Greening the Dutch car fleet: the role of differentiated sales taxes

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Abstract

In the Netherlands a number of taxes target car purchase, car ownership and car use. Since 2006 the car taxes became increasingly dependent on the CO_2-emission of the car, culminating in the introduction of a progressive tax system for the vehicle sales tax (VST) in 2010. The VST was made (progressively) dependent on the CO_2-emission level of the car. As a consequence small fuel-efficient cars became cheaper and the price of most gas guzzlers increased. At the same time vehicles became more fuel efficient and the annual road tax for the most fuel efficient cars was eventually abolished.
Using a discrete choice model we analyze to what extent changes in purchase price and operating costs may explain changes in vehicle type choice behavior. Furthermore, we analyze to what extent the vehicle tax reform in the VST can explain the observed changes in purchasing behavior. The model allows us to simulate and illustrate the effect of certain price changes on the probability of purchasing a type of vehicle. We used car attributes in combination with household characteristics as explanatory variables. The data we used consists of respondents with privately owned cars selected from a Dutch automotive internet panel maintained by the market research firm TNS-NIPO. The sample is choice based for which we corrected in the estimation of the model. The differentiation of the sales tax seems to be rather effective. According to the model simulation the share of small petrol and small diesel cars increased relatively by 27% and 22% respectively. We show that substantial differentiated fuel price increases are needed to obtain similar results.

JEL-codes: C35; C51; H31; Q54; R48
Key words: Vehicle type choice; Choice based sample; Multinomial logit model; Car taxation; Greenhouse gas emissions

1. Introduction

Taxes can be used to reduce the emission of greenhouse gases by cars by influencing car use and/or car ownership. In the last decade, European countries launched policy initiatives to reduce vehicle emissions like carbon dioxide (CO_2). A range of fiscal measures in the form of vehicle and fuel taxes are applied, which affect consumer behavior with respect to car purchase and usage. The implemented taxes together with the tax rates vary significantly across the countries (Kunert and Kuhfeld, 2007; Nijland et al., 2012).
In the Netherlands a number of taxes target car purchases, car ownership and car use, for example an excise tax on fuel targets car use while a VST and an annual road tax (ART) target car purchases and car ownership, respectively[1]. The Netherlands started

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using the VST and the ART as CO_2 related policy instruments in 2006. This resulted in a feebate system for the VST between 2006 and 2008. Depending on the energy label of the car the amount of the one-off payment, i.e. the feebate, varied. Furthermore, policy instruments, such as a surcharge for very fuel inefficient cars (Dutch: 'slurptax'), CO_2 based tax exemptions, and company car tax rebates were introduced as well. Starting in 2010, the net list price as a base for the VST was slowly phased out and replaced by the 'absolute' CO_2 emission of the car, as measured during the European type-approval (i.e. the New European Driving Cycle (NEDC) used for emission measurement). The VST for new cars became dependent on the absolute CO_2 emission level of the car with a tax rate that increases with the emission level. As a consequence fuel-efficient cars became cheaper and the price of most gas guzzlers increased. Table 1 gives for selected before-tax prices (net list price), the value and the rate of the VST in the Netherlands for 2005 and 2010.

Table 1: Vehicle sales tax for 2005 and 2010

Vehicle characteristics		2005			2010		
fuel type	CO_2 emission (gr/km)	net list price (euro)	VST	VST rate	net list price (euro)*	VST	VST rate
gasoline	90	10000	2980	30%	10800	0	0%
gasoline	150	15000	5240	35%	16200	4511	28%
gasoline	200	20000	7500	38%	21600	9530	44%
gasoline	250	20000	7500	38%	21600	15830	73%
gasoline	300	25000	9760	39%	27000	28470	105%
Diesel	90	10000	4848	48%	10800	0	0%
Diesel	150	15000	7108	47%	16200	7385	46%
Diesel	200	20000	9368	47%	21600	14704	68%
Diesel	250	20000	9368	47%	21600	23920	111%
Diesel	300	25000	11628	47%	27000	39800	147%

* inflation adjusted prices (2005=100)

From Table 1 it is clear that the sales tax is rather high and forms a major share of the net list price in the Netherlands.[2] After the tax reform the VST decreased for low-emission fuel efficient cars and increased substantially for less fuel efficient cars.[3] Also the flat tax rate became progressive after the reform: the higher the emission level the higher the VST rate.

The change in the VST coincided with an exemption from the annual road tax for highly fuel efficient cars; the annual road tax is a tax on car ownership and is differentiated by fuel type and weight. The combination of tax incentives was intended to stimulate the purchase of low CO_2 emission (small) cars and to discourage the purchase of high CO_2 emission (big) cars. During the tax reform new car models were introduced. Also existing car models were modified (for instance by adding a start-stop system) to

[1] In the literature, the vehicles sales tax is also known as vehicle registration tax or vehicle purchase tax.

[2] Actually the tax burden on cars is even higher since the value-added tax (VAT) levied on the net list price is not included in Table 1. However, in this study we are only interested in the share of the VST. Besides, the VAT didn't change in this period.

[3] There are exceptions. Depending on the emission level some less fuel efficient cars with a relatively high net list price actually became cheaper after the tax reform.

comply with the new tax rules and as a consequence cars became more fuel efficient. Since small cars also have a lower operating costs it is important to determine the relative importance of the purchase price and the operating costs in the vehicle type choice decision. To this end, we develop a discrete choice model to capture vehicle purchasing behavior. Using our model we analyze to what extent changes in purchase price and operating costs may explain changes in vehicle type choice (in this case the choice for smaller cars). Furthermore, the model allows us to simulate and illustrate the effect of the VST reform by controlling for other changes in vehicle characteristics not caused by the tax reform. It should be mentioned that we consider the choice for a vehicle type conditional on the event that a car is purchased, but not the choice of the number of cars in a household. We do not examine the effects on total car ownership and by that the impact on car use. We only analyze the effects on the composition of new car sales. Therefore the total effect on the greenhouse emissions of the Dutch car fleet is not addressed in this paper.

