for a German passenger car was 13,500 km in 2002, about 5 % less than in 1993 (14,200 km per car). When both privately and business owned cars are included in the models, only car–specific characteristics can be used as explanatory variables. In these models there is a high effect of the survey year on the car mileage even if other variables – as car size, car age, and type of engine – are controlled for.

However, if we consider private cars only, additional variables of individual users can be included in the models. In addition to engine type, age of car, horsepower, the age and gender of the driver are central variables explaining car mileage. The dummy variable for the year is significant as well, but its effect on average mileage is lower, although, e.g., fuel prices did rise by 50 % between 1993 and 2002. Obviously the demographic changes in motorization are dominant, while an effect of fuel price increase is not evident – apart from the trend towards diesel cars. These observations confirm research results, stating that individual preference for car use is a high-level inelastic demand.

Keywords: Travel behavior, car mileage, car use

1 Introduction

Information on annual vehicle mileage traveled is a requirement for evaluating the quality of road networks, e.g., in relation to infrastructure investment or the numbers of persons injured or killed in traffic accidents. The annual demand for car kilometers is also one of the major components of modeling the overall travel demand.

Given the lack of periodically collected statistical data on total mileage traveled by each vehicle recorded in the national vehicle register, we need to develop practical estimation procedures. The generation and application of suitable methods requires that models be optimized based on input–data availability and adapted to carry out future forecasts of car mileage traveled for use in the evaluation of transport and environmental policy measures.

In 1993 and 2002, sample surveys of motor vehicle mileage traveled (Fahrleistungserhebung, FLS) were conducted.[1] Vehicle kilometers traveled during a stated time period, information on personal characteristics of the vehicle owner and users, and comprehensive data on vehicle attributes were collected. These additional data obtained made it possible to get detailed information on motor vehicle mileage traveled for specific vehicle as well as user and owner categories for the years 1993 and 2002.

The objective of this paper is to use the survey data for a quantitative analysis of structural effects exhibited by vehicle attributes as well as by personal characteristics of both the car owner and the car user on the annual passenger car mileage traveled. The existence of comparable data records for two years made it possible to determine changes in the influence of these structural effects over time. The regression analysis conducted emphasizes the examination of a potential time effect for the both years by analyzing pooled data from the two samples of 1993 and 2002 and including interaction effects of the year-dummy variable with selected explanatory variables contained in the sample.

The organization of the paper is as follows. Section 2 gives a description of the data used in this paper. In Section 3, several descriptive statistics are introduced to give an outline of the relationships between car use and several key vehicle attributes as well as personal characteristics of users or holders. In addition, general information on the economic and demographic

[1] BASt 2005: Fahrleistungserhebung 2002 (Car Mileage Survey 2002).

development in Germany in the decade 1993 – 2002 is given. Evidence suggests that an influence of aggregate key indicators is inherent in the regression results for car mileage traveled even though these indicators were not explicitly included as explanatory variables. Section 4 contains aspects of the model specification together with a summary illustration of estimation techniques used in this paper. In Section 5 the results of our econometric analysis are presented together with a detailed interpretation. Section 6 sums up our main conclusions.

2 The data base

In Germany all types of motorized vehicles are registered in a central database at the Kraftfahrt–Bundesamt (KBA, Federal Bureau of Motor Vehicles and Drivers). In contrast to other countries where official odometer readings are collected when cars are inspected or when there is a change in the registration data, no such information is available in Germany. For this reason two surveys on car mileage were conducted in 1993 and 2002 on behalf of the German Federal Highway Research Institute (BASt).[2] Both surveys followed (nearly) the same method and design: a sample of registered cars was taken and the car holders were asked to submit two consecutive odometer readings in a ten–week interval.[3]

The survey of the sampled vehicles covered the whole year. However, for technical reasons samples were drawn in six waves. The survey conducted in 2002 included approximately 127,000 vehicles. They were taken from the master file of about 50 million vehicles and the holders were sent an interview questionnaire by post. The overall response rate was approximately 65 % for passenger cars. The two surveys covered not only passenger cars, which are the focus of this paper, but all ten existing categories of registered motorized vehicles.

One noteworthy point in this study concerning the surveys has to be mentioned: the odometer readings at the beginning and at the end of the ten-week interval were collected by mail, without a chance for correction of possible errors. If erroneous readings happened to be submitted, they could be eliminated only in the case of negative mileage results. Errors could not

[2] See BASt 2005; cited as FLS–data in this paper (vehicle mileage is called Fahrleistung in German).

[3] Noteworthy aspects of the FLS-data are the two different time dimensions involved in the generation of the sampling results. In general, the registered stock of vehicles is referenced to a fixed point in time, whereas the target population –vehicles in use– is obviously exposed to continuous alterations by new registrations, final deregistration or temporary lay-ups and the target variable –vehicle miles traveled– is totaled and averaged over a specific time period respectively. The vehicle stock reported at midyear was pinpointed as the reference value to calculate the average mileage traveled per registered vehicle.

be identified if the mileage remained positive. Algorithms to discover implausible respondent mileage values have therefore been introduced, checking the resulting average speed and average daily driving hours. In any case, there remains the possibility of asymmetric errors, which may lead to an overestimation of mileage. A general problem is, that the number of cars with high mileage is small, but their contribution to the calculation of overall yearly mileage – the main result of the survey – may be substantial.

In addition to behavioural parameters affecting car distance travelled, technical vehicle attributes, some information on the use of the car within the ten-week interval, and finally personal characteristics of the car holder and the car user were coded in the FLS-dataset.[4] Technical vehicle data and data on specific fuel consumption by manufacturer, model, and engine from other sources could be matched to the FLS-survey data giving an enriched set of variables to be analyzed.

Additionally, results of the nationwide travel survey conducted in 2002[5] can be compared to the surveys on vehicle mileage traveled. In spite of the different sampling units (vehicles mileage vs. households and car driver mileage) and different sampling frames of the two surveys (central vehicle register vs. community person registers) and the different survey methods applied (postal vs. computer aided telephone interviews), there is a remarkable congruence of the survey results.

Table 1: Basic results from the surveys

	1993	2002	both
Observations	17 405	25 386	42 791
Mean km	43.53	41.97	42.70
Median km	34.73	32.06	33.35
Std. Deviation	35.56	42.64	37.33
Source: FLS-data			

[4] Car properties included manufacturer and model, type of car, key number of type (in 2002), number of seats, emission class, mode of drive train, maximum speed cylinder capacity, engine power, category of car registration (business or private), age of the vehicle, weight and maximum load. Features of car use included main use of car, number of rides and stated mileage travelled abroad, and kilometres covered on long distance trips. As attributes of the car holder and of the main car user were coded gender, age, and in 2002 characteristics of the household as household size, number of employed persons in the household, number of children, number of driving permit owners, household motorization, postal zip-code and the (nuts 3 level).code of the region.

[5] MiD 2002, see http://www.mid2002.de/engl/index.htm for detailed information.

3 Descriptive analysis and basic statistics

Some descriptive statistics drawn from the survey data and some additional data concerning relevant demographic and economic facts are introduced in the following subsection as a framework for the interpretation of the output from the statistical analysis.

A brief examination of characteristics related to the motorization process in Germany between 1993 and 2002 is introduced with reference to the following aspects: socio-demographic changes between the two survey years, differences between the holder categories (private vs. business) as well as between gender and age of the users of private cars, and finally size and structure of the car fleet.

3.1 Demographic data and vehicle use

Driving a car becomes a reality for young adults in Germany at the age of 18, the official age at which one may obtain a driving permit for a passenger car. Apart from a small number of exceptions where car driving permit holders are below this age limit, the population 18 and older makes up the universe of potential car users.[6]

Between 1993 and 2002, the German population increased slightly from 81.3 to 82.5 mill. people. The ageing process in Germany has continued. The population age group 18 years and older increased by 2.8 %. This was twice the growth rate of the whole German population, while the number below 18 decreased by 4 %.

Germany's total labor force has remained fairly stable over the last decade: in 1993, it amounted to 36.9 mill. persons compared to 36.5 mill. in 2002. In contrast, the number of registered unemployed has steadily grown, going up from 3.4 mill. in 1993 to 4.1 mill. individuals in 2002. Looking at the employment status, part-time employment increased. In 1993, nearly 6 mill. part-time employees were reported, 16 % of the total labor force. In 2002, corresponding figures were 10 mill. part-time workers, i.e., 28 % of the total labor force. A remarkable aspect of part-time employment in Germany is its distribution among female and male employees: the share of part-time employed women was considerably above that for

[6] Very few exceptions from the age limit required to obtain a passenger car driving permit in Germany arise mainly from cases where the permit has been received abroad – e.g., in the USA – and was transcribed into a German and EU driving permit. As far as an upper age limit to active car use is concerned nothing alike exists in Germany, i.e., neither a renewal of permits, nor ability checks (e.g., on eyesight) are required as a special regulation for aging drivers. Only few people return their driving permit, when they feel to have lost the ability to drive a car.

men both years. In 1993, one-third of the total female labor force was employed part-time. This fraction increased to nearly 50 % in 2002. The number of people working part-time rose by about 2 mill. for male and 2.5 mill. for female employees. As a result, 13 % of the male labor force had a part-time job in 2002 compared to only 4 % in 1993.

