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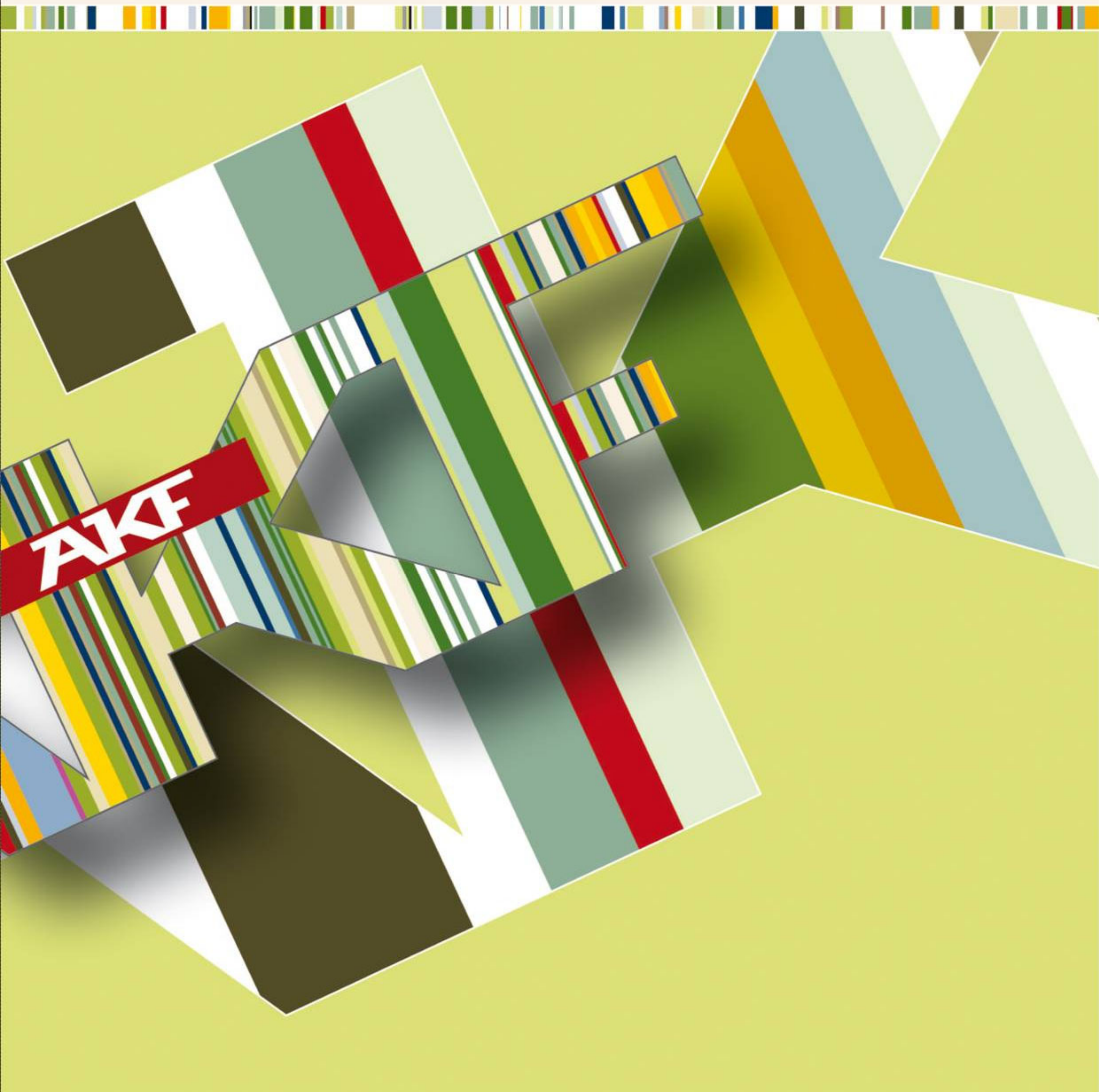
Fuel Costs and Consumers' Choice of Car



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Fuel Costs and Consumers' Choice of Car

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Abstract

Technological progress has led to the introduction of more fuel-efficient car variants, which in principle makes it possible to increase traffic levels without increasing energy use and greenhouse gas emissions. However, the potential for energy reduction offered by the technological improvements is not realised by the consumers when buying new cars. In this study we estimate a multinomial logit model for consumers' choice of a new car among 1,266 alternatives in order to calculate the impact of fuel prices on car choice and ultimately fuel efficiency. The model is estimated using a random sample of about 20 percent of new car sales to private consumers in Denmark from 1992 to 2001. As expected increases in fuel costs are found to increase the probability of choosing a more fuel-efficient car variant. However, the derived impact on average fuel efficiency appears to be modest. The derived elasticity of average fuel efficiency with respect to fuel price is -0.07. No significant effect of the Danish annual ownership tax on car choice is found.

Key words: Car choice, characteristics models, fuel efficiency, fuel price.

Contents

1 Introduction[1]

Using a very large, detailed and accurate dataset, a random sample of 20 percent of all new passenger car sales in Denmark during 1992-2001, this paper estimates the impact of fuel prices and annual ownership taxes on consumers' choice of which new car to buy and through this the impact on the average fuel efficiency of the new cars.

Road transport accounts for an increasing share of energy use and CO_2 emissions in most developed countries. In Denmark, 17 percent of energy use derived from road traffic in 1980; this share increased to 25 percent in 2006, while the energy use for road transport increased by 63 percent. With respect to private car transport, increased car ownership has contributed to the increase in energy use, while the annual distance driven per car has also increased. Thus, there is a large incentive to seek to reduce energy use and CO_2 emissions from passenger cars. Technological innovation has given consumers the possibility to choose more fuel-efficient cars, such as the dieseldriven Volkswagen LUPO, which was availble at the Danish market in 2000 (33 km/l). This has made it possible, in principle, to increase the overall car use without also increasing energy use for car traffic. However, the average fuel efficiency of new gasoline-driven cars in our sample has improved only some (from 13.80 km/l in 1992 to 14.10 km/l in 2001). The average fuel efficiency of the new diesel-driven cars improved more, especially in 2000 and 2001 (from 13.89 km/l in 1992 to 20.98 in 2001). In the period analysed the average fuel efficiency is about 75 percent of the fuel efficiency of the most efficient car variants sold in the period. This suggests that there is some scope for reducing energy use by policies that changes the composition of the car stock. So it is well motivated to look into the effect of fuel prices on the composition of new passenger car sales.

