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The PLANET model Methodological Report: The Car Stock Module

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Abstract - The vehicle stock module calculates the size and composition of the car stock. Its output is a full description of the car stock in every year, by vehicle type, age and (emission) technology of the vehicle. The vehicle stock is represented in the detail needed to compute transport emissions. The integration of the car stock module in PLANET will allow to better capture the impact of changes in fixed and variable taxes levied on cars. Among these impacts, the effect on the environment is of particular interest.

Jel Classification - R41, R48

Keywords - Passenger road transport, vehicle stock modelling

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Introduction

The car stock module calculates the *size and composition of the car stock*. Its output is a full description of the car stock in every year, by vehicle type (fuel), age and (emission) technology of the vehicle. The vehicle stock is represented in the detail needed to compute the transport emissions.

For buses, coaches, road freight vehicles, inland navigation and rail the car stock is not modelled in detail. In these cases the model uses information about the vkm and tkm rather than the vehicle stock to determine resource costs, environmental costs, etc.

The past version of the PLANET model used an exogenous evolution of the car stock taken from other research projects. From now on the vehicle stock module is integrated in the rest of the PLANET model.

The assumptions that are made are described in a detailed way in the report on the business-as-usual scenario[1]. In this paper we describe the work that has been done to endogenise the evolution of the vehicle stock.

This document describes the first version of the car stock module. The methodology presented here might undergo some changes in the future[2].

1 Desmet, R., B. Hertveldt, I. Mayeres, P. Mistiaen and S. Sissoko (2008), The PLANET Model: Methodological Report, PLANET 1.0, Study financed by the framework convention "Activities to support the federal policy on mobility and transport, 2004-2007" between the FPS Mobility and Transport and the Federal Planning Bureau, Working Paper 10-08, Federal Planning Bureau, Brussels.

2 For example, in the actual version of the model, the definition of car size is linked to cylinder size. In the future, we will look at the possibility to define car size linked to power.

1. Modelling approach

Several approaches exist to model the magnitude and composition of the car stock. De Jong et al. (2002) give a review of the recent (since 1995) international literature on car ownership modelling. In PLANET we will use an aggregate approach. Other examples of this approach can be found in TREMOVE (De Ceuster et al., 2007) and ASTRA (Rothengatter et al., 2000).

We first describe the general principles, and then discuss the different steps in more detail. The general approach is similar as in ASTRA and TREMOVE. For each car type the vehicle stock is described by vintage and vehicle type. If $Stock_i(t,T)$ represents the vehicle stock of type i (diesel and gasoline car) in year t and of age T, the two basic equations are:

$$Stock_i(t,0) = Sales_i(t)$$

$$Stock_i(t,T) = Stock_i(t\text{-}1,T\text{-}1) - Scrap_i(t,T) \quad \text{for } T > 0$$

$Sales_i(t)$ stands for the sales of new cars of type i in year t and $Scrap_i(t,T)$ is the scrappage of vehicles of type i and age T in year t.

In each year t the stock of vehicles surviving from year t-1 is compared with the desired stock of vehicles needed by the transport users. If the desired stock is larger than the surviving stock, new vehicles are bought. This approach requires the determination in each year of the total desired vehicle stock (Section 2), the number of vehicles of each type that is scrapped (Section 3) and the composition of the vehicle sales (Section 4).

The model includes vehicles from age 0 until the age they are scrapped or leave the country. Any changes in ownership in between are not modelled. No separate categories are considered for new and second hand vehicles.

In a first stage no distinction is made between cars owned by private business, government and utilities on the one hand and personal cars on the other hand. This distinction could be useful because the policy instruments can be different in both cases and because changes in the composition of the fleet stock eventually filter down to the personal car stock. Including a separate category of fleet cars would require modelling the transition of these cars to the personal car stock. Account should also be taken of exports and imports. The National Energy Modelling System (NEMS) of the US Department of Energy (US DoE, 2001) is an example of a model that incorporates the distinction between fleet and personal cars.

2. The total desired stock

In order to derive the total desired stock we can consider the following two approaches:

– to derive the desired stock from the vkm, as calculated in the MODAL and TIME CHOICE module, and the evolution of the annual mileage per vehicle. This is the approach that is taken in the TREMOVE model.
– to relate the desired car stock to economic development, transport costs and population. The function relating the desired stock to its explanatory variables may either be calibrated (cf. the ASTRA model; Rothengatter et al., 2000) or estimated (cf. for example, Medlock and Soligo, 2002). For the other vehicles the same approach as in TREMOVE continues to be used.

The first approach has the drawback that assumptions need to be made about the average annual vehicle mileage. The second approach allows to derive for cars an average annual mileage by confronting the car stock with the car transport demand that is derived in the MODAL and TIME CHOICE module.