Table 2: Data on demography and car use

		1993			2002			Change in %		
		Male	Female	Total	Male	Female	Total	Male	Female	Total
Population	mill.	39.5	41.8	81.3	40.3	42.2	82.5	2.1	0.9	1.5
Population. of age 18+	mill.	31.4	34.1	65.5	32.5	34.8	67.3	4	2	3
Labor force	mill.	21.6	15.3	36.9	20.3	16.2	36.5	-6	6	-1
Full-time employed	mill.	20.8	10.3	31.1	17.6	8.7	26.3	-16	-15	-16
Part-time employed	mill.	0.8	5.0	5.8	2.7	7.5	10.3	252	49	76
Registered unemployed	mill.	1.7	1.7	3.4	2.2	1.8	4.1	32	5	19
Private cars by user group										
Total	mill.	23.1	10.9	34.1	24.1	15.4	39.5	4	41	16
Full-time employed	mill.	13.1	4.3	17.4	12.5	5.6	18.1	-5	29	4
Part-time employed	mill.	0.3	2.1	2.3	0.5	3.5	4.0	94	67	70
Other	mill.	9.8	4.5	14.3	11.1	6.4	17.5	14	40	22
Private cars per 100 inhabitants*)										
Population		59	26	42	60	37	48	2	40	14
Population of age 18+		74	32	52	74	44	59	1	38	13
Full-time employed		63	42	56	71	64	69	13	52	23
Part-time employed		33	41	40	18	46	39	-45	12	-3
Others of age 18+		100	24	50	91	34	57	-9	42	13
Average annual mileage per car by car users										
Population of age 18+	1000km	14.2	11.4	13.3	13.3	11.4	12.6	-6	0	-5
Full-time employed	1000km	15.8	13.2	15.2	15.7	13.0	14.9	-1	-2	-2
Part-time employed	1000km	15.5	10.7	11.2	13.3	12.0	12.2	-14	12	9
Others of age 18+	1000km	12.0	10.0	11.3	10.6	9.6	10.3	-11	-3	-9

*) Denominator is from official statistics, numerator from FLS-data (self-stated employment status).
Sources: Destatis, FLS-data, DIW Berlin.

The distribution of passenger car driving permit holders over age categories as well as between males and females may have important implications for the pattern of car ownership, but in particular for vehicle mileage.[7] The same is true for structural transformations taking place on the labor market, since daily trips to and from work generally account for a high share of a person's total daily travel activity.[8] Later in this study, relationships between pas-

[7] It has to be kept in mind that the FLS-data covers only the population of vehicle users, not the entire population. This is of particular importance when relative data, e.g., mileage per person, is compared.

[8] See MiD 2002.

senger road travel demand and key economic, demographic, and sociodemographic factors will be addressed in more detail.

All in all, the number of private cars per 100 inhabitants 18 and above has risen from 52 cars per 100 persons in 1993 up to 59 in 2002. The total increase of 16 % between 1993 (34.1 mill. cars) and 2002 (39.5 mill. cars) was due to all employment groups: full-time employed labor force declined by 16 %, but car ownership of those having a full-time job rose from 56 to 69 cars per 100 persons. As a result, 18 mill. cars were owned by individuals with a full-time employment in 2002, compared to 17.4 mill. in 1993. The car ownership rate of part-time workers remained on the level of 40 cars per 100, but since their total number increased (by more than 70 %), so did the number of cars in use by this group. The car density of the rest of the population 18 years of age and older (mainly retired persons, housewives, or unemployed) increased from 50 to 57 per 100 individuals.

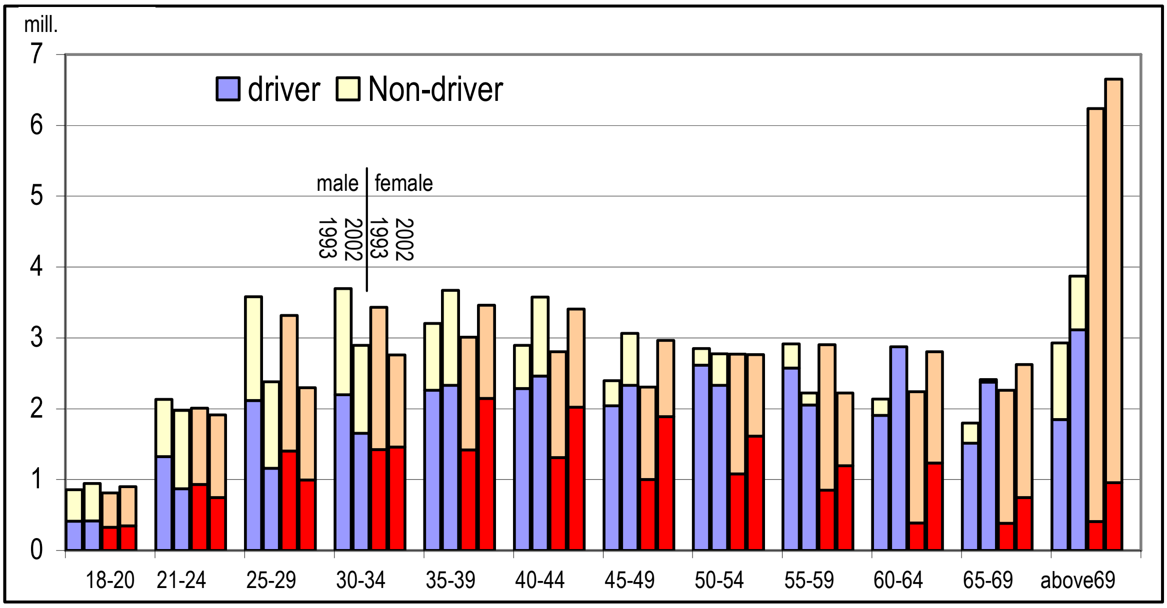
A comparison of average vehicle mileage traveled by female vs. male users shows that female drivers still fall behind their male counterparts. A male user drove on average around 14,200 km in 1993 (39 km per day) in contrast to female user with approximately 11,400 km (31 km per day). However, while women obviously maintained a rather constant level of car utilization intensity over the last decade, corresponding average values for men dropped to 13,300 km in 2002. The most remarkable result regarding motorization and gender is that mainly women contributed to the increase in the overall passenger car fleet: 4.5 mill. more cars were used by a woman in 2002 than in 1993 (40 % more female car users). The number of cars used by men increased by only 1 mill. (4 %). However, men by far still dominate women in car user rates (60 % men vs. 37 % women).

Figure 1 illustrates the dynamics of car ownership development in Germany by age categories. For each age group in the left two columns the male population in 1993 and 2002 can be compared, the share of car users is marked in a darker color. The two columns on the right side of each age category display the female population in 1993 and 2002 and car use in these groups. The increase of female car users is obviously due to women 35 and above. Regardless of gender, age categories above 60 have exhibited the strongest growth as to the number of car users with respect to their total number and their share, respectively. On the other hand, the number of those under 30 years of age has dropped by about 18 % (2 mill.). The same applies to the rate of car users in this group, falling from 61 to 44 vehicles per 100 persons.

Examining car utilization intensities over the categories age and gender of the user reveals further differences.

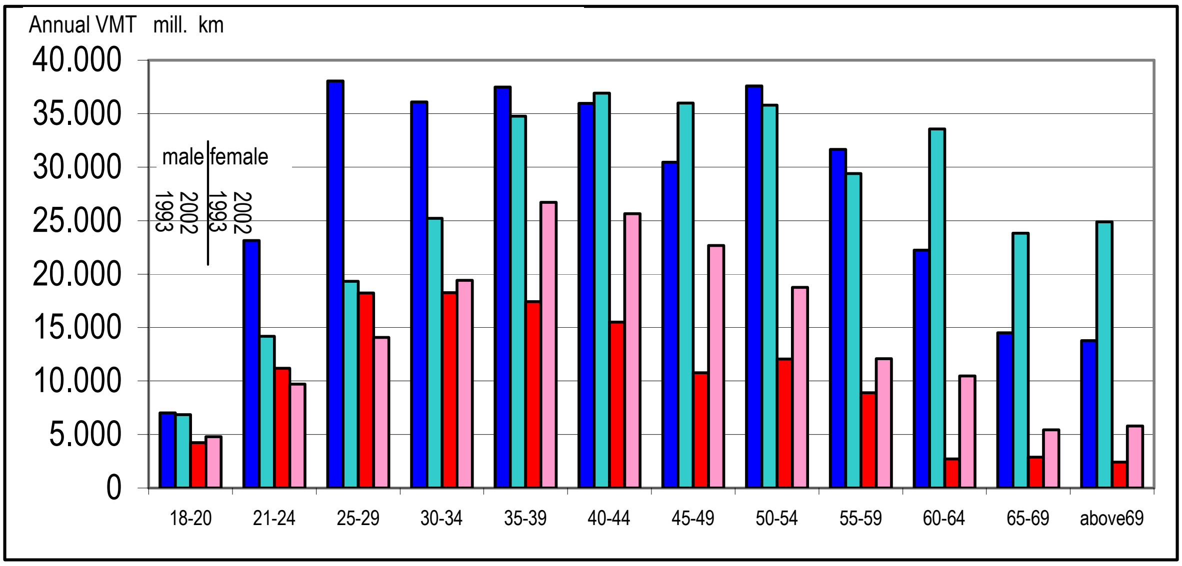
Figure 2 shows in total the annual mileage traveled in 1993 and in 2002 subdivided into age categories and gender of the drivers. As in Figure 1 the left two columns of an age category allow us to compare the contribution of male driver to the total mileage in 1993 resp. in 2002, the right two columns show the mileage driven by female drivers.

Figure 1: Population and car use 1993 and 2002 by gender and age groups



It is obvious that the rise in total mileage is due to the elderly male categories, and in particular to nearly all age categories of female drivers. To some extent a reverse trend can be concluded from looking at annual car mileage totals driven by young males: here, the share of car users and the average annual mileage driven per vehicle both decreased during the last decade.

Figure 2: Car mileage 1993 and 2002 by gender and age categories



3.2 Car fleet structure 1993 and 2002

Motorization in Germany has been continuously increasing. The growth of the German passenger car fleet can be attributed to private as well as business car registrations. According to this categorization, in 1993 almost 4.5 mill. cars were registered by commercial entities vs. 34.1 mill. passenger vehicles registered by private persons. In 2002, related figures amounted to 4.7 mill. and 39.5 mill. cars respectively, hence leaving the number of business cars nearly constant.

Looking separately at the car fleet breakdown by engine types, considerable differences can be identified among holder categories. In 1993, one in four registered business cars and 11.7 % of private-sector registrations were diesel-powered vehicles. Ten years later, both sectors had an increase of 1 mill. cars each; the corresponding shares were 45 % in the commercial sector and 13 % in the private sectors (Table 3). The shift from petrol to diesel cars has also been observed in other European countries.[9]

[9] See Schipper (2002).