Although the international literature on the effects of purchase prices, fuel efficiency, fuel prices or variable car costs on the choice of vehicle type is extensive (e.g., Lave and Train, 1979; Mannering and Winston, 1985; Berkovec and Rust, 1985; Berry et al., 1995; de Jong, 1996; Mannering et al., 2002), research regarding the effectiveness of national taxation systems on the composition of new car sales is less extensive, especially with respect to the effectiveness of a major CO_2-related tax reform in the one-off payment for newly purchased cars like the VST, as a high VST rate is not very common in EU countries. In the Netherlands differentiation of the VST is possible because it is among the highest in the European Union (e.g., Kunert and Kuhfeld, 2007; Nijland et al., 2012). With respect to the influence of national fiscal measures on the composition of new car sales, Ryan et al. (2009) and Nijland et al. (2012) conducted cross national analyses. Although the analyses were conducted on a high level of aggregation, i.e. the ratio of petrol to diesel vehicle sales in EU countries, they examined the influence of national fiscal measures on the CO_2 emissions intensity of the new car fleet. Based on the sample period 1995-2004, Ryan et al. (2009) found that the vehicle sales tax does not appear to have an important impact. The circulation tax (=road tax) is more influential in determining the fuel efficiency and hence CO_2 emissions of the vehicle purchased. This results runs counter to the conclusions of Nijland et al. (2012), who found, for the period 2001-2010, that a vehicle sales tax is an effective instrument to influence the shares of diesel and petrol cars, while annual road taxes and fuel taxes only have small effects. Regarding the influence of a major change in the one-off payment for newly purchased cars, D'Haultfoeuille et al. (2013) estimated the impact of the introduction of a feebate system in France, the "Bonus/Malus écologique". Depending on the class of the vehicle, the amount of the one-off payment, i.e. the feebate, varied. Using discrete choice modelling, they observed a significant shift towards the vehicle classes benefiting from rebates. Consumers do react to the feebate in their car choice. However, they emphasized that, regarding the primary goal, i.e. reducing CO_2 emissions, the environmental impact of the policy is negative. Due to the tax reform the sales levels increased, leading to an increase in manufacturing and traveling emissions.

In the Netherlands there has been some previous research on the effect of operating costs and purchase price on the car type choice in the context of major tax changes as well (e.g., Muconsult, 2002). Among other things, they examined the effects of the introduction of a national road user charge system (road pricing), accompanied by a reduction or abolition of the vehicle sales tax, on the vehicle type choice. As such major tax changes were not actually observed at that time, they had to rely on stated preference data. Choices in stated preference experiments are hypothetical and may be different from choices made in the real world for various reasons. This deviation from real choices is referred to in the literature as hypothetical bias. In order to reduce this bias the methods listed in Hensher (2010) are often used. For example, the attribute levels of the alternatives in a choice experiment are centered on an actually chosen alternative. The main reason that stated preference data are used in empirical analysis is that they give the researcher the option to create alternatives with attributes that do not exist in the market, for instance alternatives with a price that is much higher/lower than has been observed.

Our research contributes to existing literature regarding the influence of car taxes on the composition of car sales. We estimate cost sensitivities and analyze the influence of the VST reform on the composition of new car sales in the Netherlands by means of a discrete choice model. Contrary to previous research in the Netherlands we do not have to rely on stated preference data. In our study we had the opportunity to examine cost sensitivities by means of revealed preference data over a period where consumers are exposed to major tax changes. These data of Dutch households who recently, i.e. 2004-2011, acquired privately owned cars is used to examine the effects of changes in both fixed and variable costs on vehicle type choice. Using the estimated coefficients from the discrete choice model we simulate and illustrate the effect of the VST reform by controlling for other changes in vehicle characteristics not caused by the tax reform.

The paper is organized as follows. In the next section we describe the modeling framework used to examine the vehicle type choice of households. In section 3 we describe our data. Section 4 presents the estimation method together with the estimation results. The implications for policies directed towards a more fuel efficient car fleet are described in section 5. Section 6 concludes.

2. Discrete Choice Model

The main focus of this study is to examine to what extent the type of car purchased is affected by purchase price and variable costs. However, there are many other factors that influence the vehicle type choice of consumers. Over the past decades researchers have been interested in identifying those factors, and to that end various models of vehicle type choice have been developed. The most popular models have been discrete choice models as multinomial logit (e.g., Lave and Train, 1979; Mannering and Winston, 1985), nested logit (e.g., Berkovec and Rust, 1985; Mannering et al., 2002) and random coefficient logit (Berry et al., 1995). Ideally the alternatives in the discrete choice model are car models (as in Berry et al., 1995). Given that at any moment the number of car models that people can actually choose is over 1000, this requires a very large data set, e.g. administrative data on car sales. With survey data as used in this paper some aggregation of alternatives is necessary. Because vehicles can be characterized by a large number of attributes, e.g. fuel type, weight, age, horse power, size, many classifications are possible. In our sample the privately owned cars are classified according to fuel type, weight and age. The classification used will be described in more detail in the data section.

Discrete choice models can be based on utility theory in two ways. Either the "strict utility" theory of Luce (1959) or the "random utility" theory of Thurstone (1927) can be used. We use the theory of random utility to model the vehicle type choice. The "random utility" theory assumes that the utility of a particular alternative is determined by observable characteristics and by a random component. The utility $u_{i,j}$ that household i derives from car type j is

$$u_{i,j} = \mathbf{X}_j^{'}\beta + \mathbf{Z}_{i,j}^{'}\delta + \varepsilon_{i,j} \quad , \tag{1}$$

where $\mathbf{X}_j$ is a vector containing vehicle attributes and $\mathbf{Z}_{i,j}$ a vector of interaction terms of socio-demographic characteristics of household i with vehicle attributes of car type j, and ε_{ij} is an unobservable random component. β and δ are parameter vectors to be estimated. The component $\mathbf{X}_j^{'}\beta + \mathbf{Z}_{i,j}^{'}\delta$ is the average utility. The random component accounts for the effect of variables not included in the average utility that may influence the choice (McFadden, 1973).

Purchase price, weight, fuel efficiency, horsepower and/or number of cylinders are commonly used as vehicle attributes. Of great interest in the present study is to what extent the choice of car types is affected by the purchase price and the variable costs. So the main focus will be on price and cost variables. However, in order to isolate the price and variable cost effects, other vehicle characteristics must be included as well.