We are not the first to estimate a model for consumers' choice of new car. Previous studies have either been based on aggregate market shares of the different car types (e.g. Wojcik, 2000 and 2001; Berry, Levinsohn & Pakes, 1995) or micro-level data collected from surveys (e.g. Berkovec & Rust, 1985; Berkovec, 1985; de Jong, 1996; Brownstone & Train, 1999; Brownstone, Bunch & Train, 2000; Jordal-Jørgensen & Kristensen, 2003; Berry, Levinsohn & Pakes, 2004; Bento et al., 2005; Train & Winston, 2007). Brownstone & Train (1999) apply stated preference data, i.e. data from surveys where the respondents state their preferences for car characteristics. The rest of the micro-studies noted above apply revealed preference data, that is, information about households' car purchases or car holdings. Brownstone, Bunch & Train (2000) apply both revealed and stated preference data. This study uses a 20 percent random sample of all new passenger car sales to private households in Denmark during the period 1992 to 2001. In comparison with previous studies, we are thus able to achieve higher data quality, a larger number of observations, and we have no problems with non-response bias as there might be in surveys.

The micro-studies referenced above vary a lot with respect to how they cover the consumer population and the available set of cars in the market (the choice set). Berry, Levinsohn & Pakes (2004) use a large data set with information about 37,500 registered car purchases in the U.S. in 1993. This is a random sample conditional on the purchased cars. The choice set consists of 203 options between makes and models. An alternative is defined as the most sold option for the particular model (i.e. the combination of characteristics that was most commonly sold). Train & Winston (2007) have surveyed U.S. consumers who bought a car in year 2000. Their estimations are based on information about 458 car buyers and the choice set consists of 200 options between makes and models. The rest of the micro-studies apply less rich data. We analyse 131,214 car sales, with a choice set consisting of 1,266 differ-

[1] The research was supported by The Danish Social Science Research Council and AKF.

ent car alternatives. These alternatives arise from combinations of make/manufacturer, model and variant and cover 99 percent of all car purchases in the sample.[2]

Cars are heterogeneous goods and a number of characteristics are important for consumer choice in addition to the costs of ownership and use. These include size, performance, perceived quality, and safety. Our econometric model takes these characteristics into account using detailed data for the characteristics of 1,266 different car variants. Furthermore, the importance of such attributes is likely to depend on socioeconomic characteristics of the consumer like income level, family size etc. Our data link the characteristics of the new cars sold to household data from official registers and our econometric model incorporates a number of variables describing the households.

We analyse the impact of fuel prices on the composition of new car sales. Regulators may use fuel taxes to seek to influence the consumer choice of new cars towards more fuel efficiency. Regulators may also use a registration tax or an annual tax. Thus, the Danish annual car ownership tax was reformed in 1997 in order to induce car buyers to choose more fuel-efficient cars. With our dataset we may also be able to analyse the effect of this reform.

In section 2 we describe the applied model. In section 3 we introduce and describe the data used in estimation. Estimation results are presented and interpreted in section 4. Summary and conclusions are drawn in section 5.

[2] Note that not all variants were available in each year. In the estimated choice model, consumer chooses between the car variants available in the year he was buying a car.

2 Econometric Model

The studies referenced in the introduction and also the present employ a characteristics model (Lancaster, 1971; McFadden, 1974). In these models, products are viewed as bundles of characteristics, and consumers have preferences defined on this characteristics space. The choice of car is determined by the consumers' preferences for car characteristics. One of the motivations for characteristics models is that the number of different varieties or types of goods may be very large on differentiated product markets like the market for cars. If a traditional demand system (like the almost ideal demand system) were to be estimated, with a specified demand for each of the different types, this would result in a very large number of parameters to be estimated. By instead looking at the characteristics of the different types, the number of parameters to be estimated becomes considerably smaller (provided that the large number of different types can be described by a smaller vector of characteristics).

The choice of car type has mostly been estimated with a multinomial logit model, which is easy to estimate. However, this advantage is obtained at the cost of imposing a restrictive substitution pattern between the different alternatives (following directly from the so-called independence of irrelevant alternatives property – denoted IIA in the following). This property states that the odds ratio for choosing between two cars does not depend on the characteristics, or existence, of any other type in the choice set. More flexible substitution patterns may be achieved for example with a GEV model (e.g. Ben-Akiva & Lerman, 1985) or a mixed logit model (McFadden and Train, 2000). With 1,266 alternatives and 131,214 observations, we have decided against these more flexible models (computationally infeasible) and stayed with the multinomial logit model.

We shall briefly sketch the structure of the MNL model. In equation (1) u_{ij} is the utility consumer *i* obtains from choosing car type *j*. Let *j* = 1,2,....,*J* index the different car types competing in the market. The choice of car is conditional on the household choosing one of the *J* new cars. Thus, we do not model the outside good, which is not buying a new car. We discuss this issue more thoroughly below. Let *k* index the product characteristics observed in the data set, while *r* indexes the observed household attributes. The model is then given by:

$$u_{ij} = \sum_k x_{jk}\beta_{ik} + \xi_j + \varepsilon_{ij} \qquad (1)$$

with

$$\beta_{ik} = \gamma_k + \sum_r z_{ir}\gamma_{kr} \qquad (2)$$

where:

- x_{jk} and ξ_j are the observed and unobserved product characteristics, respectively,
- β_{ik} are the »tastes« of consumer for product characteristic *k*
- z_i is a vectors of observed consumer characteristics
- ε_{ij} is an i.i.d. extreme value disturbance term.

The alternative specific constants (ξ_j) are included to capture unmeasured aspects of the quality of the car. In the final empirical specification we allow ξ_j to vary with car make only, as opposed to car model or car variant, because we do not want the ξ_j's to capture explanatory power from the observed car characteristics. The taste parameters are assumed in equation (2) to be functions of observed consumer attributes z_i, where γ is the parameter vector for the household attributes. The household attributes are modelled as interaction terms with selected car characteristics. It is assumed that each household chooses the car type that yield the highest utility. The MNL model for consumer *i*'s choice of car is then:

$$P(Y_i = j) = \frac{e^{\sum_k x_{jk}\beta_{ik} + \xi_j}}{\sum_j e^{\sum_k x_{jk}\beta_{ik} + \xi_j}} \tag{3}$$

The observed vehicle characteristics (x_{jk}) include measures of price and costs, like the real price of buying a car, the annual ownership tax and the fuel cost for driving 1 kilometre. In our application these price variables change over time (subscript *t* is omitted for simplicity), because the price of fuel changes each year, while the real purchase »price« of a car depends not only on the nominal price that changes over a period of time, but also on general price inflation that changes from year to year. Also, the annual ownership tax changes over time, mainly due to the tax reform in 1997, which changed the structure of the annual taxation from a weight-based system to a green tax depending on the fuel efficiency of the car. Other vehicle characteristics include size, performance and safety characteristics of cars: Acceleration, weight, maximum cargo weight, number of doors, airbags, abs, transmission (automatic/manual), fuel type (diesel/petrol) and body type (sedan, hatchback etc.). Characteristics of the household include socioeconomic variables like family income, education, family size, children, age of family members etc.