Table 3: German car fleet and mileage 1993 and 2002

		1993 Mode of drive			2002 Mode of drive			Change in %		
		Petrol*)	Diesel	Total	Petrol*)	Diesel	Total	Petrol*)	Diesel	Total
No. of cars										
Private	Mill.	30.0	4.0	34.1	34.4	5.1	39.5	15	26	16
Business	Mill.	3.4	1.1	4.5	2.6	2.1	4.7	-23	95	6
Total	Mill.	33.4	5.1	38.5	37.0	7.2	44.2	11	41	15
Annual Mileage Totals										
Private	bn km/a	380	71	453	402	94	496	6	33	10
Business	bn km/a	69	27	96	44	58	102	-36	115	7
Total	bn km/a	449	98	548	446	152	598	-1	56	9
Average mileage per car										
Private	1.000 km/a	12.7	17.5	13.3	11.7	18.5	12.6	-8	6	-5
Business	1.000 km/a	20.5	24.6	21.4	17.1	27.1	21.6	-16	10	1
Total	1.000 km/a	13.5	19.0	14.2	12.1	21.0	13.5	-11	11	-5
Fuel price	Euro/liter	0.69	0.56		1.03	0.84		49	50	

*) Including other modes of drive (electric, gas)
Sources: FLS-data, DIW Berlin.

In 1993, business cars covered on average 20,500 km per annum (56 km/day) and 24,600 km (67 km/day) when running on petrol and diesel fuel respectively. Related utilization intensities of private cars were 35 km/day and 48 km/day respectively. From 1993 to 2002 the corresponding utilization intensities evolved to 47 km/day for petrol driven and 74 km/day for diesel-driven business cars. In the private car sector analogous values amounted to 32 km/day for petrol vs. 51 km/day for diesel-engine cars. This development is due in part to the rise of overall fuel prices by 50 % between 1993 and 2002, but also to the introduction of diesel-run cars in the smaller car-segments of the automobile market. Since 1989 petrol in Germany has been about 20 to 25 % more expensive than diesel fuel. Higher annual circulation tax is applied to diesel-driven cars to level out the difference in the petroleum tax levied on the two fuel types. Depending on car type and car size, the break-even point for both engine types lies at an annual mileage of 10,000 km.[10] For those driving more kilometers a year, diesel cars have become more and more attractive, in particular against the background of overall fuel price augmentation, but also due to higher fuel efficiencies attributed to diesel engines.

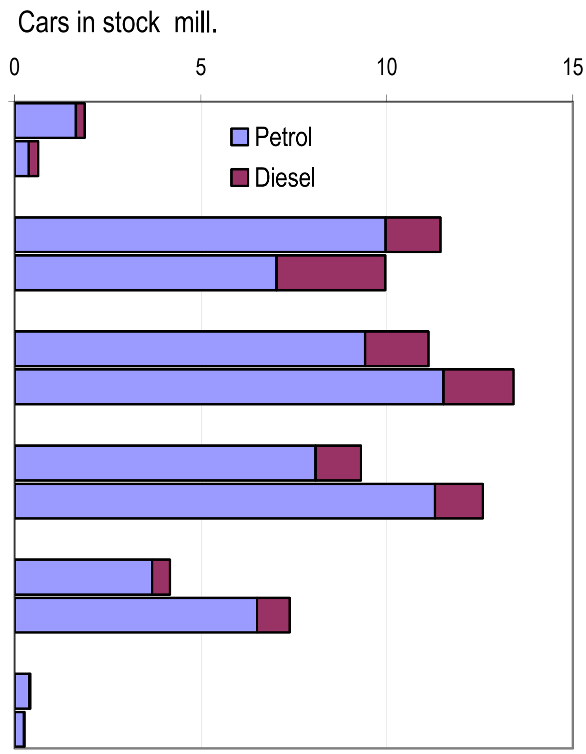
Another relevant vehicle attribute affecting its usage intensity is the age of the car. Cars registered by commercial entities have always been mainly new cars while in the private car sector, the share of old cars increased between 1993 and 2002. This is shown in the right part of Ta-

[10] See Kuhfeld, Kunert 2005.

ble 3. While in 1993 one-third of the car fleet was not more than 3 years old, the corresponding share for 2002 went down to 24 %. One main explanation for the age structure of the German car fleet in 2002 can be found in the country's reunification process from 1989 to 1992, when East Germans were faced with the opportunity to buy cars; as a consequence, household motorization increased rapidly. Many of the vehicles purchased in the early 90's still appear in the fleet reported for 2002. In contrast, the business car fleet fluctuates considerably faster and its entries are – disregarding a few possible exemptions – always newly produced, first-registration automobiles. Therefore, the overall fleet of business cars was on average significantly newer than private cars, both in 2002 and in 1993. Hence, almost half of the diesel-driven cars enclosed in the business car fleet in 2002 were not older than four years.

Table 4: German car fleet and mileage 1993 and 2002 by engine type and age of car

Survey year	Average mileage 1000 km /year			Age of car
	petrol	diesel	all cars	
1993	17.4	27.4	18.6	less 1 year
2002	13.8	26.4	18.8	
1993	15.8	23.9	16.8	1 - 3 years
2002	14.0	25.8	17.5	
1993	14.3	18.0	14.8	4 - 7 years
2002	13.2	21.0	14.3	
1993	11.2	15.5	11.7	8 - 11 years
2002	11.1	15.5	11.5	
1993	9.5	13.1	9.9	12 - 20 years
2002	9.7	11.8	10.0	
1993	7.2	6.9	7.2	> 20 years
2002	7.0	10.9	7.2	



Sources: FLS-data, DIW Berlin.

As shown in detail in Table 4, the vehicle age is apparently linked to the average utilization intensity. This correlation appears to be predominant in the case of cars run on diesel fuel, whereas new cars account for an annual mileage twice as high as the corresponding value accounted for by older diesel cars. To some extent, this can be explained by the high percentage of diesel business cars, which are in general new and intensively used vehicles.

The conclusion to be drawn from analyzing descriptive results from the two car mileage surveys corresponds to general observations as well as to results obtained from other studies[11] where potential relationships between passenger road travel demand and related characteristics have been examined. The demand for motorized travel varies with physical vehicle attributes and selected socio-demographic characteristics. Modeling these dependencies allows to tap the full potential of the survey data.

4 Method

The distribution of the daily average vehicle mileage is asymmetric with a skewness of 3. The mean of the pooled data of 1993 and 2002 is 42.7 km, while the median is 33.3 km. This suggests to analyze the log-transformed data (see fig. 3, graph 1 and 2). So we use a log-normal analysis of the variance of vehicle kilometers per day as method, i.e., we fit the model

$$\ln(km) = c_0 + \sum_i c_i * x_i + \varepsilon \qquad (1)$$

where km represents the daily mileage per car, x_i the values of the i independent variables, c_i the resulting coefficients, and ε the error term. All explanatory variables are given in categorical form, an indicator contrast is used.[12] Thus each category is represented by dummy variables with a reference (omitted) category. The pooled data is analyzed with an additional dummy variable for the survey year. The influence of time is analyzed in three steps:

- Calculating separate models for each year and comparing explanatory coefficients for 1993 and 2002,
- Running one model with all data, including a dummy variable for the survey year,
- Refining this model with yearly interaction terms.

4.1 Logarithmic transformation of the dependent variable

Fitting the model to a logarithmized dependant variable gives several advantages. The log–transformation of vehicle mileage allows the dependent variable to enter the regression analysis in a form closer to normal distribution than it is the case for the distribution of the original values and therefore the same can be expected for the distribution of resulting residuals.

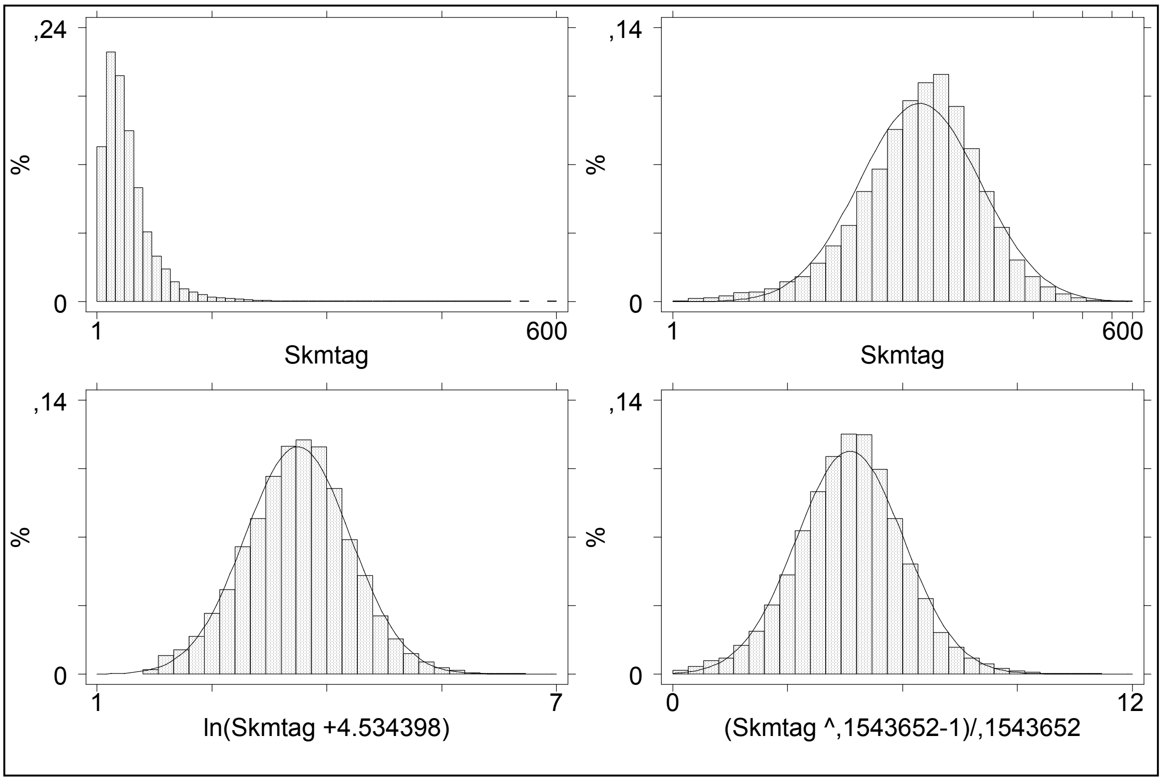
[11] See Schipper 2002, Dargay et al 2003, Giuliano 2006.

[12] All calculations were made in Stata 8.2. Handling the calculations was made easy by using John Hendrickx desmat procedure (used in the Stata version). See Hendrickx 2002.