Furthermore, interaction terms of car characteristics and household characteristics will be included to account for the variation of the marginal utilities of attributes with household characteristics. These interactions are hopefully sufficient to improve the often unrealistic substitution patterns between alternatives associated with the multinomial logit model. Because of the Independence of Irrelevant Alternatives (IIA) property of the multinomial logit model, the cross-price elasticity is proportional to the prevalence of the alternative considered. If the price of a car type increases, the substitution is to the most popular alternative. For instance, if the price of fuel-inefficient cars increases and the most efficient cars are the popular choice then the model will mechanically predict that households will substitute to those small efficient cars. For a large family this is not very likely. The substitution is likely to be to a smaller more fuel-efficient car, but not to a very efficient mini car. By interacting the weight with the household size large households will attach a relatively large marginal utility to weight, so that if the price of large cars increases the substitution is to cars that are popular among large households. In our model we only consider observed household characteristics. Random coefficient logit models (see Train, 2009) allow for unobserved heterogeneity in marginal utilities. If households maximize utility, then household i chooses alternative j if

$$u_{i,j} = \max(u_{i,1}, ..., u_{i,J}) . \tag{2}$$

If we assume that the random components have an extreme value distribution then the probability that household i chooses option j is, given by the multinomial logit (MNL) model (McFadden, 1973):

$$\Pr[Y_i = j \mid \mathbf{X}_j ; \mathbf{Z}_{i,j}] = \frac{\exp(\mathbf{X}_j^{'}\beta_j + \mathbf{Z}_{i,j}^{'}\delta_{i,j})}{\sum_{l=1}^{J}\exp(\mathbf{X}_l^{'}\beta_l + \mathbf{Z}_{i,l}^{'}\delta_{i,l})} . \tag{3}$$

3. Data description

We used information of Dutch households who recently bought a private car. For this car we collected various car attributes. The characteristics of the household were gathered as well. In this paragraph the data sources and data characteristics are described in more detail.

3.1. Data sources

Approximately 3700 respondents with privately owned cars were selected by a stratified design from a Dutch internet panel of more than 40,000 households with one or more cars maintained by the market research firm TNS-NIPO. Although the questionnaire was primarily focused on the demand for certain vehicle technologies in future car purchases, information regarding the characteristics of the current car and current car use was collected as well. The data are not ideal for the estimation of a vehicle choice model. Only certain characteristics of the car that is most heavily used in the household, in terms of mileage, were collected. By matching the make/model, fuel type, year of manufacture, and weight of the cars in the survey with the cars in the Dutch vehicle registry maintained by the Rijksdienst voor het Wegverkeer (RDW) and the private Dutch company RDC, the sample was supplemented with additional vehicle characteristics, e.g., purchase price, fuel efficiency and CO_2 emission. For the prices of used cars we used export and disposal information from Statistics Netherlands (CBS) and a depreciation curve as used by the Dutch Tax and Customs Administration (Belastingdienst), i.e., for used cars the purchase prices when new are converted into used car prices with this depreciation schedule.

3.2. Sample selection and statistics

Respondents were excluded if the vehicles that they reported in the questionnaire could not be traced in the TNS-NIPO panel data, the RDW data or the RDC data (953 respondents). Furthermore, 620 respondents were excluded because their household income was missing. Finally, detailed vehicle characteristics from newly purchased cars are only available from 1996. Because our choice model is for new and used cars, the vehicle characteristics (in particular the price of the used car that is not in the RDW/RDC registry) of a used car at the time of purchase are obtained from the registry in the year the car was new. Therefore we decided to restrict our sample to car purchases for the period 2004-2011 in order to have a good balance between reliable data on used cars and a reasonable sample size. Eventually, the dataset used for estimation purposes contains 1790 respondents/vehicles.

In Appendix A we compare the 3700 households to the 1790 that remain after applying our selection criteria. Only cars with a mileage of less than 7500 km are underrepresented in our sample. The other differences are insignificant at the 5% level.

Cars in our sample are classified by the following attributes:[4]

- Fuel Type: Gasoline, Diesel and LPG
- Weight Class: <951 kg, 951-1150 kg, 1151-1350 kg and >1350 kg
- Age of the car: new, 1-2 years, 3-5 years and >5 years

Because of the limited amount of observations in certain weight classes (in particular diesel and LPG vehicles), some classes were aggregated. Eventually, 32 car types are distinguished (see also Appendix B).

The 3700 selected respondents from the TNS-NIPO panel comprise a stratified sample from the population of Dutch households. The strata are defined by ownership of a new or second-hand car and by fuel type. The stratified design leads to overrepresentation of diesel and LPG cars and of new vehicles (relative to second-hand cars). To obtain results for the population of all households that bought a car in the observation period we have to take this overrepresentation into account. Therefore we constructed weights based on the shares of the 32 vehicle types within the population of recently acquired privately owned "principal cars"[5]. We combined information from different data sources. The distribution of the vehicle age classes was obtained from Statistics Netherlands (CBS). Information regarding the distribution over the fuel types and weight classes is based on the distribution in the TNS-NIPO panel and our constructed sample, respectively. The 32 vehicle types and the sample and population shares are presented in Appendix B. These shares were used to construct weights that reweight our sample to the population of households that purchased a car in 2004-2011.

Based on our estimation sample, some characteristics of cars that were bought in the most recent years are presented in table 2. The second hand cars are not included in this table. An increase of the share of fuel-efficient cars can be found by looking at the share of the small cars in each fuel class. We use small cars as a proxy for fuel efficient cars. Furthermore, significant drops in the average CO_2 emission level of the newly purchased cars are observed, especially in the years the VST reform took place, indicating that the VST reform might have been effective.

[4] The classification is broadly consistent with that used in the Dutch car ownership model "Dynamo" (MuConsult, 2010).

[5] By principal car we mean the car that is most frequently used by the household in terms of mileage.

Table 2: Characteristics of cars purchased new (N=827)

Year	CO_2 emission (gr/km)	Small gasoline (<950 kg)*	Small diesel (<1350 kg)*	N
2007	163	14%	3%	86
2008	159	19%	2%	125
2009	153	20%	3%	144
2010	142	28%	9%	181
2011**	135	31%	10%	96

* Share within the fuel class

** Information based on the first six months of 2011

4. Estimation

In this paragraph we describe the estimation procedure and the variables we used. Finally the estimation results are presented.