In the first version of PLANET the first approach was used. In the new version of PLANET, the second approach is used. With the first approach we start from the total vkm per car that is derived in the MODAL and TIME CHOICE module. The number of vkm is then divided by the average annual mileage to get the desired number of cars for a given year. The determination of the average annual mileage for cars will be discussed in Section 5.

3. Vehicle scrappage

In order to know the surviving car stock in year *t* a scrappage function needs to be determined. In this version of the model scrappage is assumed to be exogenous. In a later stage an endogenous scrappage function will be considered[3].

3.1. Methodology

The scrappage function is estimated for the following car types: diesel cars and gasoline cars. The scrappage rate of these vehicles is estimated according to the age of the vehicle (*T*), with a scrappage function determined by a loglogistic distribution. The following equation gives the hazard function of the loglogistic distribution which describes the rate at which cars are scrapped at age *T* given that they stay in the vehicle stock until this age.

$$h(T) = cons + \frac{\lambda\rho(\lambda T)^{\rho-1}}{1+(\lambda T)^{\rho}}$$

where λ and ρ are shape and scale parameters and *cons* is a constant term. If the value of the shape parameters (λ) lies between 0 and 1, the shape of the hazard function first increases and then decreases with age. The loglogistic hazard function is also concave at first, and then becomes convex. The shape of this hazard function is close to the shape of the scrappage rates for all vehicle types observed during the years 2000 to 2005[4]. The parameters λ and ρ and the constant term are estimated on the basis of data obtained from the DIV. These are described in the following paragraph.

3.2. Observed scrappage rates

The DIV has provided us with time series of the age distribution of the car fleet according to fuel. The time series refer to the years 1997 to 2005 (except 1999). These data are used to calculate scrappage rates according to fuel and age for all reported years. The observed number of scrapped vehicles of age *T* is defined as the difference between the number of vehicles of age *T* in year *t* and the number of vehicles of age *T*+1 in year *t*+1. The scrappage rate is then obtained by dividing the number of scrapped vehicles per age in year *t* by the total number of vehicle of this age in the fleet during the same year.

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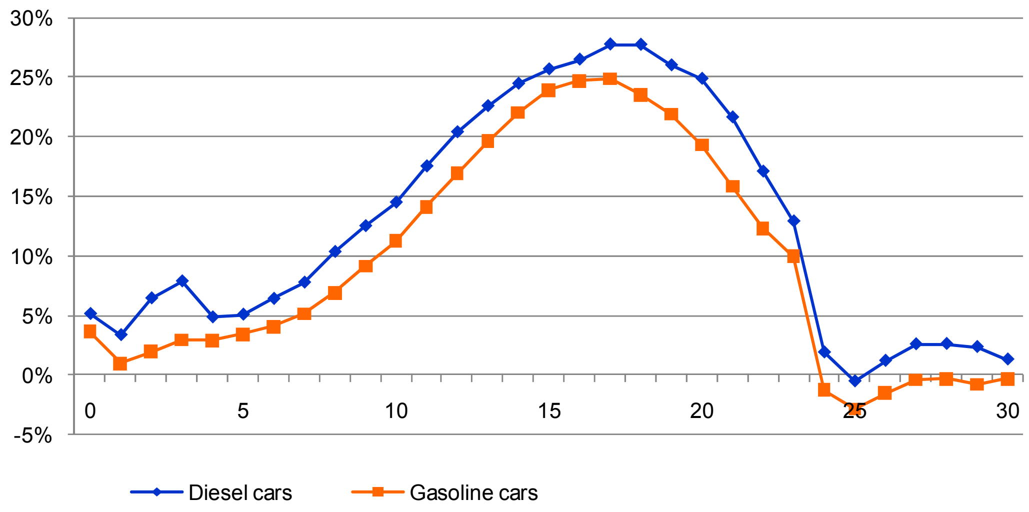
3 In general, scrapping depends on the technical lifetime of a vehicle, the probability of breakdown before the end of the planned technical life and policies that directly or indirectly affect vehicle costs such as purchase taxes and scrapping incentives. The following studies could prove to be useful for modelling endogenous scrappage rates: Hamilton and Macauley (1998), De Jong et al. (2001), Logghe et al. (2006).

4 A Weibull distribution is often used to model duration data, but the shape of its hazard function -"s-shape"- does not correspond well to the shape of the observed scrappage rates.

The next figure presents the average scrappage rates derived from the data of the DIV for the different types of cars from 1 to 30 years old. The averages are calculated over the period 2000-2005.