The model in equation (3) is conditional on the household actually buying a new car. Thus, we are not controlling specifically for related choices. This is in line with Train & Winston (2007), who argue that the distribution of preferences among new car buyers is estimated more accurately by estimating it directly on a sample of new car buyers. Another approach is to aggregate all related choices to one alternative that is often denoted the outside good (See Berry, Levinsohn & Pakes, 2004). The weakness is that it is difficult to specify attributes that meaningfully characterise this alternative. Included in the outside good is both »not buying a car« and buying any type and »vintage« of used car. Thus, including an outside good may still produce biased estimates, because unobserved tastes that affect the households' assessments of new cars can also affect the households' assessments of other alternatives through the attributes of those alternatives.

Unlike most previous micro-level studies on car choice we have cross-section data for several consecutive years (1992 to 2001). For the estimation of our final model we pool the car purchases for the entire period into one big estimation sample. Not all car variants are available every year, this is reflected in the application of the model by restricting the choice set in different years. We exploit having cross-section data for a period of years to examine the stability of the estimated parameters over time by estimating separate models for single years.

Given a sample of households and a set of car alternatives, we may use the estimated model to compute predicted choice probabilities. From these we may compute the predicted average fuel efficiency of new cars. We do this and compare situations with and without a 10 percent increase in fuel prices (petrol and diesel).

3 Data

Data on the purchase of new passenger cars were extracted from the Central Register for Motor Vehicles (CRMV). We included only new cars sold to households and no company cars. The information in CRMV is considered very accurate as it is used to issue licence plates and to collect annual ownership taxes. From these data we obtain for each car sold, the make, model and variant as well as a code that allows us to identify the owner in the registers at Statistics Denmark where we obtain characteristics of the owner and his family. Information on the characteristics of the different car variants is from the Danish Automobile Dealers' Association (DAF), who maintains such a database.

We obtained a sample from CRMV including about 20 percent of all new vehicle sales from 1992-2001 (182,555 observations). We deleted a number of observations due to either missing values, if the vehicle is a van or a bus, if the owner of the car pays reduced annual car tax[3], if there are more than 10 persons in the household, if the car owner lives with his parents or is less than 18 years old or if the particular car variant is sold less than five times during the period 1992-2001. This leaves us with 131,214 observations in the final sample used for estimation.

The data from DAF are very detailed. Examples of cars are: Volkswagen Polo 1.6 and Mercedes-Benz E 300 D Turbo. For the first, »Volkswagen« is the make, »Polo« is the model and »1.6« is the variant. The definition of a variant in the DAF database is in some cases more detailed than the car variant code available in CRMV. This implies that for example the Volkswagen Polo 1.6 (1996) is registered in DAF as two variants, with and without automatic transmission, but in CRMV the variant code only informs us that the car is a Volkswagen Polo 1.6 with no information regarding automatic transmission. When the match between the CRMV and DAF is ambiguous, we defined the characteristics variables as an average of the characteristics from DAF of the relevant variants. In the example regarding Volkswagen Polo 1.6 the automatic transmission variable is defined as 0.5. The match between CRMV and DAF data improves during the estimated period.

Table 3.1 provides the definition of the car characteristics. All prices (*Price*, *P/km* and *Tax*) are deflated by the Danish consumer price index (1992 prices). The sales prices (*Price*) is the list prices registered by DAF. The sales price of a car variant may change from year to year. The dummy variable *Airbag* indicates whether or not the car has an airbag. Every car is characterised as hatchback, MPV, station car or sedan. Two dummy variables for hatchback and MPV/station car are used. *Tax* is the annual car tax paid by the owner. From 1992-1997 the tax was paid according to the weight of the car. In 1997 a reform changed the car tax system and from 1997 the tax was paid according to the fuel efficiency of the car. Owners of diesel cars are charged an extra tax, which is included in the variable: *Tax*. For a more detailed description of the annual car taxes from 1992 to 2001, see appendix A.

[3] In Danish: »Gulpladebiler«. The cars with reduced tax (annual as well as purchase tax) have restrictions in the way they can be used (only seats in the front row). Because of these restrictions we have excluded them from the analysis as they appeal to a special and limited share of the households.

Table 3.1 – Definition of car characteristics

Year	The year that the new car is purchased
Price	The sales price of the car in DKK
P/km	Cost in DKK per kilometre. Fuel price per litre (petrol octane 95 or diesel) / fuel efficiency (km/litre)
Tax	Annual car taxes in DKK
Acc	Acceleration (weight/horsepower)
Cap	Cargo-carrying capacity in kilos
Airbag	Airbag. Dummy variable (1=yes)
4-doors	More than 3.5 doors. Dummy variable (1=yes)
Weight	Car weight in kilos
Automatic	Automatic transmission. Dummy variable (1=yes)
Diesel	Diesel. Dummy variable (1=yes)
ABS	ABS. Dummy variable (1=yes)
Hatch	Hatchback. Dummy variable (1=yes)
MPV/st	MPV or station car. Dummy variable (1=yes)

Note: Price, P/km and tax are deflated by the Danish consumer price index (1992-prices). (One Euro equalled 7.45 DKK the 31.01.2001).

For illustration table 3.2 provides the characteristics of a number of car variants that are sold frequently or with special characteristics. The most frequently sold car (in a given year) is Toyota Carina 1.6 in 1994. Lada Samara 1.1 is an example of a cheap car variant, which was popular in 1994. As noticed earlier Volkswagen Polo 1.6 from 1996 is sold both with and without automatic transmission, which is why $Automatic = 0.50$.