4.1. Estimation model

We are interested in estimating the parameters of the probability of purchasing a specific type of vehicle. This probability is given in (3) and the parameters can be estimated by the Maximum Likelihood method. However, as the sample is choice based, standard maximum likelihood estimation (MLE) techniques do not produce consistent estimates of the underlying model parameters. To account for the choice based sampling, we use weighted exogenous sampling maximum likelihood (WESML) estimators derived by Manski and Lerman (1977). The weights that are constructed by using the population and sample distribution of purchased cars, as shown in Appendix B, are applied to the log-likelihood function. The weighted log-likelihood function is described by:

$$l(\theta)=\sum_{i=1}^{N}\sum_{j=1}^{J}w(j)(I[y_i=j]\log\Pr[Y_i=j]) \quad , \tag{4}$$

where $w(j)$ represents the weight equal to the population share of vehicle type j divided by the sample share of that vehicle type, θ is the parameter vector and $I[y_i=j]=1$ if household i chooses vehicle type j and 0 otherwise. This weighted log-likelihood is maximized with respect to the parameters. The resulting WESML estimator is consistent and asymptotically normal (Manski and Lerman, 1977).The WESML is convenient but not efficient (Imbens, 1992). The software package Limdep is used to maximize the weighted maximum likelihood function (Greene, 1995). To adjust for the non-efficient estimators, the sandwich formula is used to compute the asymptotic variance (Greene, 1995).

4.2. Explanatory variables

In the model we use combinations of vehicle attributes and household characteristics as explanatory variables. As the main focus of this study is to examine to what extent the type of car purchased is affected by purchase price and variable costs, we incorporated those price variables, i.e. purchase price and variable costs in our model specification. However, in order to isolate those price effects other car attributes which influence the car type choice have to be included as well. Vehicle attributes like purchase price, weight, fuel efficiency, horsepower and/or cylinder capacity are commonly used as vehicle attributes in literature (e.g. Lave and Train, 1979; de Jong, 1996; Mannering et al., 2002). Most of these car attributes are often interacted with certain household characteristics, e.g., income and/or household size, to account for the variation of the marginal utilities of attributes with household characteristics.

The distribution of some categorical variables together with the descriptive statistics for the variables used in the estimation are listed in Appendix C. We describe each of the variables in more detail below.

Car attributes

For car attributes we use the purchase price, variable costs, the annual road tax, cylinder capacity, horse power, weight and the range of car models available on the market.

• Purchase Price

For the purchase price, we used the consumer price which is the sum of the net list price, the VST and the VAT. The VST is not used separately as an explanatory variable as this would not be realistic. Consumers only observe the consumer price when they buy a car and are generally not aware of the VST rate.[6]

• The annual variable car costs

The variable costs depend on the fuel consumption of the vehicle, the fuel price and the annual vehicle mileage (class) as reported by the respondent. When examining the influence of the operating cost on the purchasing choice behavior of consumers, the way consumers form expectations about future gasoline prices should be acknowledged. We assume that consumers use current fuel prices to construct predictions over future fuel prices. This is consistent with statistical tests on time series of fuel prices conducted in academic literature, which indicate that fuel prices appear to follow a random walk (Hamilton, 2008). This suggest that knowledge of the current fuel price is sufficient to inform predictions over future fuel prices. Hence, we used fuel price information from the year of purchase in our analysis. The annual fuel prices for the different fuel types are derived from the quarterly price statistics from Statistics Netherlands.

• Annual road tax

The annual road tax (Dutch: MRB) is based on the weight and fuel type of the vehicle. Since 2008 the annual road tax depends on the CO_2 emission as well. Highly fuel-efficient cars receive a discount. Since 2010 these cars are exempt from the road tax.

• Performance

We use the cylinder capacity, horse power and weight as a proxy for vehicle performance.

• Model range

Previous research has shown that consumers prefer a variety of models (Dynamo, 2010). We take this into account by including (the log of) the number of models for a car type as an explanatory variable.

Besides these variables fuel type dummies are included to reflect the general preference for a specific fuel type. We also include dummies for the age of the car (see Section 3 for the categories).

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[6] Besides, as the VST is highly correlated with the net list price, especially in the period 2004-2009, using the VST as a separate variable will likely introduce multicollinearity problems resulting in unreliable estimates.

Household characteristics
For household characteristics we use household income, household size and mileage. The coding of each variable can be found in Appendix C.

• Household income
This is the gross annual income of households in three categories. Low income households are expected to be more price sensitive in comparison to high income households. To this end, we include the interaction of price and the income level of the household.

• Household size
Interaction terms between the size of the car and the household size are included in the model to allow that the preference for larger cars increases with the household size.

• Mileage
Households that drive relatively many kilometers are expected to be more sensitive to changes in variable costs. They will be more inclined to purchase more fuel efficient cars compared to households that have a lower annual mileage. To take this into account the variable costs are interacted with the annual vehicle mileage of the household.

4.3. Attributes for all vehicle types

As mentioned in the previous section, we distinguish 32 vehicle types according to fuel type, weight and age. A general concern in models based on revealed preference (as opposed to stated preference) is that only the information of the car owned by the respondent is known. However, to estimate the parameters of the MNL model based on revealed preference data, the full choice set of each respondent has to be specified. To this end, for each of the 32 vehicle types we constructed a "representative" car by taking the sales-weighted average of the cars within that category.[7] Depending on the year the respondent bought his / her car and the manufacturing year the attributes in the 32 types were determined using the RDW and RDC data files.[8]

The use of weighted averages of car attributes can be considered as a first-order approximation of a Nested Multinomial Logit (NMNL) model (McFadden, 1973) where the nests are the 32 autotypes and the choices are the models that belong to these 32 types. If we initially simplify model (1) to a model with only car attributes then the utility of model m that belongs to type j is

$$u_{i,j,m} = X'_{j,m}\beta + \varepsilon_{i,j,m} \tag{5}$$

If we consider the choice of type j then the NMNL model captures the availability of a range of models by the inclusive value that is equal to

$$\rho.\left(e^{X'_{j,1}\beta/\rho} + \cdots + e^{X'_{j,M_j}\beta/\rho}\right) \approx \left(P_{j,1}.X'_{j,1} + \cdots + P_{j,M_j}.X'_{j,M_j}\right)\beta \tag{6}$$

with the right-hand side the first-order approximation in β and $P_{j,m}$ the choice probability of model m that belongs to vehicle type j. The parameter ρ is the within nest correlation of the random components. Note that our model includes household characteristics and the weights should depend on these as well. We ignore this dependence so that the weighted average is an imperfect approximation of the inclusive value.