Hence, tests of the regression coefficients are more robust.[13] Besides, the transformation allows a more straightforward interpretation of the regression estimates obtained for the categorical data. They can be treated as percentage difference compared to the reference category. Another effect is that the few outliers with high values of reported mileage and consequently higher values of random noise (in line with general expectations) have less influence on the estimation results. However, it has to be kept in mind that the results are strictly valid only for the log–linear model, although interpretation (see Section 5 below) relates mainly to the re–transformed mileage estimations.

Figure 3: Transformation of average daily mileage travelled

Comparison of the original distribution, a log–transformation, a log-transformation with an additional parameter k, and a Box–Cox transformation with $\lambda = 0.15$



To check whether the log-transformation is adequate and relevant for the validation of the model coefficients, a transformation $\ln(km - k)$ with an additional parameter k and a Box-Cox transformation of mileage were considered. In the first transformation, by introducing the additional parameter k the skewness can be set to zero, the Box-Cox transformation can be

[13] See Wooldridge, J. M. 2003, p. 116.

used to receive residuals which are distributed closely to the normal distribution and which are less heteroskedastic.[14] The transformation is defined as

$$y^{(\lambda)} = \frac{y^{\lambda} - 1}{\lambda}$$

with λ as parameter. For λ → 0 the Box-Cox turns towards a logarithmic transformation. In a maximum likelihood estimation with the pooled dataset parameters of k = -4,5 rsp. λ = 0.15 result (Fig. 3, graph 3 and 4). Both parameters are highly significant, so each of the regression procedures described in the next chapter was additionally calculated with such transformed dependent variables. However, significance levels were the same as when the logarithmic transformation was applied to the endogenous variable. Therefore, results from the log linear model are described in this paper, since they allow to interpret the coefficients as factors.

[14] See Davidson, MacKinnon 1993.

5 Results

The linear regressions with ln(km) as dependant and with categorical variable specifications as dummy variables $x_i \in \{0,1\}$ for the explaining variables allow the coefficients to be interpreted as factors when taking delogarithmized values $\hat{c}_i = e^{c_i}$ of the linear regression coefficients c_i. For an easy comparison of the models and results for 1993 and 2002 a comprehensive outline of the resulting models is given in Table 5 and Table 6. The values presented in these tables correspond to the coefficients $\hat{c}_i$ as given above instead of the original coefficients c_i.

The indicator contrasts used in the parameterization refer to the most prevalent category of the explanatory variable. The constant term $\hat{c}_0$ therefore is the base value of the daily mileage traveled by a car with all "standard" attributes from the reference categories of exogenous variables included into the model.[15] Coefficients $\hat{c}_i$ of the independent variables can be interpreted as percentage values modifying the base value of daily mileage traveled when attributes different to the reference category are present.[16]

5.1 Car type related effects

When observations for all cars –business and private– enter the model, the personal characteristics of the user or the holder cannot be included into the estimations, since such information was not considered for business cars. Hence in model (1) to (7) explanatory variables refer exclusively to vehicle attributes (engine type and power, cylinder capacity, maximum weight, maximum speed, fuel consumption), the owner in general (business or private car, residence of the owner), and survey characteristics (year, month).

[15] As most common average and therefore reference category a vehicle with a petrol engine, belonging to the engine power category between 90 and 189 kW and cylinder capacity between 1 400 and 1 699 ccm, between 7 and 10 years old, driven in the German Bundesland Nordrhein-Westfalen, surveyed during the first two months of the year 1993 and registered by a private holder has been chosen.

[16] When two re-transformed estimated mean values of mileage are compared, both values have the variance as a factor. So the coefficient $\hat{c}_i$ gives the correct relative change only under the assumption of homoscedacity, that the variance for both values is the same for both. As relative change to the median the re-transformed coefficient can be interpreted without this assumption.

A model including all eleven possible variables is considered as the initial model. Fuel consumption and the weight of the car are not significant and since a strong correlation exists between maximum speed and engine power only the latter was kept in model (1). The same applies for the other models. In model (2) and (3) estimated coefficients were calculated for each year separately in order to directly see differences between resulting factors determining car use over time. Since the engine type and kind of car registration have obviously great influence on the daily mileage covered, separate models have been run for private cars and for business cars (model (4) and (5)) as well as for petrol and diesel cars (model (6) and (7)) respectively. As will be stressed later in chapter 5.3, estimations containing interactions with a dummy variable for the survey year give us further explanation of the relationship between the mode of drive, i.e., fuel demand, and the time effect between 1993 and 2002.

Table 5: Estimation results for daily mileage – all cars

	All poolded data Model (1)[1]			Data 1993 Model (2)[2]			Data 2002 Model (3)[3]			Business cars Model (4)[1)4)]			Private cars Model (5)[1)5)]			Petrol cars Model (6)[1)6)]			Diesel cars Model (7)[1)7)]		
	F[8)]	S[9)]	T[10)]	F[8)]	S[9)]	T[10)]	F[8)]	S[9)]	T[10)]	F[8)]	S[9)]	T[10)]	F[8)]	S[9)]	T[10)]	F[8)]	S[9)]	T[10)]	F[8)]	S[9)]	T[10)]
Constant term km/day	29.2	***	163	31.3	***	94	29.4	***	122	41.5	***	67	28,2	***	150	27,8	***	133	41,7	***	33
Engine power (kW)																					
-25	0.58	***	-15.5	0.60	***	-11.2	0.61	***	-4.4	0.51	***	-7.2	0.60	***	-13.6	0.61	***	-12.6	-		
26-48	0.77	***	-14.7	0.77	***	-9.3	0.83	***	-7.6	0.69	***	-8.3	0.81	***	-11.4	0.83	***	-8.3	0.72	***	-9.9
49-60	0.88	***	-10.1	0.89	***	-5.8	0.89	***	-6.9	0.78	***	-7.9	0.91	***	-6.6	0.92	***	-5.5	0.84	***	-6.9
61-90	*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*		
91-190	1.11	***	8.0	1.13	***	5.3	1.10	***	5.6	1.17	***	6.1	1.06	***	3.7	1.05	**	3.1	1.19	***	6.7
Above 190	1.25	***	3.8	1.32		1.6	1.23	**	3.3	1.24	**	2.9	1.23	*	2.1	1.15	*	2.4	1.00		0.0
Cylinder capacity (ccm)																					
- 999	0.91	***	-4.6	0.86	***	-4.6	0.91	**	-3.2	0.93	0	-1.3	0.90	***	-4.4	0.90	***	-5.0	0.81		-1.0
1000-1400	*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*		
1401-1700	1.00		0.1	1.04		1.5	1.02		0.9	1.03	0	0.7	1.01		0.4	1.04		2.1	1.14		1.2
1701-1900	1.08	***	4.4	1.11	***	3.7	1.10	***	3.8	1.10	*	2.0	1.09	***	4.2	1.12	***	5.2	1.19		1.6
1901-2400	1.03		1.3	1.08	*	2.6	1.03		1.0	1.00	0	-0.1	1.06		2.6	1.11	***	4.5	1.10		0.9
Above 2400	1.03		1.2	1.08	0	1.9	1.04		1.1	0.96	0	-0.7	1.09	**	3.2	1.19	***	5.7	1.02		0.2
Age of vehicle																					0.0
Under 1 year	1.14	***	6.4	1.19	***	7.1	1.05	0	1.5	1.24	***	5.7	1.09	***	3.6	1.10	***	4.0	1.24	***	5.6
1-3 years	1.08	***	8.7	1.07	***	4.8	1.09	***	6.6	1.22	***	9.4	1.03	**	2.9	1.05	***	4.2	1.20	***	9.2
4-7 years	*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*		
8-11 years	0.91	***	-8.6	0.92	***	-4.5	0.90	***	-7.3	0.78	***	-7.2	0.92	***	-6.9	0.91	***	-8.3	0.91	***	-3.4
12-20 years	0.76	***	-17.1	0.78	***	-9.0	0.75	***	-14.8	0.63	***	-8.5	0.77	***	-15.6	0.76	***	-16.2	0.75	***	-6.7
Above 20 years	0.61	***	-7.3	0.78	**	-3.3	0.42	***	-7.1	0.66	*	-2.3	0.60	***	-7.1	0.62	***	-7.0	0.33	***	-3.3
Federal state																					
Schleswig-Holstein	1.02		0.8	1.02		0.3	1.02		0.6	0.94		-0.8	1.03		1.1	1.01		0.4	1.06		1.0
Hamburg	0.92	*	-2.5	0.89		-1.4	0.92	*	-2.2	0.96		-0.8	0.89	**	-2.8	0.90	**	-2.8	1.00		0.1
Niedersachsen	1.04	*	2.5	1.07		2.0	1.04		1.8	1.01		0.3	1.05	*	2.6	1.03		1.6	1.07	*	2.2
Bremen	0.99		-0.2	1.25		2.4	0.92		-1.1	1.22	*	2.1	0.91		-1.4	0.93		-1.0	1.24	*	2.5
Nordrhein-Westfalen	*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*		
Hessen	1.03		1.4	1.07		1.9	1.01		0.5	1.03		0.7	1.02		0.8	1.02		0.7	1.05		1.3
Rheinland-Pfalz	1.07	**	3.1	1.04		1.0	1.07	**	2.9	1.00		0.0	1.08	***	3.5	1.09	***	3.7	0.99		-0.3
Baden-Württemberg	0.94	***	-4.3	0.90	***	-3.5	0.95	**	-3.2	0.90	**	-2.9	0.95	***	-3.3	0.95	**	-3.1	0.90	***	-3.5
Bayern	0.97	*	-2.0	0.95		-1.9	0.98		-1.4	0.94	0	-2.0	0.99		-0.9	0.97		-1.5	0.95		-1.7
Saarland	1.00		0.0	1.03		0.3	0.99		-0.2	1.03		0.3	0.99		-0.2	0.99		-0.2	1.06		0.7
Berlin	0.92	***	-3.5	0.94		-1.8	0.92	*	-2.5	0.88	*	-2.1	0.93	**	-3.1	0.90	***	-4.0	1.02		0.4
Brandenburg	1.09	***	4.9	1.14	***	5.0	1.02		0.7	1.12		2.5	1.08	***	4.0	1.08	***	3.9	1.13	**	3.0
Mecklenburg-Vorpommern	1.12	***	5.2	1.15	***	5.0	1.07		1.8	1.12		2.4	1.11	***	4.6	1.10	***	4.0	1.17	***	3.7
Sachsen	1.00		0.1	1.03		1.5	0.96		-1.6	1.03		0.8	0.99		-0.4	0.99		-0.4	1.03		1.0
Sachsen-Anhalt	1.00		0.1	1.02		0.6	1.01		0.3	1.01		0.2	1.00		-0.2	0.99		-0.6	1.06		1.5
Thüringen	1.01		0.5	1.04		1.6	0.96	0	-1.2	0.99		-0.3	1.01		0.6	1.01		0.5	1.01		0.2
Month																					
Jan.-Feb.	*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*			*1.00*		
March-April	1.08	***	5.7	1.14	***	7.1	1.03		1.9	1.04		1.4	1.09	***	6.1	1.08	***	5.1	1.07	**	2.6
Mai-June	1.10	***	7.4	1.16	***	7.5	1.07	***	3.7	1.02		0.7	1.13	***	8.3	1.11	***	7.1	1.07	*	2.4
July-Aug.	1.10	***	7.4	1.17	***	8.1	1.06	***	3.4	1.02		0.7	1.12	***	8.2	1.11	***	7.0	1.08	**	2.7
Sept.-Oct.	0.98		-1.7	1.03		1.5	0.95	**	-3.1	0.93	*	-2.2	0.99		-0.6	0.98		-1.5	0.97		-1.1
Nov.-Dec.	0.91	***	-6.6	0.95	*	-2.5	0.89	***	-6.4	0.91	**	-3.2	0.92	***	-5.6	0.92	***	-5.7	0.91	***	-3.4
Year																					
1993	1.15	***	14.8							1.10	***	4.1	1.17	***	15.5	1.17	***	15.1	1.08	**	3.1
2002	*1.00*									*1.00*			*1.00*			*1.00*			*1.00*		
Mode of drive																					
Other or unknown	0.65	***	-3.7	0.83	0	-1.4	0.52	***	-3.6	0.47	***	-3.5	0.75	*	-2.3						
Petrol engine	*1.00*			*1.00*			*1.00*			*1.00*			*1.00*								
Diesel engine	1.51	***	36.1	1.41	***	16.8	1.56	***	29.9	1.47	***	16.6	1.49	***	30.1						
Registered car owner																					
Business	1.31	***	25.6	1.25	***	14.1	1.35	***	20.9							1.31	***	21.0	1.26	***	12.9
Private	*1.00*			*1.00*			*1.00*									*1.00*			*1.00*		
	n=42,791			n=17,405			n=25,385			n=8,746			n=34,045			n=33,718			n=8,984		
	R^2=0.17			R^2=0.17			R^2=0.18			R^2=0.19			R^2=0.12			R^2=0.11			R^2=0.14		
Model specification	1) Pooled estimation with both survey years 1993 and 2002. 2) Survey 1993. 3) Survey 2002. 4) Business cars. 5) Private cars. 6) Cars with a petrol engine. 7) Cars with a diesel engine. 8) Coefficient as factor. 9) Significance level: * p < .05, ** p < .01, *** p < .001. 10) T-Value. *In italics* : Reference category.																				
Source: FLS-data 1993 and 2002, DIW Berlin.																					