Figure 1: Average scrappage rates at age 0 to 30 during the period 2000 to 2005 for diesel and gasoline cars



Source: FPB based on DIV.

The data for gasoline and diesel cars refer to "ordinary passenger cars" and "mixed cars". Based on the data of the DIV, we note some findings:

- The car data present some irregularities during the first year of registration[5].
- The data show that the scrappage rates are relatively high during the 4 first years of registration, in particular for diesel cars. This can be explained by leased and company cars leaving the stock before being 4 years old.
- We observe that the scrappage rates are higher for diesel than for gasoline cars as, at a given age, the mileage of diesel cars is higher.
- Cars of 25 years and older have negative scrappage rates because "old-timers" are reentering the stock (as taxes and insurance costs become cheaper). Many of those are gasoline cars.
- During the period 1997-2005, the market share of gasoline cars has fallen from 60% to 50%. Furthermore, the diesel stock is younger than the gasoline stock. So, there is a phenomenon of "dieselisation" of the car stock.
- For the period 1997-2005, 97% of the car stock was between 0 and 30 years old, 96% was younger than 20 years.

5 Some car dealers realize "fictive registrations" in order to increase their sales figures. Vehicles are registered and retired of the stock after less than a month. So, registrations for new cars are overestimated.

3.3. Estimation results

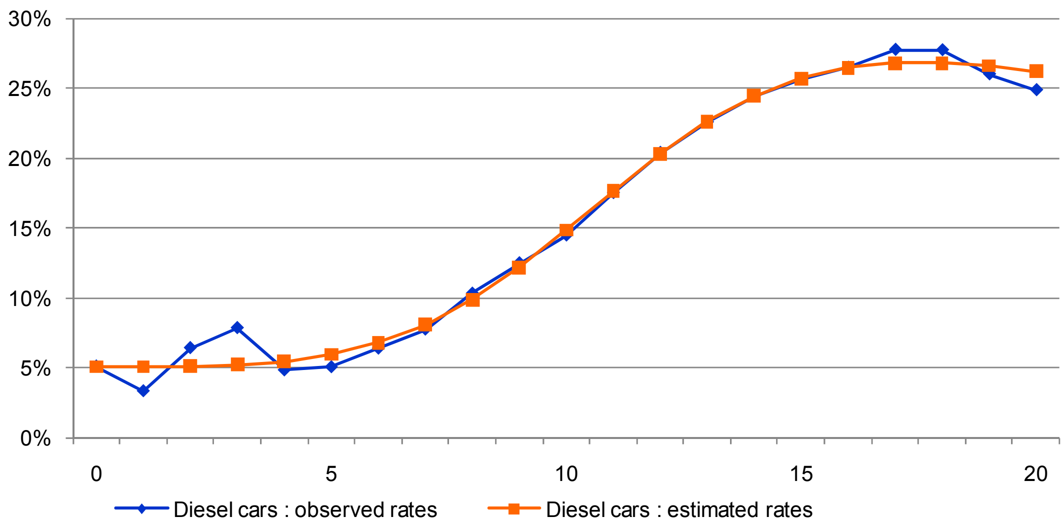
Based on the observed scrappage rates presented above, the constant and the parameters λ and ρ of the loglogistic hazard function were estimated by means of a nonlinear least squares estimator in TSP. The estimation only takes into account vehicles of 20 years and younger. This is done because the stock after this age becomes less representative as the number of old vehicles becomes smaller and smaller[6]. Table 1 presents the estimated values of the parameters λ, ρ and *cons* and the corresponding t-statistic. It also gives the R-squared of the estimated models.

Table 1: Estimated parameters of the loglogistic hazard function (t-statistic between brackets)

	Diesel cars	Gasoline cars
λ	0,075	0,076
	(68,28)	(53,58)
ρ	4,816	4,734
	(56,23)	(44,97)
Cons	0,051	0,020
	(14,48)	(4,63)
R^2	0,990	0,983

Figure 2 and 3 present the observed and estimated scrappage rates for the 2 vehicle types.