[7] This is also done by Lave and Train (1979).
[8] Within this respect it is important to note that a small error is introduced when creating the choice sets as average values are used for each of the 32 vehicle types including the alternative chosen by the respondents.

4.4. Estimation results

We estimated various MNL specifications in which we varied the included vehicle attributes, the interactions with household characteristics and the specification of the price variables. Based on the significance of the estimated parameters, the log likelihood value of the model specification and whether plausible coefficient signs where obtained we selected a final model specification.[9] The parameter estimates are given in table 3. The parameters are the marginal utilities of the car attributes. The interactions with the household variables show that these marginal utilities vary among the households. All price coefficients are negative as expected. The results show that low income households are more price sensitive than high income households. Households with a high annual vehicle mileage are more sensitive to variable cost per kilometer than households that drive fewer miles. The annual road tax does not contribute significantly to the model specification, implying that the annual road tax is not effective in affecting the vehicle type choice. The small effect of the road tax on the vehicle type choice was also observed in MuConsult (2002). However, this small effect may be the result of a relatively small variation in the average road tax values between the aggregated vehicle types in the model. Furthermore, the results show that larger (heavier) cars are preferred over smaller (lighter) cars and that new cars are preferred over used cars. The preference for larger cars increases with household size as expected. Furthermore, gasoline cars are preferred over diesel and LPG cars.

Table 3: WESML estimates of the parameters

Variable	Parameter	SE	P-value
Ln Price x Income < 32500 euro	-3.53	0.37	0.00
Ln Price x Income 32500-65000 euro	-3.27	0.36	0.00
Ln Price x Income > 65000 euro	-3.02	0.36	0.00
Ln Annual road tax (MRB)	-0.13	0.35	0.71
Variable costs (1000) x Income < 32500 euro	-0.90	0.25	0.00
Variable costs (1000) x Income 32500-65000 euro	-0.60	0.19	0.00
Variable costs (1000) x Income > 65000 euro	-0.49	0.21	0.02
Variable costs (1000) x Mileage > 25000 km	-0.42	0.14	0.00
Ln Power x Income 32500-65000 euro	0.79	0.30	0.01
Ln Power x Income > 65000 euro	1.26	0.39	0.00
Ln Size	0.37	0.11	0.00
Ln CarWeight x HHsize 1	3.66	1.15	0.00
Ln CarWeight x HHsize 2	5.82	1.12	0.00
Ln CarWeight x HHsize > 2	6.77	1.15	0.00
Car New	5.03	0.72	0.00
Car Age 1-2 year	3.14	0.57	0.00
Car Age 3-5 year	2.36	0.37	0.00
Diesel	-1.14	0.28	0.00
LPG	-3.24	0.23	0.00

N = 1790

Log likelihood = -5222.26

Log likelihood alternative specific intercepts only = -5380.01

[9] The variable cylinder capacity and interactions with cylinder capacity are left out in the final model specification due to non-convergence of the model or an unexpected significantly negative sign caused by correlations with other included variables.

To explore the model performance the changes in the estimated probabilities between two sample periods (2004-2009 and 2010-2011) are compared with the weighted sample fractions. The results are shown in Appendix D. In general the model predicts smaller effects in comparison with the observed changes, however the signs are mostly correct. Increases and decreases of the purchase probability are correctly estimated. Choice probability changes for used cars are less well predicted by the model, especially for vehicle types of more than five years old. This could be caused by the small number of observations when the sample period is divided into two time periods and/or the possibility of not accurately specified car attributes for vehicle types of more than five years old. However, the main focus of this paper is on the purchase probabilities of new cars for which the model is suitable.

5. Implications of the estimation results

5.1. Elasticities

In order to examine the sensitivity with respect to changes in purchase price and changes in variable costs, we calculated the elasticities for the various vehicle types.[10] We used the averages in the sample period as values for the vehicle attributes. Since we are interested in the greening of the Dutch car fleet we calculate the effects for the market for new cars: the second hand market is left out in this analysis. The elasticities are only calculated for the probability that a new car is bought. For example, the own price elasticity of a certain vehicle class is obtained by calculating the change of the probability of choosing the vehicle type in response to a 1% change in price. The probability is obtained by the probability of choosing the vehicle type divided by the probability of choosing any new car. In table 4 we present the vehicle price elasticities and in table 5 we present the fuel price elasticities.

The own purchase price elasticities are all negative; for example a 1% price increase for the smallest petrol car decreases the probability of buying that car by 2.7%. All other own price elasticities are (approximately) of the same magnitude (-2.5 to -3.1).[11] The fuel price elasticities are negative as expected. Increasing the petrol price with 1% leads to a small decrease in the probability of buying small petrol efficient cars, but discourages the purchase of larger less petrol efficient cars even more. As expected higher petrol prices increase the probability of buying diesel and LPG cars. Increasing the diesel price has little effect on buying petrol cars; diesel cars are mainly substituted by LPG cars. Diesel and LPG cars are often used by households with high mileage. By comparing the elasticities, choosing a small new gasoline car seems to be more sensitive to the purchase price than to the fuel price. However, one has to bear in mind that a 1% change in fuel price and a 1% change in purchase price is only of comparable magnitude if someone uses the cars for at least 10 years (a 1% change in purchase price equals approximately 190 euro versus approximately 15 euro per year for a 1% change in variable cost).