In the first regression model (1) the basis value is 29.2 km per day, estimated for the mentioned reference car type[17] in 2002. In 1993, the daily mileage was significantly higher (15 %) than in the survey period 2002. Mileage varies with engine power far more (from -40 % to 25 % compared to the average) than with cylinder capacity, which is the basis for yearly taxation in Germany.[18] As expected, older cars have on average a lower daily mileage. Status of the car holder proves to be another highly influential predictor variable. Business cars' daily mileage was 31 % above that of private cars. As already seen from the descriptive statistics, there is a remarkable difference in mileage of petrol and diesel cars. Controlling for other explanatory variables, diesel engine alone accounts for 51 % higher mileage compared to petrol cars.

When interpreting the regression results it should be kept in mind that the explanatory power assigned to significant predictor variables does not necessarily reflect the degree of causality between these and the dependent variable. Taking as one example the effect of age of the vehicle on its usage it is likely to find out that newer cars display higher mileages than older ones. But the conclusion from this result is not automatically that newer vehicle are used more frequently just because it is a new car. Instead, obviously very mobile people are more likely to buy new cars and therefore low vehicle age correlates with high vehicle mileage.

Possible spatial effects on overall mileage driven per day turned out to be fairly low compared to some of the other factors. Some of the categories of the regional variable even lack statistical significance. This can be mainly explained by the heterogeneity of, e.g., land use and population density characteristics implicit in the spatial variable "Bundesland" (federal state), which itself refers rather to a territorial administration unit than to a homogenous in structure residential area.[19] Nevertheless estimation results obtained for the different federal states appear fairly plausible in their general tendency. Reference was set to be Nordrhein-Westfalen as the by population largest state in Germany. Hence, in city states like Hamburg covering a relatively small area, but characterized by a rather high population density and an attractive public transport, average car mileage traveled was about 8 % lower with reference to the contrast state Nordrhein–Westfalen. On the contrary, for sparsely populated regions like Meck-

[17] See footnote 15.

[18] This is due to diesel cars, as can be seen in model (7). Engine power is highly correlated with cylinder capacity only for petrol cars, less for cars with a diesel engine. The correlation coefficient between engine power and cylinder capacity dropped for diesel cars from 0.69 in 1993 to 0.49 in 2002. Obviously other technical changes than increasing cylinder volume were more effective to gain more power from the diesel engine.

lenburg-Vorpommern with only few urban agglomerations average car utilization intensity lay 12 % above the value for the reference case.[20]

Results from model (2) and (3) allow to compare the determining factors of mileage for 1993 and 2002. The constant term for 1993 (31.4 km) is 7 % higher than for 2002. Otherwise, both models yield quite similar results, except from differences in the intensities of single effects. For instance, new cars were used more intensively in 1993 than in 2002, an effect that might be assigned to the motorization trend among East Germans boosted by the reunification process. The generally positive effect of diesel engines on daily mileage compared to petrol cars was even higher in 2002 than in 1993. This rather follows from lower mileage of petrol cars than from higher mileage of diesel cars, when the different constant terms are taken into account. The significance of the differences between 1993 and 2002 were tested, when they were considered as interaction effects (see chapter 5.3).

In model (4) we focused on business cars. Obviously, this specific car sector can be differentiated mainly into two age groups. As a result, an intensively used majority of new cars is distinguished from only a small number of "old–timers" with far less mileage.[21] In the latter age category petrol cars are still present,[22] while new intensively used business cars are mostly diesel cars in Germany nowadays. The analysis of variance containing variables as described above yields better results for business cars (model (4), R^2=0.19) than for private cars (model (5), R^2=0.12).

To analyze the variance of the dependent variable in case of private cars additional variables (see models (8) to (10), next section) can be considered in the regression model and as a consequence even more satisfying results are obtained. Model (5) for private cars is presented here just for the comparison with model (4) for business cars. Thus as expected model specific values of the constant terms differ noticeably between 41.5 km per day for business cars

[19] Other spatial variables were surveyed in 2002 but are not coded in the survey of 1993.

[20] Model (5) containing only private cars, gives better estimations for the spatial effects. Usually business cars are registered at their companies headquarters, but rented throughout Germany. So the spatial information for these cars reflects more sector differences of the companies than the connection between daily distance and settlement structure.

[21] Of course, cars only used on special occasions like weddings are included in this sector.

[22] The average age is 4.7 years for petrol driven business cars and 3.3 years for diesel driven cars.

and 28.3 km per day for private cars. Moreover, the influence of spatial aspects on daily mileage implied by the federal state variable can only be verified for private cars.[23]

Another difference between the two models specified for the owner category of the vehicle is the variable cylinder capacity. It plays a role for private cars, but not so for business cars. The background of this result is the high share of diesel cars in the business car sector, in contrast to the fairly small share of "just" 13 % found for private cars in 2002. This results from the fact that a high correlation between engine rating and cylinder capacity can be found only for petrol cars.[24] Thus, cylinder capacity has no statistically significant effect on mileage traveled by diesel cars (model (7)).

Model (6) and (7) illustrate engine type specific estimation results; again a remarkable difference in the base effect can be seen by comparing the values of the constant, amounting to 27.8 km for a petrol car and to 41.7 km for a vehicle with a diesel engine. The coefficient of the year-dummy for 1993 in the petrol car model (6) is 1.17, compared to 1.08 for the diesel car model (7). This is consistent with the results obtained when interactions with the dummy variable for the survey year are included as shown in section 5.3.

[23] See footnote 19.

[24] See footnote 17.