Table 3.2 – Characteristics of selected car variants

Variant	Toyota Carina 1.6	Lada Samara 1.1	Volks-wagen Polo 1.6	Fiat Punto 60	Merce-des-Benz E 300 D Turbo	Ford Es-cort 1.6 St.	Volks-wagen Passat Limou-sine 1.9 TDI	Citroen Saxo 1.5 D
Year	1994	1994	1996	1996	1998	1998	2000	2000
Sales in year	859	109	511	517	44	247	29	67
Price	180,482	71,175	138,156	117,972	706,572	143,094	230,669	117,615
P/km	0.3778	0.3977	0,4670	0.3857	0.3627	0.4780	0.3246	0.3177
Tax	2,189	2,189	2,099	2,099	5,338	2,981	3,063	2,572
Acc.	9.3	16.5	12,3	13.8	8.3	12.8	12.5	16.2
Cap.	525	525	500	525	644	550	601	499
Airbag	1	0	1	1	1	1	1	1
4-doors	1	1	1	1	1	1	1	0
Weight	1,075	875	925	825	1,475	1,125	1,288	875
Automatic	0	0	0.50	0	1	0	0	0
Diesel	0	0	0	0	1	0	1	1
ABS	0	0	1	1	1	1	1	1
Hatch.	1	1	1	1	0	0	0	1
MPV/st.	0	0	0	0	0	1	0	0

In table 3.3 the mean car characteristics is presented. The cheapest car in the sample has a sales price of 64,999 (Lada 2105, 1992), whereas the most expensive car costs 1,004,617 (Mercedes-Benz S 350 D, 1994).[4]

[4] As noted we have only included variants that were sold at least five times in our sample, which includes 20 percent of vehicle sales in the period. Thus, there may have been more expensive car variants sold, which are not included in the estimation sample.

Table 3.3 – Car variant characteristics (131,214 observations)

	Mean	Std	Min	Max
Price	162,226	60,594	64,999	1,004,617
P/km	0.43	0.07	0.17	0.81
Tax	2,373	621	116	7,736
Acc.	11.95	1.90	5.79	20.63
Cap.	534	268	175	850
Airbag	0.88	0.32	0.00	1.00
4-doors	0.84	0.36	0.00	1.00
Weight	1045	157	650	2,000
Automatic	0.06	0.18	0.00	1.00
Diesel	0.05	0.22	0.00	1.00
ABS	0.79	0.41	0.00	1.00
Hatch.	0.60	0.49	0.00	1.00
MPV/st.	0.18	0.39	0.00	1.00

In table 3.4 the variation and development of the fuel efficiency is described. It appears that there is a wide range in the fuel efficiency of cars sold on the Danish market in the estimation period. Generally, fuel efficiency of the most efficient gasoline driven cars has been more than twice as high as the least efficient car variant. For diesel-driven cars the difference is even larger in the last years (due to the emergence of the Volkswagen Lupo). Looking over the whole period the average fuel efficiency is about 75 percent of the most fuel efficient car variants available.

Table 3.4 Fuel efficiency (km/l) of cars in estimation sample

		1992	1995	1997	1999	2001
Gasoline	Mean	13.80	13.92	13.11	13.66	14.10
	Max	17.90	17.10	18.11	20.00	18.9
	Min	8.80	7.80	8.00	8.70	8.80
Diesel	Mean	13.89	15.70	15.88	18.04	20.98
	Max	18.70	18.90	20.00	22.70	33.30
	Min	11.30	10.30	11.60	11.60	13.90

In 1992 there were 7,659 car sales in the estimation sample (table 3.5). Car sales increase in the following years, but car sales decrease in the last part of the period. A car variant is available in a specific number of years. For example Toyota Carina 1.6 is sold in the period 1993-1996 and Citroen Saxo 1.5 D in the period 1997-2001. In 1992 the households could choose among 207 car variants in the data set, and in 2001 430 car variants are available. In the period 1992-2001 1,266 car variants are present in the data. As shown in table 3.5 some of the »standard« car characteristics change during the time period. In 1992 30 percent of the cars in the sample had airbags. The number of new cars with airbags rapidly increased. In 2001 97 percent of the cars had airbags[5]. The number of new cars with ABS has increased as well. The mean sales prices are more or less constant from 1992-2001. The sales prices vary less than +/- 5 percent around 160,000 DKK. New technologies, more effective production and the composition of car variants affect the mean car prices. The petrol price has increased around

[5] Information on the *number* of airbags of the car variants is not available in all years. Therefore, we are forced to include a dummy variable for the presence of airbag(s).

25 percent from 1992 to 2001 in constant prices. This is the main reason why mean *P/km* increases from 1992 to 2001.

Table 3.5 – Mean car characteristics by year (131,214 observations)

	1992	1995	1997	1999	2001
Sales in year	7,659	15,017	17,142	15,287	8,026
Car variants available	207	355	488	538	430
Price	160,321	163,926	164,512	161,053	157,555
P/km	0.39	0.40	0.46	0.45	0.45
Tax	2,281	2,300	2,338	2,454	2,341
Acc.	11.77	12.07	11.81	12.12	11.77
Cap.	532	533	538	530	533
Airbag	0.30	0.91	0.97	0.98	0.97
4-doors	0.83	0.87	0.82	0.86	0.87
Weight	964	1,015	1,055	1,084	1,112
Automatic	0.05	0.05	0.07	0.04	0.06
Diesel	0.01	0.03	0.02	0.10	0.18
ABS	0.42	0.70	0.92	0.95	0.98
Hatch.	0.72	0.68	0.57	0.51	0.53
MPV/st.	0.10	0.10	0.17	0.30	0.34

Some socioeconomic characteristics of the car purchasing households are shown in table 3.6. The mean income of the households[6] is 303,575 DKK (measured in 1992-price level). This is almost twice as much as the mean car price. 25 percent of the households earn more than 345,000 DKK per year. Besides income the households demographics includes information regarding small children (0-6 years old), long commuting distance, and if the buyer of a car is male or female. CRMV registers the buyer of a car. There is no information regarding who actually uses the car.

Table 3.6 – Household demographics (131,214 observations)

	Mean	Std	Min	Max
Income (in DKK)	303,575	190,330	12	9,927,107
Income top quartile (>345,000 DKK)	0.25	0.43	0	1
Buyer is female	0.27	0.44	0	1
Household with small children (0-6 years old)	0.18	0.38	0	1
Long commute (>50 km per day per adult)	0.04	0.20	0	1

[6] A household is defined of one or two persons living together at the same address and such as no change in partner is registered of the households in the period 1992-2001. Two people who live together are a household if they are married, have shared children, or the age difference of a man and a woman is less than 15 years. For example, two people getting married and moving together in 1997 were considered two single households before 1997 and a new household from 1997-2001 (or until they separate).

Table 3.7 provides the mean household demographics of the households in the sample. The income (1992 prices) of the households is slightly decreasing from 1992-1997, but slightly increasing from 1997-2001. This is the opposite development of the mean car price, which increased from 1992-1997 and decreased from 1997-2001. However, the mean income of households varies very little (+/- 3 percent).

In 1992 less than 20 percent of the buyers were female. This has increased substantially in 2001 to about 30 percent. In Denmark, the average commuting distances have increased during the period. This is reflected in the increase in the share of households were the daily commute (one way) is longer than 50 km. In 2001 5.4 percent of the sales were households with long commuting distances.