[10] The vehicle type model was programmed in a spreadsheet model. This spreadsheet model applies the estimated coefficients to the estimation sample (N=1790) and reweights the households to make the estimation sample representative for the population of households who bought a private car (hybrid cars excluded) in the observation period. The spreadsheet program can be used to derive elasticities and to simulate the effects of tax schemes and certain scenario's with respect to changes in purchase price and/or fuel price.

[11] Because the car manufacturers are oligopolists the price elasticities have to be bigger than 1 in absolute value.

Table 4: Elasticities based on 1% purchase price increase of new cars

	(cross)elasticity							
	Gasoline <950 kg	**Gasoline 950-1150 kg**	**Gasoline 1150-1350 kg**	**Gasoline >1350 kg**	**Diesel <1350 kg**	**Diesel >1350 Kg**	**LPG <1350 kg**	**LPG >1350 kg**
Gasoline < 950 kg	**-2.67**	0.56	0.56	0.55	0.57	0.56	0.57	0.56
Gasoline 950-1150 kg	0.70	**-2.51**	0.70	0.70	0.70	0.70	0.70	0.70
Gasoline 1150-1350 kg	0.68	0.68	**-2.49**	0.70	0.69	0.70	0.69	0.70
Gasoline > 1350 kg	0.59	0.60	0.61	**-2.52**	0.60	0.62	0.60	0.62
Diesel < 1350 kg	0.23	0.23	0.23	0.22	**-2.93**	0.24	0.24	0.24
Diesel > 1350 kg	0.28	0.28	0.29	0.29	0.29	**-2.83**	0.29	0.30
LPG < 1350 kg	0.06	0.06	0.06	0.06	0.06	0.06	**-3.11**	0.06
LPG > 1350 kg	0.06	0.06	0.06	0.06	0.06	0.06	0.06	**-3.05**

Table 5: Elasticities based on 1% fuel price increase

	(cross)elasticity							
	Gasoline < 950 kg	**Gasoline 950-1150 kg**	**Gasoline 1150-1350 kg**	**Gasoline > 1350 kg**	**Diesel < 1350 kg**	**Diesel > 1350 kg**	**LPG < 1350 kg**	**LPG > 1350 kg**
Gasoline	**-0.06**	**-0.23**	**-0.35**	**-0.53**	1.26	1.12	1.33	1.22
Diesel	0.17	0.16	0.15	0.13	**-0.68**	**-0.9**	0.3	0.28
LPG	0.04	0.03	0.03	0.02	0.06	0.05	**-0.78**	**-0.99**

5.2. Composition of the Dutch car fleet

The CO_2 dependent VST alters the composition of the Dutch new car sales. We determine the effects of the new tax scheme for the VST on the composition of new car sales and also try to establish whether the same effect could be achieved by increasing the variable costs. To this end we compare the market shares of the 32 vehicle types in the situation with and without the differentiated VST by means of simulation. The reference situation, i.e. the situation without the differentiated VST, is characterized by the former tax scheme where the VST was based on the net list price of the car. By means of simulation we can illustrate the effect of the VST reform by controlling for other changes in vehicle characteristics not caused by the VST reform. The vehicle characteristics are based on the information of newly purchased cars as reported in Dutch vehicle registry maintained by the Rijksdienst voor het Wegverkeer (RDW). For 2011 the differentiated VST led to changes in the average purchase price of new cars as reported in table 6.[12]

[12] Due to the aggregation into weight classes the effects are averaged. For individual vehicles, bigger price changes are observed. Furthermore, we assume that price changes induced by the tax changes are completely passed through to consumers. This is probably an overestimation of the price effect, as it is likely that net list prices will be adjusted by car manufactures, as noticed by Goldberg and Verboven (2004).

Table 6: Relative changes in average purchase price

Vehicle type	2011
New Small Gasoline (< 950 kg)	-6.8%
New Small Diesel (< 1350 kg)	-6.3%
New Large Gasoline (> 1350 kg)	4.6%
New Large Diesel (> 1350 kg)	5.6%

Table 7: Relative change in probabilities of new cars due to the VST reform

Fuel weight	2011*	2011**	dif 2011
New Gasoline <950 kg	17.3%	22.0%	27.1%
New Gasoline 950-1150 kg	20.9%	21.2%	1.5%
New Gasoline 1150-1350 kg	25.8%	24.3%	-5.9%
New Gasoline >1350 kg	17.2%	14.5%	-15.9%
New Diesel <1350 kg	5.7%	6.9%	21.5%
New Diesel >1350 kg	9.0%	7.4%	-18.2%
New LPG <1350 kg	2.3%	2.2%	-1.0%
New LPG >1350 kg	1.8%	1.5%	-14.5%

* Probability based on the tax scheme without the progressive tax scheme for the VST
** Probability based on the tax scheme including the progressive tax scheme for the VST

The predicted shares are shown in table 7. In 2011 the differentiation of the sales tax led to a <u>relative</u> increase in the probability of purchasing a small gasoline and small diesel car of approximately 27% and 22% respectively. Furthermore, in 2011 the probability of purchasing the heaviest gasoline and diesel vehicles dropped. It seems that implementing a progressive tax system dependent on CO_2 for the VST is an effective policy measure to achieve a higher market share of fuel efficient cars.

An alternative policy would be to increase variable cost. It is difficult to differentiate fuel prices by type of car; we can only study general untargeted price increases. Higher fuel prices lead to higher variable cost and hence should favor the purchase of new fuel-efficient petrol, diesel and LPG cars. The results in table 8 show that an overall fuel price increase of 10% leads to a shift to more fuel-efficient (small) vehicles. However it also increases the probability that relatively heavy diesel and LPG cars are bought. To this end we simulated the effects of a fuel price increase of 25%, 50% and 75% of gasoline, diesel and LPG respectively. Although the market shares of small cars increase at the expense of the market shares of heavy cars, the impact of this large increase in fuel prices on the market shares of the different vehicle types is still much smaller than the impact of the changes in the VST. In order to obtain similar effects, substantial fuel price increases are needed.

We conclude that the differentiation of the VST is a more effective way to stimulate the purchase of small fuel efficient cars and therefore is an effective way to influence the composition of the Dutch car fleet. By using the VST, the most efficient cars can be targeted without encouraging the purchase of other car types as is the case with changes in the fuel tax. Only by a differentiated fuel tax per vehicle type the effects of a differentiated VST can be replicated. However, it is unlikely that such a differentiated fuel tax can be implemented in practice, since the required tax increases are substantial.