Table 6: Estimation results for daily mileage – private cars

	Pooled data-Model (8)[8]			Data 1993-Model (9)[9]			Data 2002-Model (10)[10]		
	Factor, Significance, T-Value			Factor, Significance, T-Value			Factor, Significance, T-Value		
Constant term km/day	36.6	***	148.7	40.4	***	66.0	36.0	***	111.0
Engine power (kW)									
-25	0.63	***	-12.8	0.64	***	-9.6	0.74	**	-2.6
26-48	0.82	***	-11.0	0.81	***	-7.3	0.86	***	-6.2
49-60	0.94	***	-5.0	0.93	***	-3.5	0.96	**	-2.7
61-90	*1.00*			*1.00*			*1.00*		
91-190	1.05	**	3.0	1.08	**	3.1	1.04		1.8
Above 190	1.18		1.7	1.06		0.2	1.23	*	2.1
Cylinder capacity (ccm)									
- 999	0.91	***	-4.5	0.86	***	-4.4	0.93	*	-2.5
1000-1400	*1.00*			*1.00*			*1.00*		
1401-1700	1.01		0.8	0.99		-0.3	1.04	*	2.0
1701-1900	1.08	***	4.0	1.03		0.9	1.12	***	4.5
1901-2400	1.08	***	3.7	1.06		1.8	1.11	***	3.8
Above 2400	1.12	***	4.3	1.12	*	2.5	1.13	***	3.6
Age of car									
Under 1 year	1.10	***	4.3	1.16	***	5.6	1.02		0.5
1-3 years	1.05	***	4.7	1.08	***	5.0	1.03	*	2.0
4-7 years	*1.00*			*1.00*			*1.00*		
8-11 years	0.91	***	-8.3	0.93	***	-4.3	0.91	***	-7.1
12-20 years	0.79	***	-15.4	0.81	***	-7.9	0.77	***	-13.4
Above 20 years	0.59	***	-7.2	0.75	***	-3.8	0.43	***	-6.3
Survey Month									
Jan.-Feb.	*1.00*			*1.00*			*1.00*		
March-April	1.09	***	6.5	1.16	***	7.5	1.04	*	2.4
Mai-June	1.13	***	9.0	1.21	***	9.6	1.07	***	4.0
July-Aug.	1.13	***	9.0	1.20	***	9.0	1.08	***	4.5
Sept.-Oct.	0.99		-0.9	1.05	*	2.3	0.95	**	-2.8
Nov.-Dec.	0.92	***	-6.1	0.96		-2.0	0.89	***	-6.4
Year									
1993	1.06	***	6.0						
2002	*1.00*								
Mode of drive									
Other or unknown	0.71	**	-2.8	0.80		-1.5	0.58	*	-2.4
Petrol engine	*1.00*			*1.00*			*1.00*		
Diesel engine	1.41	***	27.4	1.38	***	15.1	1.45	***	22.2
Age of driver									
18-20	1.40	***	10.8	1.45	***	8.0	1.35	***	7.4
21-24	1.26	***	11.5	1.28	***	8.7	1.25	***	7.3
25-29	1.16	***	8.3	1.13	***	5.2	1.18	***	6.3
30-34	1.01		0.7	1.01		0.3	1.01		0.5
35-39	*1.00*			*1.00*			*1.00*		
40-44	0.99		-0.8	0.99		-0.3	0.98		-0.9
45-49	0.94	***	-3.6	0.92	***	-3.3	0.96	*	-2.1
50-54	0.89	***	-7.0	0.84	***	-7.2	0.93	**	-3.3
55-59	0.81	***	-12.4	0.73	***	-11.8	0.86	***	-6.8
60-64	0.73	***	-17.1	0.69	***	-12.0	0.76	***	-12.1
65-69	0.65	***	-20.7	0.59	***	-13.9	0.68	***	-14.7
Above 69	0.51	***	-31.1	0.48	***	-18.7	0.53	***	-23.7
Number of drivers									
1	*1.00*			*1.00*			*1.00*		
2 or more	1.07	***	8.1	1.03	*	2.1	1.10	***	8.5
Employment									
Part-time	0.98		-1.4	0.98		-0.7	0.97		-1.8
Full-time	*1.00*			*1.00*			*1.00*		
Not employed	0.87	***	-13.7	0.91	***	-6.3	0.85	***	-12.3
Sex of driver									
Male	*1.00*			*1.00*			*1.00*		
Female	0.84	***	-18.3	0.80	***	-14.1	0.85	***	-12.5
	n=34,042 R^2=0.23			n=13,789 R^2=0.25			n=20,252 R^2=0.21		

Significance levels: * p < .05, ** p < .01, *** p < .001

Model specification: [8] Pooled estimation with both survey years. [9] Survey 1993. [10] Survey 2002.

Annotation: Variable F*ederal state* has been included in each estimation though corresponding coefficient results are not shown in the table for reasons of transparency. *In italics* : Reference category.

Source: Fahrleistungserhebung 1993 und 2002, DIW Berlin.

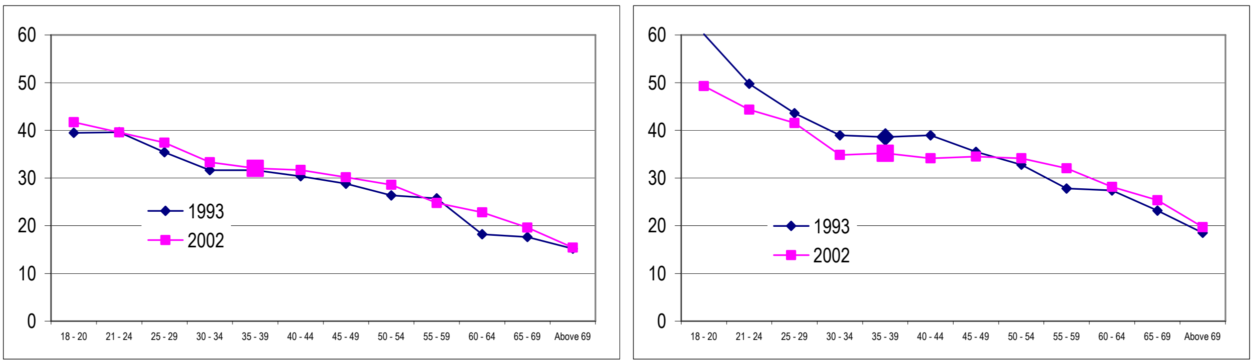
5.2 Personal effects of car users

For private cars the regression analysis was extended (Table 6) by variables representing personal characteristics of the main vehicle user and the holder. Gender and age of the user were be added as explanatory variables. At the outset, data from the two survey years were combined (model (8)). Results obtained for the pooled model were compared with regression output estimated for each year separately (model (9) and (10)). By the inclusion of categorical variables describing socio-demographic user characteristics the goodness of the model fit improved up to $R^2 = 0.23$.

One powerful explanatory variable is the age of the driver.[25] Cars with young drivers have in general a 40 % higher daily mileage than those mainly used by persons at the age of 30 to 45 years. After reaching the age of 45 years daily mileage traveled gradually decreases to two-thirds of the value realized by the (middle-aged) reference category. Cars of "very old" drivers display only half the average mileage realized by cars with 30 to 44 years old drivers.[26] Comparing model (9) to model (10) it becomes evident, that influence of the drivers' age has weakened over the last ten years.[27] In 2002, both young and senior drivers exhibited car utilization intensities that were closer to the overall average compared to results estimated for data of 1993.

Figure 4: Average daily mileage travelled by age and gender of the driver

Daily mileage of cars mainly used by female drivers — Daily mileage of cars mainly used by male drivers



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[25] It should be kept in mind that mileage of car, not mileage of person as in personal surveys is the dependent variable. The personal variables used for explanation are attributes of the car. Especially young drivers may have a substantial part of their first mileages as drivers in cars, they are not the "main user" of.

[26] These results are controlled by the variable employment status; e.g., in the category "Not employed" a further reduction of mileage of about 10 % results for retired persons.

[27] For similar results of observed life-cycle effect and generation-effect for the UK see Dargay, J. (2004) or Lipps, O. and U. Kunert (2004).

As already suggested by the descriptive analysis (Fig. 2), the decrease in overall mileage from 1993 to 2002 is mainly due to young *male* drivers. However, since in the car mileage survey we observe cars and their mileage not persons, it is uncertain, whether this is really due to a reduction of car use of young men. At least partial this result can be an outcome of a more intense use of parents car, too, to avoid some tanking costs for the own car. [28]

The variable "employment status" divided into three categories (full-time employed, part-time employed, and not employed[29]) was also included into the models (8) to (10). The car ownership rate for part time workers is lower than for full-time employees,[30] but when comparing car users – only these are in the mileage survey – the daily mileage of both groups does not differ. In contrast, the average daily mileage traveled by not employed was significantly lower in both survey years.

Another variable that was included into the regression model for private car utilization intensities and proved to produce a significant effect is the number of drivers regularly using the car. In case of two or more drivers sharing one car, the mileage of the vehicle turns out to be slightly higher. In 1993 existence of multiple users increased the average mileage of the vehicle by 3 %, in 2002 this effect amounted up to 10 % compared to the single-user category.

Even in a model specification where effects of the age of the car user, the employment status, and additional technical and personal explanatory variables are included, gender has a strong effect on the daily car mileage. In the case of cars with a female as main driver the average daily mileage declines by 16 % compared to cars with a male driver (model (8)). However, a clear trend towards the convergence of gender specific effects can be observed over the time. While the gender related difference resulted in 20 % in 1993 it was just 15 % in 2002 (model (9) and (10)).

The coefficient for the year-dummy variable obtained from model (8) is significant, but the effect for the ten-year period appears to be rather low with a 6 % mileage decrease from 1993

[28] For lack of space the coefficients of interaction effects are not shown in Table 5. Figure 4 in section 5.3 presents the results, when interaction effects between age and sex are included.

[29] The category "not employed" includes unemployed and all other people without employment, such as retired persons, housewives, but also those individuals who did not specify any response as to their "employment status".

[30] According to the German National Travel Survey (MiD 2002) 85 % of full time workers always have a car at hand, 76 % of those working 18 to 35 hours a week, and 71 % of those working less.

to 2002. This result implies that most of the change in average daily car mileage driven attributed to the time effect can be explained by socio-demographic factors.

5.3 Interaction effects

To further improve the quality of the regression results the initial models were extended by incorporating interaction effects between selected variables.

The extension of the regression equation for car mileage travel demand as specified in (1) yields the following functional form for a 2-way interaction effect represented by the multiplication of two exogenous variables from the preliminary model:

$$km = c_0 + c_1x_1 + c_2x_2 + \ldots + c_{1.2}x_1x_2 + \varepsilon \qquad (3)$$

The regression coefficient $c_{1.2}$ resulting from the product of the two explanatory variables x_1x_2 quantifies the effect of the independent variable x_1 on the dependent variable *km*, conditioned on the variation of the other multiplier variable x_2. In other words, the magnitude of estimated interaction effects of two predictor variables x_1x_2 of a linear model indicates the change in the slope of the regression line of *km* on x_1 when an one-unit change of x_2 occurs.

The number of statistically significant explanatory variables included in the main models allows an analysis of various plausible interaction effects. For the following description of the results obtained from refined models only those interaction effects are considered for further interpretation that are tested statistically significant at probability levels of 0.1 % and contribute substantially to the explanation of behavioral patterns of motorized passenger travel demanded by German car holders and users respectively.

Again, a reduced form model based uniquely on technical vehicle attributes including all cars and a full form model containing in addition personal user characteristics but limited to private cars was specified and estimated.

As shown in the previous sections one result obtained from the estimations of main effects is the significance of the year-dummy variable. As expected, there exists an effect between 1993 and 2002. By estimating models with the year-dummy interacting with other regressor variables, additional explanatory quality validated by a significance test can be gained for the time effect. The first extension (II) based on model (1) contains interaction effects from engine type and year of the survey. The second extension (III) displays coefficients for the interacting term of car age together with the survey year.