Table 3.7 – Mean household demographics

	1992	1995	1997	1999	2001
Income (in DKK)	305,206	305,086	300,825	305,102	309,696
Income top quartile (>345,000 DKK)	0.2264	0.2375	0.2355	0.2696	0.2676
Buyer is female	0.1885	0.2558	0.2696	0.2992	0.3020
Household with small children (0-6 years old)	0.1430	0.1757	0.1880	0.1960	0.1686
Long commuting (>50 km per day per adult)	0.0333	0.0376	0.0374	0.0441	0.0536

4 Results

We first present estimation results without inclusion of socioeconomic characteristics. Subsequently, socioeconomic characteristics are included as interaction terms with selected car characteristics. Estimation results without inclusion of socioeconomic characteristics are presented in table 4.1 based on the full sample. In addition to the characteristics shown in table 4.1, the model also includes make dummies (Opel, Toyota, Ford, etc.) to capture unobserved perceived quality levels of different car brands. By and large these producer dummies have the expected relative levels, e.g., the highest dummy is for Mercedes, while the lowest value is found for Lada.

Table 4.1 – Estimation results for 1992 to 2001 without household characteristics

	Coefficient	Std. Error		MWTP
LOG PRICE	-4,2602	0,0395	**	-
P/KM	-8,3388	0,1290	**	-317537
TAX (KR/YEAR)	0,00004	0,00001	**	1,56
ACC (SEC 0-100 KM/H)	-0,1421	0,0021	**	-5413
CAP (KG.)	0,0014	0,0001	**	52
AIRBAG	0,4396	0,0110	**	16738
4 DOORS	0,7329	0,0095	**	27908
WEIGHT (KG)	0,0054	0,0001	**	205
AUTOMATIC	-0,2587	0,0153	**	-9851
DIESEL	-1,8822	0,0310	**	-71674
ABS	0,0708	0,0089	**	2696
HATCHBACK	0,1638	0,0085	**	6238
MPV/STC	-0,1373	0,0094	**	-5229
Nobs	131214			
Number of alternatives	1266			
Log likelihood	-749019			

Note: Significance levels: 1 percent = **, 5 percent =*
Marginal WTP calculated at the mean value of price (MWTP not constant due to the logarithmic transformation of car price applied in the model)

In the model three different types of costs are included: car purchase costs, fuel costs (variable) and yearly taxes (fixed annual tax). Fuel cost depends on fuel efficiency as well as the fuel price. Thus, the fuel costs of a given car variant may change over time subject to changes in fuel prices, even though fuel consumption per kilometre is constant for the car variant.[7]

[7] We expect that the coefficient on fuel cost is identified mainly by the variation in the fuel efficiency of the different car types. However, it seems reasonable to assume that households use information on fuel costs per km (instead of only information on fuel efficiency) when choosing between car alternatives. This specification implies that fuel efficiency becomes more important in years where fuel prices are high. The choice of fuel costs pr. km, also allows us to simulate the impact of changes in fuel prices/taxes on the predicted average fuel efficiency of new cars.

The car price is measured in logarithms, while the other costs, fuel price per kilometre and the annual taxes, are measured in levels. This combination yielded the best likelihood value compared to alternatives with and without taking logarithms. As expected, parameters for car price and fuel costs are negative. However, the coefficient on the annual car tax is unexpectedly positive, we will return to a discussion of this finding later in this section. The parameters for the remaining characteristics all have the expected sign. Thus, slower acceleration (measured as seconds to reach 100 km/h) reduces utility, more cargo capacity increases the utility of the car, cars with airbags are preferred, cars with more than three doors have higher utility compared to cars with few doors and larger cars (measured by their weight) are preferred. Further, cars with ABS brakes have higher utility and hatchbacks are preferred to sedans (base case). Characteristics like diesel fuel and automatic transmission have a negative impact on the utility. Diesel cars and cars with automatic transmission were not sold very frequently during the period under consideration (only about 6 percent of the cars in the estimation sample had automatic transmission and the share of diesel-driven cars was even smaller). Finally, more spacious cars like station cars and MPV's have lower utility for the average car buyer, ceteris paribus, than sedans.

A measure of the marginal willingness to pay (MWTP) for the different characteristics has been calculated by dividing the coefficient on the respective characteristics by the marginal utility of money. The latter we take to be the negative of the marginal effect of price in the utility function (equation 1). As we use a logarithmic transformation of car prices the marginal value is not constant, but depends on the level of the car price.[8] Here, the marginal value is calculated for the average car price.

Focusing first on the non-cost characteristics, the MWTP does generally seem reasonable. To give some examples, the MWTP for a car with more than three doors rather than three doors or less is 29,000 DKK. The MWTP for airbag(s) is 17,332 DKK. However, the negative marginal utility for diesel cars (as compared to gasoline) does seem unrealistically high. Turning to the two characteristics which involve future expenditures for the car buyer (fuel costs and annual tax), the first appears very reasonable, while the second (annual tax) has the wrong sign. The MWTP of fuel costs suggests that car buyers are willing to pay 31,754 DKK more for a car that uses 0.10 DKK less in fuel costs per kilometre. Another way to interpret the MWTP is that there is »break-even« if the car drives 317,537 kilometres in its lifetime. This corresponds well with the actual number of kilometres that cars in Denmark drove in their lifetime in the period in question. It can of course be argued that the MWTP is too low (numerically) as the reduction in future fuel expenditures should be discounted, but by and large the relative size of the parameter on fuel costs and car price seems very reasonable.

Finally, it is worth noting that a measure of resale value was included in preliminary estimations. In models without inclusion of car-brand dummies the expected positive coefficient on resale value was obtained. However, when car-brand dummies were included a negative coefficient on resale value was obtained. This probably reflects that the resale values are highly correlated with brand dummies (which also capture unobserved car quality of different car makes).

Table 4.2 shows the estimation results when a number of household characteristics are included as interaction terms with relevant car characteristics. Estimation results are shown both for the full sample and for purchase observations from 1995 and 1999, which is two years before and after the reform of the annual ownership tax. To explore income effects, interaction terms are included on all cost variables for households within the top quartile of the

[8] The marginal value is given as the parameter on the logarithmic transformed variable divided by the level of the variable (without logarithmic transformation).

household income distribution. Focusing first on results from the full sample, it appears that the price of cars is less important for the car choice for high-income households as the interaction term is positive (for high-income households the two parameters on income should be added). This reflects that the marginal utility of money is lower for high-income households.