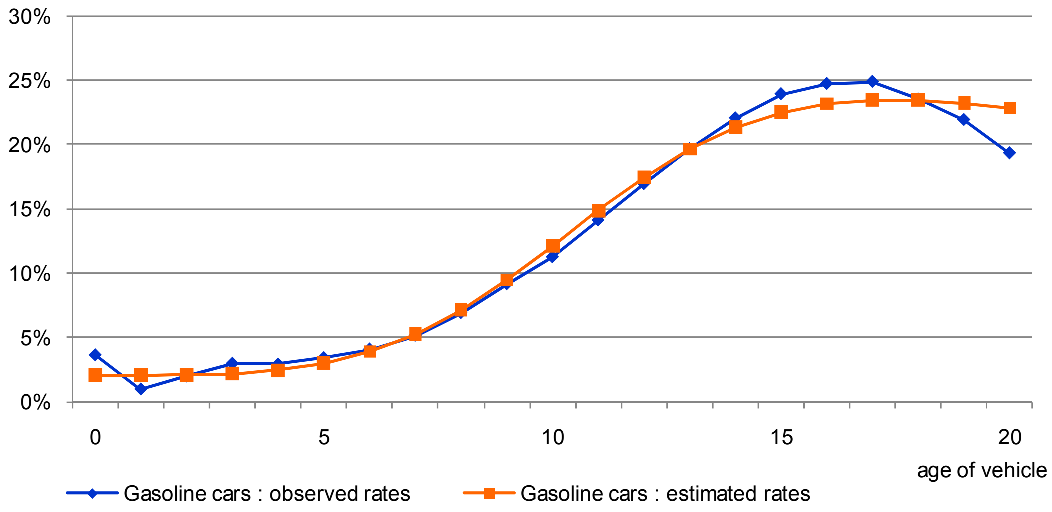
Figure 2: Observed and estimated scrappage rates for diesel cars between 0 and 20 years old



Source: FPB.

[6] In the period 2000 to 2005, 96% of the car stock was between 0 to 20 years old.

Figure 3: Observed and estimated scrappage rates for gasoline cars between 0 and 20 years old



Source: FPB.

The comparison of the observed and estimated scrappage rates shows that the estimated scrappage rates are able to reflect rather well the specificities of the car fleet evolution. Nevertheless, for the 4 first years of registration, the estimated scrappage rate cannot reproduce the fluctuations of the observed scrappage rate.

4. The composition of car sales

In this section we describe the way in which the technology choice for new vehicles is modelled. We model the choice between three car sizes (small, medium and big)[7] and between different technologies (diesel, gasoline, hybrid diesel, hybrid gasoline, LPG and CNG). The EURO type of the cars is assumed to be determined by the year in which it is bought. The car choice is modelled by means of a nested logit model[8].

4.1. The nested logit model for car sales

The decision structure for determining the share of the different car types in car sales is presented in Figure 4. Simultaneously with the choice of the car type, the model also determines the annual mileage of the new cars. In Figure 4 Level 1 describes the choice between small and medium cars on the one hand and big cars on the other hand. Conditional on this choice, the category of small and medium cars is split into small cars and medium cars (Level 2). Finally, given the decision on the car size, the choice between diesel and gasoline cars is determined at Level 3. Finally, the number of hybrid and conventional diesel cars is determined by applying exogenous shares of these two subtypes in total diesel car sales. Similarly, total gasoline car sales are split into conventional and hybrid gasoline cars, CNG cars and LPG cars by applying exogenous shares for these four subtypes.

In more formal terms we are dealing with a multidimensional choice set:

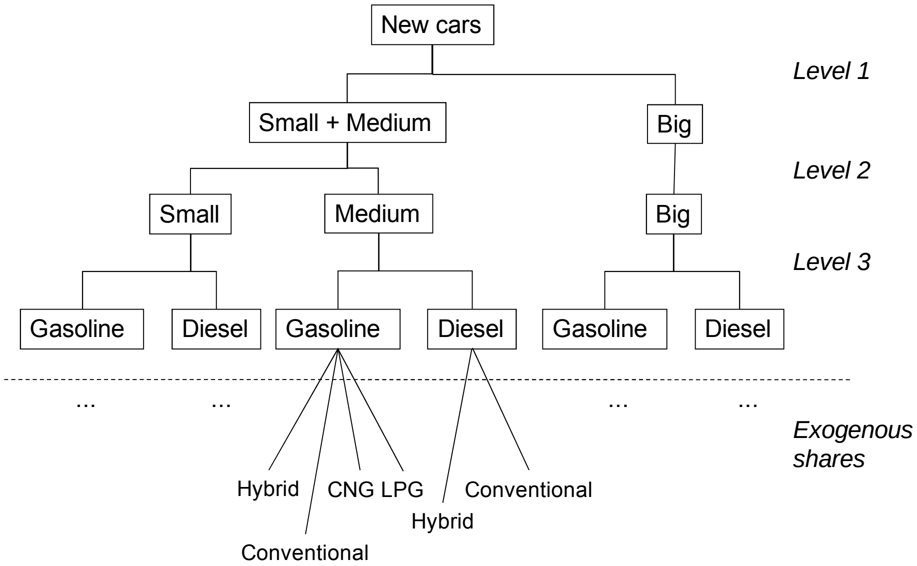
C_1	size (small, medium, big)	indexed by s
C_2	fuel type (gasoline, diesel)	indexed by f

and we take into account that elements of the choice set C_1 share unobserved attributes. Therefore, we model an additional level, where the choice is made among different composite sizes (small+medium, big), indexed by cs.