Extended specifications estimated for the full form model (8) consider vehicle user characteristics. Extension (V) contains interactions between the gender of the main car user and the year of the survey as well as the employment status category of the car user and the year of the survey respectively. Additionally, an interaction effect between vehicle user's age category and the survey year were included in model (V).

Table 7 and Table 8 illustrate the regression results computed under consideration of interaction effects as depicted above. The first model variant exhibited in each table – model (I) and model (IV) respectively – refer to regression results obtained from the main model specification with no interaction effects included. All coefficient estimates shown below represent exponential values and can be therefore interpreted as percentage changes from the reference case represented by the value of the constant and defined as the average daily mileage driven (km/day) in a vehicle falling into the common standard category.[31]

[31] See footnote 15.

Table 7: Models with interaction effects

	Model (I) [1)]			Model (II) [2)]			Model (III) [3)]		
	Factor, Significance, T-Value			Factor, Significance, T-Value			Factor, Significance, T-Value		
Constant term km/day	**29.21**	*******	**162.79**	**28,47**	*******	**156,45**	**29.12**		**158,7**
Year									
1993	1.15	***	14.8	1.17	***	15.6	1.14	***	9.1
2002	*1.00*			*1.00*			*1.00*		
Mode of drive									
Other or unknown	0.65	***	-3.8	0.52	***	-3.9	0.67	***	-3.6
Petrol engine	*1.00*			*1.00*			*1.00*		
Diesel engine	1.51	***	36.1	1.57	***	33.4	1.5	***	34.9
MODE OF DRIVE*YEAR									
Other or unknown*1993				1.65	*	2.3			
*Petrol engine*1993*				*1.00*					
Diesel engine*1993				0.90	***	-5.5			
Age of car									
Under 1 year	1.14	***	6.4	1.14	***	6.4	1.07		1.8
1-3 years	1.08	***	8.7	1.08	***	8.5	1.10	***	7.5
4-7 years	*1.00*			*1.00*			*1.00*		
8-11 years	0.91	***	-8.6	0.91	***	-8.7	0.90	***	-7.6
12-20 years	0.76	***	-17.1	0.76	***	-17.3	0.75	***	-14.8
Above 20 years	0.61	***	-7.3	0.61	***	-7.3	0.41	***	-7.2
AGE OF CAR*YEAR									
Under 1 year*1993							1.11	*	2.3
1-3 years*1993							0.97		-1.4
*4-7 years*1993*							*1.00*		
8-11 years*1993							1.03		1.4
12-20 years*1993							1.05		1.5
Above 20 years*1993							1.88	***	4.4
	n=42,790 R^2=0.17			n=42,790 R^2=0.17			n=42,790 R^2=0.17		

Significance levels: * p < .05, ** p < .01, *** p < .001

Model specification: 1) No interaction effects. 2) With interaction of year and mode of drive. 3) With interaction of year and age of car.

Annotation: The variables Federal state, survey month, registered car owner, engine power (in kW), and cylinder capacity (in ccm) have been included in each estimation though corresponding coefficient results are not shown in the table for reasons of transparency.
In italics : Reference category.

Source: FLS-data 1993 and 2002, DIW Berlin.

The coefficients obtained for the interaction effect between the year-dummy variable and engine type confirm the results gained from the comparison of coefficients estimated separately for the survey periods 1993 and 2002 from the two main models (2) and (3). The utilization intensity of diesel cars lay 40 % for 1993 and 56 % for 2002 – or close to 13 km/day and 16 km/day respectively – above the average utilization intensity estimated for petrol cars, holding all other explanatory factors constant.

Estimating the interaction between survey year and engine type confirms the different size of the effects of diesel as engine type in 1993 and in 2002. The coefficient for diesel estimated without interaction of engine type with the year variable is 1.51. This means that in general – ignoring possible time effects – diesel vehicles have been used 50 % more intensively than petrol cars. The corresponding value obtained for diesel for the year 1993 after including the interaction term “engine type*year” amounts to 1.57 * 0.90 = 1.41. Thus already in 1993 diesel engine cars had on average a 40 % higher mileage than petrol driven automobiles. Nevertheless, the positive effect of diesel as engine type was 1993 weaker than a decade later in 2002 with the value 1.57. The positive effect of diesel engine has gained even more influence within the last ten years.[32] The inclusion of an interaction term for engine type and the time variable allows not only to separate the time effect within the category of the engine type as reflected in the difference 1.41 to 1.57. Moreover, the coefficients calculated for the interaction effects allow to test their statistical significance.

The estimated results can be most likely ascribed to the shift of primarily "big drivers" from petrol cars towards passenger vehicles running with a diesel engine.[33] This can be easily justified by the relative fuel price advantage associated with the use of diesel cars and their higher fuel efficiency. Along with overall fuel price increases –starting in the late 90's– more and more car users, especially those forced to cover relatively long distances on a regular basis due to, e.g., commuting, have changed from a petrol to a diesel car. As consequence, a decomposition effect, segregating high-intensity car users out from the petrol into the diesel car sector is observed.

Another noteworthy effect results from the interaction of the two variables survey year and vehicle's age category. As shown in Table 7 only two of five age categories of the corresponding variable reveal a statistically significant effect when interacted with the year–dummy. One of them is only weakly significant with the probability of error $p<0.05$. The other significant effect appears in the car age category of "above 20 years" and concerns thus only a marginal share (round 10 % in each of the survey years) of the overall passenger car fleet. It can be therefore concluded from the results presented above that obviously the negative effect vehicle age exerts on car usage associated with progressing vehicle age has experienced hardly any significant change within the last decade.

Further, interaction effects from the full form model containing personal data of the main car user were estimated. Interacting gender with the survey year in the model specification (V) stands in line with results already obtained from the models (9) and (10), namely that the negative effect estimated for the female category of the "gender of the user"-variable has declined over the past decade. Female car drivers still tend to use their vehicle less intensively

[32] In addition a model containing interactions between the categories of the car holder variable – private vs. commercial holder – and the engine type variable has been estimated. Resulting coefficient for the interaction term of interest (diesel*commercial vehicle holder) turned out to be equal 1 and the t-test fails to prove the statistical significance of the result.

[33] In this context the attribute "big driver" refers to users with mileage above the corresponding average.

than their male counterparts. Gender specific vehicle utilization patterns tend towards stronger car use by males have been oftentimes observed and extensively studied in the past. However, rising employment rates for women together with increasing rates of female driving license holders contribute to an undoubted deterioration of the gender effect.

Table 8: Model with interaction effects and personal variables

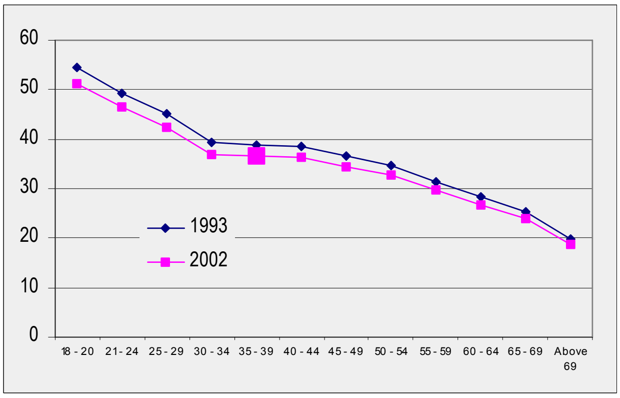
	Model (IV) [1]			Model (V) [2]		
	Factor, Significance, T-Value			Factor, Significance, T-Value		
Constant term km/day	**36.7**	*******	**148.7**	**36.7**	*******	**135.1**
Year						
1993	1.06	***	6.0	1.13	***	4,9
2002	*1.00*			*1.00*		
Employment						
Part-time	0.98		-1.4	0.97		-1.8
Full-time	*1.00*			*1.00*		
Not employed	0.87	***	-13.7	0.84	***	-12.3
EMPLOYMENT*YEAR						
Part-time*1993				1.01		0.3
*Full-time*1993*				*1.00*		
Not employed*1993				1.08	***	3.9
Gender of driver						
Male	*1.00*			*1.00*		
Female	0.84	***	-18.3	0.86	***	-12.4
GENDER OF DRIVER*YEAR						
*Male*1993*				*1.00*		
Female*1993				0.93	***	-3.7
Mode of drive						
Other or unknown	0.71	**	-2.8	0.71	**	-2.8
Petrol engine	*1.00*			*1.00*		
Diesel engine	1.41	***	27.4	1.42	***	27.3
Number of drivers						
1	*1.00*			*1.00*		
2 or more	1.07	***	8.1	1.1	***	8.6
No. OF DRIVERS*YEAR						
*1*1993*				*1.00*		
2 or more*1993				0.94	***	-4.0
Age of driver						
18-20	1.40	***	10.8	1.36	***	7.5
21-24	1.27	***	11.5	1.25	***	7.4
25-29	1.16	***	8.3	1.18	***	6.3
30-34	1.01		0.7	1.00		
35-39	*1.00*			*1.01*		*0.5*
40-44	0.99		-0.8	0.98		-1.0
45-49	0.94	***	-3.6	0.96	*	-2.1
50-54	0.89	***	-7.0	0.93	***	-3.4
55-59	0.81	***	-12.4	0.85	***	-6.9
60-64	0.73	***	-17.2	0.76	***	-12.2
65-69	0.65	***	-20.7	0.68	***	-14.8
Above 69	0.51	***	-31.1	0.53	***	-23.8
AGE OF DRIVER*YEAR						
18-20*1993				1.06		1.0
21-24*1993				1.02		0.4
25-29*1993				0.96		-1.2
30-34*1993				0.99		-0.2
*35-39*1993*				*1.00*		
40-44*1993				1.02		0.6
45-49*1993				0.97		-1.1
50-54*1993				0.91	**	-2.9
55-59*1993				0.87	***	-4.1
60-64*1993				0.92	*	-2.3
65-69*1993				0.88	**	-2.9
Above 69*1993				0.92		-1.9
	n=34,042 R^2=0.22			n=34,041 R^2=0.23		
Significance levels: * p < .05, ** p < .01, *** p < .001						
Model specification	1) Estimation without interaction effects. 2) Model including several interaction effects.					
Annotation	Variables *Federal state, survey month, age of the car, engine power (in kW), and cylinder capacity (in ccm)* have been included in each estimation though corresponding coefficient results are not shown in the table for reasons of transparency. *In italics* : Reference category.					
Source: FLS-data 1993 and 2002, DIW Berlin.						