Table 4.2 – Estimation results with socioeconomic interaction effects

	Sample 1992-2001			1995			1999		
	Coefficient	Std. Error		Coefficient	Std. Error		Coefficient	Std. Error	
LOG PRICE	-4,932	0,041	**	-3,714	0,145	**	-3,079	0,146	**
+ LOG (PRICE) x D(income top quartile)	1,867	0,032	**	0,921	0,118	**	2,134	0,097	**
P/KM	-8,119	0,133	**	-8,686	0,464	**	6,817	0,866	**
+ P/KM x D(income top quartile)	-0,073	0,109		3,234	0,501	**	-0,397	0,252	
TAX (KR/YEAR)	0,00002	0,00001		0,00007	0,00005		-0,00095	0,00007	**
+ TAX x D(income top quartile)	-0,00002	0,00002		0,00037	0,00007	**	-0,00007	0,00004	
ACC (SEC 0-100 KM/H)	-0,151	0,002	**	-0,129	0,006	**	-0,063	0,007	**
CAP (KG.)	0,001	0,000	**	0,004	0,000	**	0,000	0,000	
AIRBAG	0,450	0,011	**	0,629	0,038	**	-0,010	0,072	
4 DOORS	0,767	0,009	**	0,769	0,030	**	0,774	0,030	**
WEIGHT (KG)	0,006	0,000	**	0,004	0,000	**	0,004	0,000	**
+ WEIGHT x D(female)	-0,003	0,000	**	-0,003	0,000	**	-0,003	0,000	**
AUTOMATIC	-0,267	0,015	**	-0,598	0,064	**	-0,345	0,060	**
DIESEL	-1,909	0,031	**	-2,070	0,095	**	1,518	0,208	**
+ DIESEL x D(long commuting)	1,221	0,042	**	1,123	0,184	**	1,403	0,093	**
ABS	0,090	0,009	**	-0,035	0,026		0,756	0,048	**
HATCHBACK	0,188	0,009	**	0,070	0,029	*	0,039	0,029	
+ HATCBACK x D(small children)	-0,205	0,019	**	-0,289	0,049	**	-0,088	0,064	
MPV/STC	-0,439	0,011	**	-0,887	0,042	**	-0,331	0,030	**
+ MPV/STC x D(small children)	1,215	0,020	**	1,333	0,066	**	1,281	0,062	**
Nobs	131214			14793			14917		
Number of alternatives	1266			255			378		
log likelihood	-739934			-76397			-84364,44		

Note: Significance levels: 1 percent = **, 5 percent =*
Marginal effects evaluated at mean value of price.

There are no significant difference between »normal« income households and high-income households with respect to the impact of fuel costs. With respect to the annual car tax both coefficients are insignificant.

With respect to other characteristics it appears that women care less about size (weight of car) than men. Households with long commuting distances are more favourable towards diesel cars, which generally have lower fuel costs. However, the utility of a diesel car is still negative even for the long commuters (the two coefficients should be added). Finally, households with small children do not prefer hatchbacks to sedans in the same way as other households, but households with small children have positive utility for more spacious cars like MPVs or station cars (other households have negative utility).

We have tested a number of other specifications. For instance, we divided the car buyers into blue collar and white collar workers and we replaced the income interaction terms with interaction variables for white collar workers. Qualitatively the results were similar to the results shown in Table 4.2 with the income interactions included. The model with the income interaction terms has the best likelihood value. We have also tested a specification where age was interacted with a dummy for automatic transmission; however, the estimated parameter proved in'significant.

Table 4.2 also shows estimates for the 1995 and 1999 samples.[9] The parameter estimates and the derived MWTP estimates from these estimations are useful for evaluating the stability of the model over time.[10] Estimations based on these years also yield the expected negative coefficient on price (measured in logarithm), and again it is found that the impact of price is less important for high-income households. Most of the non-monetary attributes have constant signs in all three estimations (at least when the coefficient is statistically significant).

However, the two attributes representing future expenditures – fuel costs and annual tax – do not appear very stable over time. In 1995 fuel costs have the expected negative sign, while the annual tax has the unexpected positive sign (insignificant for »normal« income households, but significant for high-income households). In 1999 this picture is reversed. Here, the coefficient on fuel costs has the wrong (positive) sign, while the expected negative coefficient on tax is found. The instability of these parameters may be related to the tax reform in 1997. Before 1997 the annual tax depended on the weight class of the car (see section 4 and appendix A). Therefore, the annual tax (which should have a negative impact on utility) is positively correlated with the size (weight) of the car (which can be expected to have a positive effect on utility). This makes it difficult to separate the effect of size and the annual tax before 1997. After 1997, the annual tax depends on the fuel efficiency category of the car, which yields high correlation between the annual tax and the fuel costs. Calculations of MWTP based on the parameters from table 4.2 appear to confirm this. The MWTP is reported in table 4.3. As the marginal utility of money depends on income levels (divided between » normal« income and top income quartile), MWTP is calculated for the two income levels. In 1999, where the coefficient on fuel costs has the wrong sign, the MWTP of the annual tax becomes unrealistically high. For example a high-income household would be willing to pay 193 DKK more for a car variant that has a 1 DKK lower annual tax. This is clearly too high as a car

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[9] Note that when carrying out estimations based on observations in 1995 and 1999 respectively, the samples were slightly reduced. Car variants sold less than five times *within* the given year were excluded. This yielded a 2 percent reduction in number of observations in 1995 and 1999 (compare table 3.4 and 4.2)

[10] As the variance of the error term may not be the same in the models estimated on different samples the scale of the estimates is not necessarily comparable. However, the derived MWTP can be compared directly.

can only be expected to last about 15 years. It also appears that high income men's MWTP for a bigger car (weight) is considerably lower in 1995 as compared to 1999. In 1995 a wrong sign was also obtained to the coefficients on the annual tax. As the annual tax was based on weight classes in 1995 and fuel efficiency classes in 1999 this suggests that the correlation between annual tax and weight yields a downwards bias to the coefficient on weight in 1995 and also yields the wrong sign on the coefficient on the annual tax. Thus, it appears that multicolinarity are causing problems when looking at separate years and that the most plausible results are obtained using data for several years before and after the tax reform.