[7] The car sizes are defined as follows: 0-1400 cc = small, 1401-2000cc = medium, >2000cc big.

[8] For more information about nested logit models see e.g., Koppelman and Wen (1998), Heiss (2002) and Hensher and Greene (2002).

Figure 4: Decision structure for car purchases



4.1.1. Level 3

Level 3 describes, conditional on the purchase of a car of a given size s and composite size cs, the choice of the fuel type. Consistent with the discrete choice literature, indirect utility $v(f|cs,s)$ of selecting alternative f given size s and composite size cs is written as

$$v(f|cs,s) = V(f|cs,s) + \eta(f|cs,s)$$

where $V(f|cs,s)$ is the deterministic 'universal' indirect utility function, assumed to be the same for everyone, and $\eta(f|cs,s)$ is an individual-specific component that reflects idiosyncratic taste differences. Based on de Jong (1990), the following functional form is used for the deterministic component of indirect utility, conditional on the purchase of a car of type f (given s and cs):

$$V(f|cs,s) = \left[\begin{array}{l} \dfrac{1}{\beta(f|cs,s)} \exp\left(\delta(f|cs,s) - \beta(f|cs,s) MVC(f|cs,s)\right) \\ + \dfrac{1}{1-\alpha(f|cs,s)} \left(Y - K(f|cs,s) - F(f|cs,s)\right)^{1-\alpha(f|cs,s)} \end{array} \right] \Big/ \xi_{ref}(f|cs,s)$$

where $MVC(f|cs,s)$ is the monetary variable cost of travel for households buying a car of fuel type f (given s and cs) and Y represents monetary income. $K(f|cs,s)$ and $F(f|cs,s)$ are the annual fixed resource cost and the annual fixed tax for a car of type f (given s and cs). Finally, $\alpha(f|cs,s)$, $\beta(f|cs,s)$ and $\delta(f|cs,s)$ are parameters. Note that we express indirect utility in monetary terms by dividing by $\xi_{ref}(f|cs,s)$, the marginal utility of income in the reference equilibrium.

The conditional annual mileage travelled by a newly bought car can be obtained by applying Roy's identity to the conditional indirect utilities:

$$X(f|cs,s) = \exp[\delta(f|cs,s) - \beta(f|cs,s)MVC(f|cs,s)](Y - K(f|cs,s) - F(f|cs,s))^{\alpha(f|cs,s)}$$

The model therefore allows not only to determine the type of vehicle that is bought, but also the annual mileage driven by newly purchased vehicles. From the previous equation it can easily be derived that the elasticity of the conditional annual mileage w.r.t. the monetary variable cost equals $-\beta(f|cs,s)GVC(f|cs,s)$. In addition, $\alpha(f|cs,s)$ equals the elasticity of conditional annual mileage w.r.t. monetary disposable income.

Assuming that people select the fuel type that yields highest utility, and that the individual-specific components $\eta(f|cs,s)$ are distributed Gumbel i.i.d., the probability of choosing a car of type f (conditional on size s and composite size cs) is then given by the logit expression:

$$P(f|cs,s) = \frac{\exp[\mu(s|cs)V(f|cs,s)]}{\sum_{f'|s,cs}\exp[\mu(s|cs)V(f'|cs,s)]} = \frac{\exp[\mu(s|cs)V(f|cs,s)]}{\exp[IV(s|cs)]}$$

$\mu(s|cs)$ is a scale parameter and is inversely related to the standard deviation. A higher μ indicates less independence among the unobserved portions of utility for alternatives in the subnest $(s|cs)$. $IV(s|cs)$ is the inclusive value:

$$IV(s|cs) = \ln\left(\sum_{f}\exp[\mu(s|cs)V(f|cs,s)]\right)$$

It links the lower and middle level of the model by bringing information from the lower model to the middle model. It is more or less the expected extra utility from s by being able to choose the best alternative in $s|cs$.

4.1.2. Level 2

Level 2 describes the choice between small and medium cars, conditional upon the choice of a car belonging to the composite size "small+ medium". The conditional probability of choosing s, given cs, is given by:

$$P(s|cs) = \frac{\exp\left[\frac{\lambda(cs)}{\mu(s|cs)}IV(s|cs)\right]}{\sum_{s'|cs}\exp\left[\frac{\lambda(cs)}{\mu(s'|cs)}IV(s|cs)\right]} = \frac{\exp\left[\frac{\lambda(cs)}{\mu(s|cs)}IV(s|cs)\right]}{\exp[IV(cs)]}$$

$\lambda(cs)$ is a scale parameter. $IV(cs)$ is the inclusive value of the subset of alternatives in cs:

$$IV(cs) = \ln\left(\sum_{s|cs} \exp\left[\frac{\lambda(cs)}{\mu(s|cs)} IV(s|cs)\right]\right)$$

For big cars, this decision level is irrelevant, since the composite size 'big' is associated with only one size (big). Therefore $P(s{=}big|cs{=}big){=}1$.