Table 8: Relative change in probabilities due to a fuel price increase in 2011

Fuel weight	2011*	2011 (1)**	2011 (2)***
New Gasoline <950 kg	27.1%	1.4%	11.3%
New Gasoline 950-1150 kg	1.5%	-0.3%	5.6%
New Gasoline 1150-1350 kg	-5.9%	-1.8%	0.8%
New Gasoline >1350 kg	-15.9%	-3.7%	-5.2%
New Diesel <1350 kg	21.5%	7.2%	0.2%
New Diesel >1350 kg	-18.2%	2.3%	-16.8%
New LPG <1350 kg	-1.0%	9.0%	-17.6%
New LPG >1350 kg	-14.5%	5.7%	-29.4%

** Relative change in probability due to a progressive tax system for the VST

*** Relative change in probability due to a overall fuel price increase of 10%.

**** Relative change in probability due to a fuel price increase of gasoline, diesel and LPG of 25%, 50% and 75% respectively.

Greening the Dutch car fleet is not only a matter of composition but also of size of the car fleet. Both policies have different impacts on size. Since differentiating the sales tax effectively leads to a subsidy on the purchase price, it can be expected that this policy will increase the size of the car fleet. Increasing fuel prices will have the opposite effect. See for instance D'Haultfoeuille et al. (2013). These differences are not further explored in this paper.[13]

6. Conclusion

In this paper we examined the relative impact of the purchase price and the operating costs in the vehicle type choice of households. Furthermore we simulated the effects of the introduction of the new tax scheme for the VST in the Netherlands that favors purchasing small fuel efficient cars and discourages the purchase of gas guzzlers. To analyze the vehicle type choice behavior of Dutch households we estimated a multinomial logit model using revealed preference information of Dutch households who recently (2004-2011) acquired a privately owned car. We applied a weighted maximum likelihood estimation procedure to correct for the choice based nature of the sample. Due to the limited size of the sample we aggregated the various vehicle types into broadly defined classes.

All estimated price coefficients are negative as expected. We find that vehicle type choice is price sensitive (price elasticities are less than -1). This is to be expected since the car market has characteristics of monopolistic competition. Low income households are more price sensitive compared to high income households. Households with a high annual mileage are more sensitive to annual variable costs than households who drive fewer miles. Furthermore, the model results show that larger (heavier) cars are preferred over smaller (lighter) cars and that new cars are preferred over used cars. The preference for larger cars increases with household size as expected.

Compared to the price sensitivities found in previous research on the car type choice behavior of Dutch households, the estimated purchase price sensitivity is higher whereas the variable costs sensitivity is lower. Why this difference occurs and to what extent this is due to the different type of data that are used, is a topic for further research.

[13] In Geilenkirchen et al. (2013) and PBL (2014) these effects are further analyzed by using the estimated coefficients of this study in the Dutch car ownership model "Dynamo". Preliminary results show that the VST reform is an effective instrument to influence car buyers towards fuel efficient cars. The impact of fuel taxes on car type choice are small compared to the impact of the VST. However, an increase in fuel prices also leads to a decrease in car ownership and car use. As such, fuel taxes do impact total CO_2 emissions by passenger cars to a larger degree.

Furthermore, the annual road tax has no significant effect on the vehicle type choice. This is in line with previous studies: a rather small effect of the road tax on the vehicle type choice was also observed in MuConsult (2002). However it should be noted that not much variation in the road tax was found in the sample period. What the effect of a substantial increase or decrease of the road tax will be, cannot be examined with this model.

Using model simulations, we found that the new sales tax scheme is an effective way to stimulate the purchase of small fuel efficient cars and to discourage the purchase of large and inefficient cars. The share of small petrol and small diesel cars increased by 27% and 22% respectively. To reach the same effect on the composition of the Dutch new car sales through increased fuel prices, substantial differentiated increases are needed. Stimulating the purchase of small fuel efficient cars is best achieved by lowering their sales tax.

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Appendix A: Distribution in household attributes in the (estimation) sample

Variable	Classification	Full sample (N=3700)	Estimation sample (N=1790)
Vehicle Mileage	less than 7500 km	13%	8%
	7500 to 15000 km	41%	39%
	15000 to 25000 km	29%	32%
	25000 to 35000 km	11%	13%
	more than 35000 km	7%	8%
Household size	1 person	12%	14%
	2 persons	46%	48%
	3 persons or more	42%	39%
Household income	less than 32.500	22%	22%
	32.500 to 65.000	51%	53%
	more than 65.000	27%	25%

Appendix B: Distribution of the vehicle types in the sample and population

Fuel	Age	Weight (kg)	N	Sample share	Population share	Weight
Gasoline	new	<950	109	5.8%	3.5%	0.60
Gasoline	1-2 year	<950	18	1.0%	1.9%	1.90
Gasoline	3-5 year	<950	42	2.2%	4.7%	2.14
Gasoline	>5 year	<950	93	4.9%	9.6%	1.96
Gasoline	new	950-1150	114	6.1%	4.1%	0.67
Gasoline	1-2 year	950-1150	35	1.9%	2.3%	1.21
Gasoline	3-5 year	950-1150	67	3.6%	5.4%	1.50
Gasoline	>5 year	950-1150	79	4.2%	11.2%	2.67
Gasoline	new	1150-1350	137	7.3%	4.8%	0.66
Gasoline	1-2 year	1150-1350	46	2.4%	2.7%	1.13
Gasoline	3-5 year	1150-1350	84	4.5%	6.4%	1.42
Gasoline	>5 year	1150-1350	102	5.4%	13.2%	2.44
Gasoline	new	>1350	79	4.2%	2.2%	0.52
Gasoline	1-2 year	>1350	20	1.1%	1.2%	1.09
Gasoline	3-5 year	>1350	42	2.2%	2.9%	1.32
Gasoline	>5 year	>1350	32	1.7%	5.9%	3.47
Diesel	new	<1350	121	6.4%	0.8%	0.13
Diesel	1-2 year	<1350	15	0.8%	0.8%	1.00
Diesel	3-5 year	<1350	40	2.1%	2.0%	0.95
Diesel	>5 year	<1350	39	2.1%	4.1%	1.95
Diesel	new	>1350	95	5.1%	0.7%	0.14
Diesel	1-2 year	>1350	18	1.0%	0.7%	0.70
Diesel	3-5 year	>1350	47	2.5%	1.8%	0.72
Diesel	>5 year	>1350	21	1.1%	3.7%	3.36
LPG	new	<1350	60	3.2%	0.2%	0.06
LPG	1-2 year	<1350	10	0.5%	0.2%	0.40
LPG	3-5 year	<1350	37	2.0%	0.5%	0.25
LPG	>5 year	<1350	50	2.7%	1.0%	0.37
LPG	new	>1350	45	2.4%	0.1%	0.04
LPG	1-2 year	>1350	13	0.7%	0.2%	0.29
LPG	3-5 year	>1350	40	2.1%	0.4%	0.19
LPG	>5 year	>1350	40	2.1%	0.8%	0.38