Table 4.3 – Marginal willingness to pay

	1992 to 2001		1995		1999	
	Normal income	Income top quartile	Normal income	Income top quartile	Normal income	Income top quartile
Fuel efficiency (P/KM)	-255363	-491486	-366388	-354021	336179	1218026
Annual tax	0,5	-0,1	3,0	28,7	-46,8	-192,6
ACC (SEC 0-100 KM/H)	-4738	-9038	-5439	-8373	-3108	-11958
CAP (KG.)	44	84	162	249	-19	-74
AIRBAG	14146	26982	26547	40868	-470	-1808
4 DOORS	24117	46004	32438	49936	38178	146879
WEIGHT KG (MEN)	198	378	154	237	204	785
WEIGHT KG (FEMALE)	112	214	25	38	59	228
ABS	2836	5410	-1474	-2269	37257	143333
HATCHBACK (no small children)	5923	11297	2947	4537	1938	7456
HATCBACK(small children)	-538	-1026	-9235	-14216	-2414	-9288
MPV/ST.CAR (no small children)	-13816	-26355	-37423	-57609	-16299	-62704
MPV/ST.CAR(small children)	24394	46532	18791	28927	46887	180382

Note: Selected MWTP based on estimation results of table 4.2. Marginal willingness to pay evaluated at mean levels of price.
Marginal effects evaluated at mean value of price
»Normal« income denotes income below the top quartile of the income distribution

Despite these correlation problems it appears that the MWTP on fuel cost of the model estimated on the whole sample has a very reasonable size. As noted earlier, the MWTP may here be interpreted as the number of kilometres the car is expected to drive in its lifetime. Expected kilometres between 255,363 (normal income) and 491,486 (income in top quartile) appear very reasonable. This corresponds well with the actual car market, as more expensive cars (purchased by the high-income households) usually last longer and are used for a longer period of time.

With respect to the annual tax neither model appeared to give realistic MWTP. In addition, to the correlation problems described above it is also worth noting that the annual car tax only accounts for a share of total annual fixed costs. Insurance costs are generally more important and these unobserved costs depend on car variant (repair costs etc.). Some of the repair costs may also be perceived as fixed costs by the car owners.

The estimated coefficients and MWTPs may be compared to similar studies in Brownstone & Train (1999); Jordal-Jørgensen & Kristensen (2003); Berry, Levinsohn & Pakes (2004) and Train & Winston (2007). Our empirical model does not correspond entirely to the specifications in any of these studies. However, many parameters and MWTPs are similar. Train & Winston (2007) estimate a consumer level choice model, where car choice is a function of purchase price, fuel economy (km per litre), horsepower, reliability, transmission type, weight and other physical car size characteristics as well as a few socioeconomic variables – in particular income. They present estimated parameters that are qualitatively similar with respect to purchase price, acceleration, fuel consumption and physical size variables. They find that the average car buyer is more likely to buy a car if it has automatic transmission. This suggests that the American consumers in Train and Winston’s survey have different preferences for transmission type than Danish consumers. The car buyer’s income is included in the model by dividing the purchasing price with income. As expected the estimated parameter is negative. Berry, Levinsohn & Pakes (2004) estimate a consumer level choice model, where car choice is decided by purchase price, acceleration, horsepower, safety equipment, passengers and other physical car size variables as well as socioeconomic variables: income, age, family size, number of adults and children’s age. The estimated parameters are qualitatively similar to our results. In particular, they find that the top quartile of the income distribution have a lower marginal utility of money and thus their MWTP is higher. This corresponds with our results. Jordal-Jørgensen & Kristensen (2003) also estimate consumer-choice models for car characteristics with estimated parameters that are qualitatively similar to ours.

4.1 Simulating the effect of an increase in fuel prices

We use the estimated parameters and the data on the 131,214 car purchases to simulate the effect of a 10 percent increase in the fuel cost per kilometre. This corresponds to a 10 percent increase in the consumer price of petrol and diesel. We calculate the average fuel efficiency (kilometres per litre fuel) of the predicted fleet of new cars before and after the tax increase. The simulation is based using the whole estimation sample and using the parameters presented in table 4.2 (full sample with socioeconomic interaction effects). The predicted average fuel efficiency of new cars is 13.94 kilometres per litre fuel. After the fuel tax increase the corresponding figure is 13.84 kilometres per litre. This corresponds to an increase in the predicted fuel average efficiency of 0.7 percent. This implies that the elasticity of the average fuel efficiency with respect to the fuel price is modest (-0.07 percent). To comment on the inelastic response on fuel price changes: First fuel costs account for a little share of the total costs for using a car. The largest cost element is depreciation. New cars in Denmark are very expensive, because of high sales taxes. If car purchasing prices were relatively lower, the fuel price response may have been more elastic. Second, the change in the fuel efficiency of purchased new cars is only part of the response to a fuel tax increase. Households would also be expected to adjust the average amount of driven kilometres.

5 Conclusion

Based on a sample of 20 percent of new car sales to private households in Denmark for the period 1992 to 2001 we have estimated multinomial logit models for choice of car variant. In the models we have included different cost components of the different car variants (car price, annual ownership tax and fuel costs) along with a number of car characteristics like weight, performance, car body type and safety characteristics (airbag and ABS brakes). Socioeconomic household characteristics of the car buyers were included in order to investigate preference heterogeneity and to improve the estimated model. Data are obtained from a combination of official registers, which are considered very reliable. In addition, the data do not suffer from (none response) selection problems which potentially could have caused biased estimates in most previous car choice studies.

It appeared that the price of cars was less important for the car choice for high-income households as compared to other households. An interpretation of this is that the marginal utility of money is lower for high-income households. In the estimated model this yields higher marginal willingness to pay for the included car characteristics. With respect to other car characteristics it appeared that women cared less about car size than men and that households with small children had higher willingness to pay for roomier body types like station cars and MPV (households without small children had negative utility for these body types).

Comparisons of estimation carried out for a pooled sample of observations for all years and samples for selected separate years showed that the sign of the estimated parameters was generally constant except for the annual tax. Especially, it appeared that the relative size of the parameters on fuel costs and on car price was very reasonable in most of the estimations. The derived expected kilometres the cars drive during their lifetime ranges between 255 to 491 thousand kilometres (depending on the income level of the household).

The average fuel efficiency of the new cars sold has been about 75 percent of the highest if car buyers had always chosen the most fuel efficient gasoline or diesel car variant. Thus, potentially there is a huge scope for reducing energy use and CO_2 emissions without reducing car traffic. Based on the model we have calculated the impact of an increase in fuel price on the chosen car and ultimately the average fuel efficiency of the chosen cars. Here we find an elasticity of the fuel efficiency of the average new car with respect to fuel costs at about -0.07. This suggests that changes in fuel prices only have limited impact on fuel efficiency of the car fleet – at least when comparing with the technically most fuel efficient car variants available to consumers.

It should be emphasized that the elasticity of the fuel efficiency with respect to the fuel costs at -0.07 is not the full effect on energy use of an increase in the fuel price. Higher fuel prices will reduce the number of cars, reduce the average distance driven and shift the mileage towards more fuel efficient cars.