4.1.3. Level 1

Finally, at level 1, the marginal probability of choosing composite size cs is given by:

$$P(cs) = \frac{\exp\left[\frac{\rho}{\lambda(cs)} IV(cs)\right]}{\sum_{cs'} \exp\left[\frac{\rho}{\lambda(cs')} IV(cs')\right]} = \frac{\exp\left[\frac{\rho}{\lambda(cs)} IV(cs)\right]}{\exp(IV)}$$

The overall inclusive value (IV) can be written as:

$$IV = \ln\left(\sum_{cs} \exp\left[\frac{\rho}{\lambda(cs)} IV(cs)\right]\right)$$

Very often ρ is normalised to equal unity.

The probability that one buys a car of composite size cs, size s and fuel type f is given by:

$$P(cs, s, f) = P(f|cs, s).P(s|cs).P(cs)$$

4.1.4. Scale parameters

For the model to be consistent with utility maximisation the following conditions must be satisfied for the scale parameters:

$$\rho \leq \lambda(cs) \leq \mu(s|cs) \quad \text{and} \quad \rho, \lambda(cs), \mu(s|cs) > 0 \quad \forall cs, s|cs$$

This means that the variance of the random utilities at the lowest level should not exceed the variance at the middle level, which should not exceed the variance at the top level. The conditions imply that:

$$0 < \frac{\lambda(cs)}{\mu(s|cs)} \leq 1 \quad \forall cs, s|cs \quad \textit{and} \quad 0 < \frac{\rho}{\lambda(cs)} \leq 1 \quad \forall cs$$

With $\rho = \lambda(cs) = \mu(s|cs)$ the nested logit model reduces to a joint logit model (MNL model for the joint choice of vehicle size and fuel type).

4.2. The calibration of the nested logit model for car sales

4.2.1. Data

In order to construct a reference equilibrium on which to calibrate the model, we collected data on car sales, annual mileage of new cars, variable and fixed costs and monetary income for the year 2005. Table 2 gives an overview of the different cost components, monetary income (GDP/capita), annual mileage and shares of the different vehicle types in total car sales.

Table 2: The reference equilibrium

		Reference equilibrium		
		Small	Medium	Big
Fixed taxes (€/car/year)[(1)]	Gasoline	448	645	1364
	Diesel	447	769	1381
Variable taxes (€/100vkm)[(2)]	Gasoline	6.5	8.4	10.7
	Diesel	3.4	4.0	5.2
Fixed monetary costs excl. taxes (€/car/year)[(3)]	Gasoline	1163	1924	4109
	Diesel	1323	1955	3476
Variable monetary costs excl. taxes (€/100vkm)[(4)]	Gasoline	8.3	11.7	17.7
	Diesel	6.9	7.4	9.7
GDP/capita (€/person/year)		26085	26085	26085
Annual mileage (km/year)	Gasoline	12393	13747	17432
	Diesel	14808	22731	30588
Sale probabilities[(5)]	Gasoline	19.97%	8.51%	0.78%
	Diesel	27.33%	39.85%	3.56%

(1) Includes registration tax, traffic tax, radio tax and indirect taxation on purchase, insurance and control.
(2) Includes indirect taxation on maintenance and fuel (plus the fuel excise).
(3) Includes purchase, control and insurance costs net of taxes.
(4) Includes fuel and maintenance costs net of taxes.
(5) Observed shares of the different vehicle types in total car sales in base year.
Sources: BFP, CBFA, DIV, IEA, INS, FPS Economics, SPF Mobility and Transport, VITO.

The data for the reference equilibrium show monetary costs rising with size. The variable costs of diesel cars are lower than those of gasoline cars. The fixed costs of diesel cars are higher than for gasoline cars, except for the biggest cars. In the case of big cars this is because the average size of big gasoline cars is larger than that of big diesel cars. Monetary costs cannot fully explain the observed behaviour. As we will see, some characteristics or hidden taste differences cannot be accounted for by using cost data alone. A constant term is therefore introduced in the calibration to the equation for indirect utility (more detail in the next section).