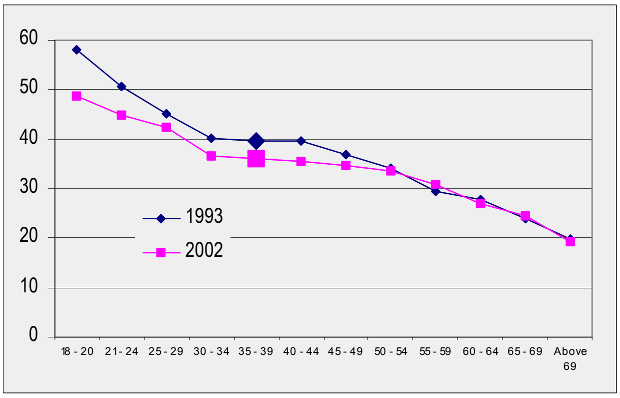
In the same model interaction effects between employment status and the survey-year variable have been estimated. It is not surprising that the state “not employed” has in general a negative effect on individual car travel demand. This can be explained twofold. Firstly, individuals without a regular professional occupation do not have to realize trips to and back from work, which account for a high share in the daily mileage of an employed; secondly, unemployment may at the same time stand for lower household income.

The negative effect of unemployment on car mileage was lower in 1993 than in 2002. Usually unemployment results on average in a 15 % or nearly a 5 km/day decline of the car utilization intensity. For 1993 the effect resulting from an absence of employment accounted for a fall in the car travel demand close to 11 % (or 4 km/day) compared with the reference value of 35.5 km/day. For 2002, the corresponding percentage change was 15 % (or more than 5 km/day). A plausible explanation for these results can be found in an increased number of unemployed who in general tend to dispose of a smaller household budget.

Figure 5: Average daily mileage travelled by age of the driver

Comparison of the results from model (IV) without and model (V) with interaction terms





Finally, interaction coefficients estimated from the variables age of the car user and survey year prove to be significant uniquely for some of the older age groups 50 – 69. Thus, car mileage in these age categories was significantly smaller in 1993 than in 2002, taking into account the overall negative effect that ageing has on personal car travel demand. Figure 5 compares estimates of daily vehicle mileage traveled by different age groups. Values presented on the right result from model (V) including interaction terms between age of the user and the year-dummy; the figure on the left-hand shows results estimated with model (IV) without interaction effects. In the left-hand chart the difference in the mileage between 1993 and 2002 is round 6 % (corresponding coefficient value of the year-dummy equals to 1.06), irrespective of the age group. However, in the left-hand chart based on the model including interaction effects it becomes clear, that the difference between 1993 and 2002 is caused mainly by young to middle–age drivers.[34] Furthermore, we see a slight increase in the average mileage traveled by 55 – 59 year-old in 2002. This result can be interpreted in the context of emerging car dependency observed in particular for senior drivers. This phenomenon has gained attention related to the issue concerning mobility and demographic change as it has been recently drawing attention in most of the European member states.

6 Conclusions

The two large surveys on vehicle mileage conducted in 1993 and 2002 allow a throughout trend analysis of the change in the determinants of car use in Germany within one decade. Since both surveys used mainly the same method, the data could be pooled and enriched by information from other sources.

The main findings are that demographic factors are important for the estimation of average car mileage. A significant differences still can be observed between female and male car usage patterns, even though over the last decade these differences reveal a tendency to converge. Furthermore, the variation in car mileage driven between young drivers and old drivers slightly decreases as well. These results suggest an existing need for a stronger consideration of the dynamics of behavior when modeling passenger travel demand. Referring to the changing effect of gender on individual car usage, the overall increase in the number of cars held in Germany in the last decade has primarily been due to female car holders. There were 4.5 mill. additional female car users in 2002 compared to 1993, but just 1 mill. more male users. 40% of cars had a female driver in 2002, whereas in 1993, only one in three cars was driven by a woman.

[34] To further examine the age effect on car utilisation intensities a supplementary model alternative has been estimated where interactions between the age of the car user variable and the gender of the user variable have been specified. Out of eleven age categories only two turned out significant according to the t-test statistics when interacted with the gender categorical variable. Thus, the results obtained from this model show that in addition to the overall negative effect age categories of elderly car users display on driving intensities becomes even higher for females falling into the age groups of 64 – 68 and 69 – 99 years old. As an example drivers reaching the age of 64 – 68 and 69 – 99 years respectively tend to reduce their car travel demand on average by 25 % (round 9 km/day) and 35 % (close to 13 km/day) respectively. Is the elderly driver a female individual the average decline of the car utilisation intensity is likely to amount up to 30 % (almost 10 km/day) and 40 % (nearly 14 km/day) respectively.

Obviously demographic and socio-economic changes have a prevailing influence on the over-all motorization process, while fuel prices appear to have a far weaker effect than may be expected –apart from the trend toward diesel cars. These results confirm research findings stating that price elasticities of car use have carefully to be considered and applied.[35] Instead of reducing mileage, German drivers try to avoid the burden of higher fuel prices by refueling in neighboring countries where fuel prices are cheaper than in Germany.[36] Alternatively many motorists prefer to change to diesel engine cars, which are more fuel-efficient and run on cheaper diesel fuel, than to cut down on their car use. At least these are the short- to mid-run effects of a fuel price increase.

The different taxation of petrol and diesel cars and petrol and diesel fuel in Germany as well as new and more attractive diesel car models have led to substantial changes in the use of petrol vs. diesel powered-cars. Annual mileage of a diesel car in Germany is on average nearly double that of a petrol-driven car. This might be a good reason for introducing the technical parameter of engine type to modeling the volume of passenger car travel. Analyzing the preference for diesel-powered cars, we observe that settlement structure and the gender of the car owner have significant influences. Drivers in rural areas who have to cover longer distances prefer diesel cars. Also male drivers favor diesel more than female car owners.

[35] See Goodwin 2004, Litman 2005.

[36] See Kuhfeld, Kunert (2005a).

Literature

BASt, Bundesanstalt für Straßenwesen (1996): Inländerfahrleistung 1993. Berichte der Bundesanstalt für Straßenwesen, Heft M 61, Bergisch–Gladbach.

BASt, Bundesanstalt für Straßenwesen (2005): Fahrleistungserhebung 2002. Berichte der Bundesanstalt für Straßenwesen, Heft V 120, Bergisch–Gladbach.

Dargay, Joyce (2004) The Effect of Prices and Income on Car Travel in the UK. Paper presented at the World Conference on Transport Research Istanbul, Turkey, July 2004.

Dargay, Joyce, Mark *Hanly*, Lauraent *Hivert*, Jean–Loup *Madre*, Bastian *Chlond* (2003) DEMOTORISATION SEEN THROUGH PANEL SURVEYS: A Comparison of France, Britain and Germany. Ppaper presented at the 10th International Conference on Travel Behaviour Research, Lucerne, August 2003.

Davidson, R., MacKinnon J.G. (1993): Estimation and Interference in Econometrics. Oxford University Press, Oxford.

ECMT/IEA (2005): Making cars more fuel efficient. Paris 2005.

Engelhardt, K., Follmer, R., Gilberg, R., Kloas, J., Kuhfeld, H., Kunert, U. and M. Smid (2003): METHODOLOGICAL ADVANCES IN NATIONAL TRAVEL SURVEYS: MOBILITY IN GERMANY 2002*,* paper presented at the 10th International Conference on Travel Behaviour Research, August 2003, Lucerne.

Giuliano, Genevieve, Joyce Dargay (2006): CAR OWNERSHIP, TRAVEL AND LAND USE: A COMPARISON OF THE US AND GREAT BRITAIN. Transportation Research Part A, Vol. 40, pp. 106–124.

Goodwin, Phil, Joyce Dargay and Mark Hanly (2004): Elasticities of Road Traffic and Fuel Consumption With Respect to Price and Income: A Review. Transport Reviews, Vol. 24, No. 3, May 2004, pp. 275–292.

Hendrickx, John (2002): Review of Regression Models for Categorical Dependent Variables Using Stata by Long and Freese. Stata Journal, 2002, vol. 2, issue 1, pages 103–105. http://econpapers.repec.org/software/bocbocode/s386402.htm

Kuhfeld Hartmut, Uwe Kunert (2005a): Fahrleistungen der Kraftfahrzeuge im Jahre 2004 so hoch wie nie. In: Wochenbericht 72 (2005), 37, pp. 529–540

Kuhfeld Hartmut, Uwe Kunert (2005b): Reform der PKW–Besteuerung überfällig: die Initiative der EU–Kommission zeigt den richtigen Weg. In: Wochenbericht 72 (2005), 49, pp. 745–757

Kuhfeld, Hartmut, Uwe Kunert (2002): Substantial Variation in the Tax Burden on Private Cars across Europe. In: Economic Bulletin 39 (2002), 12, S. 431–440

Lipps Oliver, Uwe Kunert (2005): Measuring and Explaining the Increase of Travel Distance: A Multilevel Analysis Using Repeated Cross Sectional Travel Surveys. DIW Berlin Discussion Papers 492, Berlin.

Litman, Todd (2005): Transportation Elasticities How Prices and Other Factors Affect Travel Behavior. Victoria Transport Policy Institute, 23 November, 2005

Schipper Lee*,* Céline *Marie–Lilliu,* Lew Fulton (2002): Diesels in Europe: Analysis of Characteristics, Usage Patterns, Energy Savings and CO2 Emission Implications. Journal of Transport Economics and Policy, Volume 36, Number 2, 2002, pp. 305–340.

Vance, Colin, Sabine *Buchheim* (2004): HOUSEHOLD DEMOGRAPHIC COMPOSITION, COMMUNITY DESIGN AND TRAVEL BEHAVIOR. An Analysis of Motor Vehicle Use in Germany. Paper prepared for presentation at the Research on Women's Issues in Transportation Conference, November 2004, Chicago.

Wooldridge, J. M. (2003): Introductory Econometrics: A Modern Approach 2e, Thompson South Western, Mason, Ohio.