With respect to the impact of the annual ownership tax (and the effect of the reform of the annual tax in 1997) it turned out difficult to determine the effect. Estimations carried out in separate years (as opposed to estimations from the whole sample period) suggested that this was caused by correlation between the ownership tax and other attributes like car weight and fuel efficiency. An additional explanation for the missing identification may be that the annual tax only accounts for a share of annual ownership costs (and the other annual costs could not be observed and included in the model).

Appendix A – Annual Car Tax

Owners of cars pay an annual car tax according to the date of the purchase. If the car uses diesel fuel the annual car tax charged extra. Before 30th of January 1997 owners of new cars paid an annual car tax according to the weight of the car. From the 2nd of July 1997 owners who purchase a new car have to pay an annual tax according to the kilometres per litre of the car. If a new car was purchased from 1st of February and 1st of July 1997 the owner may choose to pay the annual car tax according to either the weight of the new car or the kilometres per litre of the new car. When calculating the annual tax during this period it is assumed that the owner chose the cheapest tax scheme. The annual car tax rates are presented in tables A.1-3. The taxes are presented in current prices here (when estimating the model all prices are measured in 1992 price levels).

Table A.1 Annual car tax (DKK), petrol (in Danish: »Grøn ejerafgift«)

Fuel efficiency				1997	1998	1999	2000	2001
(kilometre per litre)			>=20.0	400	420	440	460	500
>=	18.2	<	20.0	800	840	880	920	980
>=	16.7	<	18.2	1200	1260	1320	1380	1460
>=	15.4	<	16.7	1600	1680	1750	1840	1940
>=	14.3	<	15.4	2000	2100	2190	2300	2420
>=	13.3	<	14.3	2400	2520	2630	2760	2900
>=	12.5	<	13.3	2800	2920	3060	3200	3360
>=	11.8	<	12.5	3200	3340	3490	3660	3840
>=	11.1	<	11.8	3600	3760	3930	4120	4320
>=	10.5	<	11.1	4000	4180	4370	4580	4800
>=	10.0	<	10.5	4400	4600	4810	5040	5280
>=	9.1	<	10.0	5200	5420	5660	5940	6220
>=	8.3	<	9.1	6000	6260	6540	6860	7200
>=	7.7	<	8.3	6800	7100	7410	7780	8160
>=	7.1	<	7.7	7600	7920	8270	8680	9100
>=	6.7	<	7.1	8400	8760	9150	9600	10060
>=	6.3	<	6.7	9200	9600	10020	10520	11020
>=	5.9	<	6.3	10000	10420	10880	11420	11960
>=	5.6	<	5.9	10800	11260	11750	12340	12920
>=	5.3	<	5.6	11600	12100	12630	13260	13900
>=	5.0	<	5.3	12400	12940	13500	14180	14860
>=	4.8	<	5.0	13200	13760	14370	15080	15800
>=	4.5	<	4.8	14000	14600	15240	16000	16760
		<	4.5	14800	15440	16110	16920	17720

Table A.2 Annual car tax (DKK), diesel (in Danish: »Grøn ejerafgift & udligningsafgift«)

Fuel efficiency				1997	1998	1999	2000	2001
(kilometre per litre)			>=32.1	1580	1660	1840	140	140
>=	28.1	<	32.1	1580	1660	1840	700	720
>=	25.0	<	28.1	1580	1660	1840	1280	1300
>=	22.5	<	25.0	1580	1660	1840	1860	1920
>=	20.5	<	22.5	2100	2200	2420	2460	2530
>=	18.8	<	20.5	2600	2720	2970	3040	3140
>=	17.3	<	18.8	3120	3260	3550	3620	3750
>=	16.1	<	17.3	3640	3800	4120	4220	4370
>=	15.0	<	16.1	4160	4340	4700	4820	4990
>=	14.1	<	15.0	4680	4880	5280	5420	5610
>=	13.2	<	14.1	5200	5420	5850	6020	6220
>=	12.5	<	13.2	5720	5980	6440	6620	6860
>=	11.9	<	12.5	6240	6520	7020	7220	7480
>=	11.3	<	11.9	6740	7040	7570	7800	8080
>=	10.2	<	11.3	7780	8120	8710	9000	9320
>=	9.4	<	10.2	8820	9200	9870	10180	10570
>=	8.7	<	9.4	9860	10280	11010	11380	11800
>=	8.1	<	8.7	10900	11360	12170	12580	13050
>=	7.5	<	8.1	11900	12400	13280	13720	14230
>=	7.0	<	7.5	12920	13480	14420	14900	15460
>=	6.6	<	7.0	13980	14580	15580	16120	16720
>=	6.2	<	6.6	15000	15640	16720	17300	17930
>=	5.9	<	6.2	16020	16700	17840	18460	19170
>=	5.6	<	5.9	17100	17820	19040	19700	20450
>=	5.4	<	5.6	18100	18880	20160	20860	21660
>=	5.1	<	5.4	19220	20040	21400	22160	22990
		<	5.1	20260	21120	22540	23340	24220

Table A.3 Annual car tax, diesel (in Danish: »Grøn ejerafgift & udligningsafgift«)

Petrol	1992	1993	1994	1995	1996	1997
I. Car weight up to 600 kg	1356.00	1356.00	1356.00	1356.00	1356.00	1356.00
II. Car weight 601-800 kg	1657.20	1657.20	1657.20	1657.20	1657.20	1657.20
III. Car weight 801-1,100 kg	2260.00	2260.00	2260.00	2260.00	2260.00	2260.00
IV. Car weight 1,101-1,300 kg	3013.20	3013.20	3013.20	3013.20	3013.20	3013.20
V. Car weight 1,301-1,500 kg	3917.20	3917.20	3917.20	3917.20	3917.20	3917.20
VI. Car weight 1,501-2,000 kg	5423.80	5423.80	5423.80	5423.80	5423.80	5423.80
VII. Car weight above 2,000 kg – tax per 100 kg	301.40	301.40	301.40	301.40	301.40	301.40

Diesel	1992	1993	1994	1995	1996	1997
I. Car weight up to 600 kg	1649.10	1607.00	1607.00	1607.00	2080.00	2080.00
II. Car weight 601-800 kg	2015.60	1964.20	1964.20	1964.20	2541.20	2541.20
III. Car weight 801-1,100 kg	2748.90	2679.00	2679.00	2679.00	3472.00	3472.00
IV. Car weight 1,101-1,300 kg	3665.05	3571.70	3571.70	3571.70	4625.20	4625.20
V. Car weight 1,301-1,500 kg	4764.60	4643.20	4643.20	4643.20	6013.20	6013.20
VI. Car weight 1,501-2,000 kg	6596.90	6428.80	6428.80	6428.80	8327.80	8327.80
VII. Car weight above 2,000 kg – tax per 100 kg	366.10	356.40	356.40	356.40	457.40	457.40

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