4.2.2. Methodology

Calibration of the model requires further information on the value of the income elasticity and the elasticity w.r.t. variable costs of annual mileage. Our income and cost elasticities are based on De Jong (1990). The income and cost elasticities of De Jong (1990) are adjusted to account for differentiation by car size. This permits to obtain reasonable elasticities and greatly improves the results.

Table 3: Target elasticity values of conditional annual mileage with respect to monetary income and variable costs

	Small car	0.22
Elasticity w.r.t. monetary income	Medium car	0.23
	Big car	0.39
	Small car	-0.14
Elasticity w.r.t. monetary variable costs	Medium car	-0.22
	Big car	-0.45

Given these target elasticities and information for the base year, the parameters $\alpha(f|cs,s)$, $\beta(f|cs,s)$ and $\delta(f|cs,s)$ can be easily obtained:

$\alpha(f|cs,s)$ = Target monetary income elasticity of annual mileage

$\beta(f|cs,s)$ = Target elasticity of annual mileage w.r.t. monetary cost / $MVC_{ref}(f|cs,s)$

$\delta(f|cs,s) = \ln[X_{ref}(f|cs,s)] + \beta(f|cs,s) * MVC_{ref}(f|cs,s) - \alpha(f|cs,s) * \ln[Y_{ref} - K_{ref}(f|cs,s) - F_{ref}(f|cs,s)]$

$\xi(f|cs,s) = \alpha(f|cs,s) * [Y_{ref} - K_{ref}(f|cs,s) - F_{ref}(f|cs,s)]$

Given these values, indirect utilities $V(f|cs,s)$ can be calculated. We note that in the final calibration, we added a constant (chosen to obtain reasonable elasticity values) to the equation for indirect utility. This step was necessary, since we found that some features of the data in the base year could not be properly explained within the discrete choice framework by the cost and income data alone. To capture the existence of unobservable characteristics, we added a constant to the indirect utility function. The values of these constants have been taken as small as possible.

Given these parameters, the scaling parameters can be determined. For example, given indirect utilities, the lower nest scaling parameters $\mu(s|cs)$ can be calculated as follows:

$1 / \mu(s|cs) = [V(\text{“dies”}|cs,s) - V(\text{“gas”}|cs,s)] / \ln[P(\text{“dies”}|cs,s)/P(\text{“gas”}|cs,s)]$

The scaling parameters for the other levels can be obtained in a similar way.

4.2.3. Calibrated elasticities

Table 4 and Table 5 give the calibrated elasticities of conditional annual mileage of newly purchased cars and of the probabilities of buying the different car types, in both cases w.r.t. monetary variable costs, fixed costs and money income.

The elasticity values of annual mileage w.r.t. to monetary costs and income in Table 4 largely reflect the elasticities chosen in the calibration procedure. Elasticities of mileage w.r.t. fixed costs are significantly smaller, as can be expected since these changes only influence mileage indirectly through changes in money income.

The elasticity values in Table 5 reflect to a large extent the structure of the nested utility function. By choosing this functional form, one imposes certain restrictions on the behavioural reactions that are allowed by the model. For example, the close–to–zero income elasticities of expenditure shares are a direct result of the homogeneity of the utility function. Similarly, the nesting structure will ensure that reactions of different categories in one nest of the utility function to changes in another nest will be equal. For example, the cross-price elasticities of medium gasoline and diesel cars w.r.t. to changes in the price of small cars are equal. Reactions of medium and small car sales to changes in the price of big cars are equal, owing to the separation of big cars on the one hand and small and medium cars on the other hand in the upper nest of the utility function.

The own price elasticity is less pronounced for diesel cars than for gasoline cars, while cross–price elasticities are markedly larger. Small cars are in general less sensitive to changes in the own price than big cars.

To get a better feel for the behavioural impact of a change in car costs, we have performed some additional simulations with the model. Table 6 summarises the impacts of doubling the fixed and generalised variable costs of cars of different sizes. For example, doubling the fixed costs of small cars would reduce their share from 47% to 36% of car sales. As can be expected, such a price change would primarily benefit the sale of medium cars.

Table 7 presents the impacts of doubling the fixed and generalised variable costs of gasoline and diesel cars. Doubling the generalised variable costs of gasoline cars would decrease the share of gasoline cars in sales from 29% to about 0%. For diesel cars the doubling of these costs would bring their share from 70% to 1%. The doubling of the fixed costs of diesel would result in a diesel share of 0% rather than 70%. This means that inside the same size category diesel and gasoline cars are near perfect substitutes.