Appendix C: Characteristics of the estimation sample (N=1790)

Distribution in categorical variables used for estimation purposes

Variable	Classification	Unweighted	Weighted
Fueltype	Gasoline	61%	82%
	Diesel	22%	15%
	LPG	16%	3%
Weight	<950 kg	15%	20%
	950-1150 kg	22%	25%
	1150-1350 kg	35%	35%
	>1350 kg	27%	21%
New/used	New	42%	16%
	1 to 2 years	10%	10%
	2 to 5 years	22%	24%
	more than 5 years	25%	49%
Vehicle Mileage	less than 7500 km	8%	11%
	7500 to 15000 km	39%	45%
	15000 to 25000 km	32%	30%
	25000 to 35000 km	13%	10%
	more than 35000 km	8%	4%
Household size	1 person	14%	15%
	2 persons	48%	44%
	3 persons or more	39%	41%
Household income	less than 32.500	22%	26%
	32.500 to 65.000	53%	53%
	more than 65.000	25%	22%

Descriptive statistics of the variables used for estimation purposes

Variable	Unit	Minimum	Maximum	Mean	Std. Deviation
Purchase price	euro	1116	40333	13300	10328
Road tax	euro	147	1678	689	385
Variable costs	euro	170	6257	1511	837
Weight	kg	835	1592	1211	233
Cylinder	cc	1104	2531	1666	363
Power	kw	47	125	81	23
Size	number of cars	369	4773	2315	1214
Household size	class	1	3	2.3	0.7
Household income	class	1	3	2.0	0.7
Vehicle mileage	class	1	5	2.7	1.1

Appendix D: model simulation compared with weighted sample shares

			Model simulation			Sample		
Fuel	**Age**	**Weight (kg)**	**2004-2009**	**2010-2011**	**dif**	**2004-2009**	**2010-2011**	**dif**
Gasoline	new	<950	2.00%	2.60%	32%	3.10%	4.20%	36%
Gasoline	1-2 year	<950	1.20%	1.30%	7%	2.50%	1.10%	-56%
Gasoline	3-5 year	<950	3.20%	2.80%	-13%	6.00%	2.50%	-58%
Gasoline	>5 year	<950	12.50%	16.60%	33%	10.00%	8.90%	-11%
Gasoline	new	950-1150	2.80%	2.40%	-13%	5.30%	2.30%	-57%
Gasoline	1-2 year	950-1150	1.70%	1.50%	-12%	3.10%	1.00%	-68%
Gasoline	3-5 year	950-1150	4.40%	3.60%	-19%	5.60%	5.20%	-8%
Gasoline	>5 year	950-1150	17.20%	15.50%	-10%	10.00%	13.00%	29%
Gasoline	new	1150-1350	2.70%	2.60%	-3%	5.40%	4.00%	-27%
Gasoline	1-2 year	1150-1350	1.70%	1.50%	-14%	3.50%	1.30%	-62%
Gasoline	3-5 year	1150-1350	4.40%	3.30%	-26%	6.70%	6.00%	-10%
Gasoline	>5 year	1150-1350	11.90%	13.20%	10%	10.40%	17.40%	67%
Gasoline	new	>1350	2.60%	1.90%	-25%	2.30%	1.90%	-15%
Gasoline	1-2 year	>1350	1.50%	1.30%	-12%	1.50%	0.80%	-49%
Gasoline	3-5 year	>1350	3.20%	2.90%	-9%	2.50%	3.50%	40%
Gasoline	>5 year	>1350	10.10%	8.90%	-12%	4.50%	7.90%	75%
Diesel	new	<1350	0.90%	1.00%	10%	0.50%	1.30%	161%
Diesel	1-2 year	<1350	0.60%	0.50%	-22%	1.10%	0.40%	-61%
Diesel	3-5 year	<1350	1.70%	1.10%	-35%	2.30%	1.50%	-34%
Diesel	>5 year	<1350	3.30%	6.90%	111%	3.30%	5.40%	63%
Diesel	new	>1350	1.30%	0.80%	-39%	0.80%	0.60%	-32%
Diesel	1-2 year	>1350	0.70%	0.60%	-22%	0.70%	0.70%	-2%
Diesel	3-5 year	>1350	1.50%	1.40%	-4%	2.20%	1.10%	-53%
Diesel	>5 year	>1350	3.40%	2.30%	-31%	2.60%	5.30%	106%
LPG	new	<1350	0.20%	0.20%	-3%	0.20%	0.20%	-4%
LPG	1-2 year	<1350	0.10%	0.10%	-11%	0.30%	0.10%	-83%
LPG	3-5 year	<1350	0.40%	0.30%	-23%	0.70%	0.20%	-64%
LPG	>5 year	<1350	1.10%	1.50%	37%	0.90%	1.20%	21%
LPG	new	>1350	0.20%	0.20%	-26%	0.20%	0.00%	-96%
LPG	1-2 year	>1350	0.10%	0.10%	-17%	0.30%	0.00%	-87%
LPG	3-5 year	>1350	0.30%	0.30%	-17%	0.50%	0.30%	-34%
LPG	>5 year	>1350	0.90%	0.80%	-19%	0.90%	0.70%	-17%