Table 4: Calibrated elasticity values for average annual mileage of newly purchased cars

	Monetary variable costs						Fixed costs						Mone-tary income
	Small		Medium		Big		Small		Medium		Big		
	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	
Small cars													
Gasoline	-0.14	-	-	-	-	-	-0.01	-	-	-	-	-	0.23
Diesel	-	-0.14	-	-	-	-	-	-0.02	-	-	-	-	0.24
Medium cars													
Gasoline	-	-	-0.22	-	-	-	-	-	-0.03	-	-		0.25
Diesel	-	-	-	-0.22	-	-	-	-	-	-0.03	-	--	0.26
Big cars													
Gasoline	-	-	-	-	-0.45	-	-	-	-	-	-0.10	-	0.49
Diesel	-	-	-	-	-	-0.45	-	-	-	-	-	-0.09	0.48

Table 5: Calibrated elasticity values for car sale probabilities

	Monetary variable costs						Fixed costs						Mone-tary income
	Small		Medium		Big		Small		Medium		Big		
	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	Gaso-line	Diesel	
Small cars													
Gasoline	-3.00	2.28	0.06	0.28	0.01	0.03	-2.63	2.66	0.06	0.30	0.01	0.03	0.00
Diesel	2.00	-1.88	0.06	0.28	0.01	0.03	1.76	-2.19	0.06	0.30	0.01	0.03	0.00
Medium cars													
Gasoline	0.10	0.11	-17.58	18.59	0.01	0.03	0.09	0.13	-16.37	19.55	0.01	0.03	0.00
Diesel	0.10	0.11	3.68	-4.33	0.01	0.03	0.09	0.13	3.43	-4.55	0.01	0.03	0.00
Big cars													
Gasoline	0.07	0.08	0.04	0.20	-16.52	16.38	0.06	0.09	0.04	0.21	-18.18	17.55	-0.01
Diesel	0.07	0.08	0.04	0.20	3.44	-4.44	0.06	0.09	0.04	0.21	3.79	-4.75	0.00

Table 6: The impacts of doubling the fixed or variable costs of different car sizes

	Share in reference equilibrium	Generalised variable costs x 2			Fixed costs x 2		
		Small	Medium	Big	Small	Medium	Big
Small cars	47.29%	37.27%	61.72%	48.38%	36.04%	63.76%	48.64%
Medium cars	48.37%	57.81%	33.05%	49.48%	58.97%	30.89%	49.74%
Big cars	4.34%	4.92%	5.24%	2.14%	4.99%	5.36%	1.62%

Table 7: The impacts of doubling the fixed or variable costs of gasoline and diesel cars

	Share in reference equilibrium	Generalised variable cost x 2		Fixed cost x 2	
		Gasoline	Diesel	Gasoline	Diesel
Gasoline cars	29.26%	0.30%	98.70%	0.39%	99.52%
Diesel cars	70.74%	99.70%	1.30%	99.61%	0.48%

5. Output of the car stock module

For each year of the simulation, the vehicle stock module provides the composition of new vehicle sales and calculates average cost data.

As described above, new vehicle sales are calculated each year by comparing the total desired vehicle stock (defined as total vehicle km divided by average annual mileage of the previous year) to the remaining vehicle stock of the previous year after scrappage.

Sales of new cars are then divided among gasoline and diesel cars of different sizes according to the above demand system. A final step calculates the share of LPG, CNG and hybrid gasoline and diesel cars using exogenously defined shares.

For all road vehicle types the vehicle stock module provides outputs on three classes of monetary costs which serve as an input of the Modal and Time Choice module of the next year. It concerns weighted averages, where the weights are the shares of each fuel, size and Euro category in total mileage driven.

The cost categories are:
- Taxes paid per vkm (including all taxes: indirect taxes, excises and fixed taxes)
- Fuel costs per vkm (Fuel expenditure including excises and taxes)
- Total monetary costs per vkm (All monetary costs – fixed and variable – including taxes)

In addition, the vehicle stock module determines the annual mileage of the newly bought cars. This is combined with the annual mileage of the older cars, to determine the average annual car mileage. This is used in the next period to determine the total desired car stock (by dividing the number of car vkm by the average annual car mileage).

6. Links of the car stock module with the other modules

Table 8 and Table 9 summarise the links between the car stock module and the other PLANET modules.

Table 8: Input in the car stock module of year *t* from the other PLANET modules

	Input from	Year
Total vehicle km of cars, LDV and HDV	Modal and time choice	*t*
Generalised income per capita	Macro	*t*
Taxes on the various car types	Policy	*t*
Average annual mileage of cars	Vehicle stock	*t-1*

Table 9: Output of the car stock module of year *t* to the other PLANET modules

	Output to	Year
Average emission factors per road transport mode	Welfare	*t+1*
Average monetary costs, fuel costs and taxes per road mode	Modal and time choice	*t+1*

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