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The Swedish Car Fleet Model

Evaluation of Recent Applications

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CTS Working Paper 2014:18

Abstract

The composition of the car fleet with respect to age, fuel consumption and fuel types plays an important role on environmental effects, oil dependency and energy consumption. In Sweden, a number of different policies have been implemented to support CO2 emission reductions. In order to evaluate effects of different policies, a model for the evolution of the Swedish car fleet was developed in 2006. The model has been used in a number of projects since then, and it is now possible to compare forecasts with actual outcomes. Such evidence is relatively rare, and we think it may be useful to share our experience in this respect.

We give a brief overview of the Swedish car fleet model. Then we describe policies that have been implemented in recent years and the evolution of the Swedish car fleet. We then focus on two projects which enable comparison with actual outcomes, and analyse the differences between forecasts and outcomes. We find that the model has weaknesses in catching car buyers' preferences of new technology. When this is not challenged too much, the model can forecast reasonably well on an aggregate level. We also find that he model is quite sensitive to assumptions on future supply. This is not so much related to the model, but to its use. Depending on the use of the forecasts – be it car sales, emissions or fuel demand – it may be necessary to use different supply scenarios to get an idea of the robustness of the forecast result.

Keywords: clean car policy, car fleet model, forecasting, model evaluation, scrapping model, nested logit.

JEL Codes: R40

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July 2014

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1. Introduction

A vision was adopted by the Swedish parliament in 2011. The vision states that Sweden should have a zero net emission of greenhouse gases to the atmosphere by 2050 and have a fossil independent car fleet by 2030. To achieve this goal there is a need to combine different policies and acts. In recent years, the car fleet composition has been the target of many transport policies aiming to create a more energy efficient car fleet with less greenhouse gas emissions. The composition of the car fleet with respect to age, fuel consumption and fuel types plays an important role on environmental effects, oil dependency and energy consumption. The Swedish car fleet composition has been affected largely by different policies implemented at national or local level. Based on statistics, the Swedish fleet has changed from a large, powerful fleet with high CO2 emissions to a fleet with higher share of clean cars in new sales since the implementation of these different policies[1]. In order to evaluate and quantify the effects as well as the costs of different policies, models that can predict reliably future purchasing behaviour as a response to these policies are needed. Car fleet models are usually employed for analysing and comparing different economic and demographic scenarios. These models quantify the response of individuals to policy variations. Several studies have modelled car fleet in order to evaluate the effect of different implemented policies (see e.g. Berkovec, 1985; Goldberg, 1995; West, 2004; and Fang, 2008). In 2006, a car fleet model system was developed for the Swedish Transport Administration to facilitate the evaluation of policies affecting the car fleet composition and understanding the mechanism driving the changes. This model system consists of three separate sub-models; a car ownership model, a scrapping model and a new car purchase model. These models have been developed separately but are used together in the car fleet model system. A great effort was made when developing the new car type choice model using both revealed preference as well as stated preference data in the estimation process (Transek, 2006). This model predicts what cars will be added to the car stock.

The model system has been used in several predicting studies, e.g. to measure the effects of introducing a 1 000 Euros subsidy for privately bought clean cars, a project carried out for the Swedish Transport Administration, and analysing the suggested climate policies from the Swedish Environmental Protection Agency (Naturvårdsverket, 2007). These studies were conducted some years ago, which gives us the possibility to evaluate the performance of the model system. In all application, we compare actual and forecasted outcomes. Most studies in the car-type choice area focus on model estimation and only a limited number are dedicated to forecasting (e.g. Mannering et al., 1991 and Brownstone et al., 1998). To the best of our knowledge, none compare predictions to actual outcomes as we do here. The results show that the uncertainty of future

[1] For the extensive review of these policies refer to (Beser Hugosson & Algers 2012) and (Pädam et al., 2012)

technologies are challenging even for the short-term forecast. There exists few studies that deal with new technology production models (See e.g. Berkovec, 1985a; Berkovec, 1985b). This is of great interest when developing and improving the existing Swedish model system.

In this paper we will briefly describe the Swedish car fleet model system and the data used for model estimation in section 2. In section 3 we introduce some of the interesting policies that have been implemented in Sweden and the observed effects on the car fleet. We will also compare forecasts studies carried out using the model system with actual outcome in section 4. This comparison will allow us to draw conclusions on the model system performance. It will give us more knowledge about crucial assumptions when modelling the car fleet transformation. In section 5, a discussion takes place and finally conclusions are made in section 6.

2. Swedish car fleet model system

Different policies may be more or less efficient with respect to the policy objectives. Therefore it is of great importance to be able to predict the impact that suggested policies have on consumers' behaviour. For this reason a forecasting tool has been developed, in 2006 (Transek, 2006) and further developed and updated several times. In this section a brief description is made of this model system.

2.1 Model system overview

The car fleet model system is a cohort model which annually updates the stock of the cars by subtracting scrapped cars and adding new cars. The model can be generally formulated in the following way:

$$V^{vs,t} = V^{vs,t-1} - S^{vs,t} + P^{vs,t} * N_t$$

where,
$V^{vs,t-1}$, is the number of cars of vintage v and type s in the stock in the end of year t−1,
$S^{vs,t}$, is the number of scrapped cars of vintage v and type s during year t
$P^{s,t}$, is the share of new cars of current vintage and type s added during year t,
and,
N_t, is the total number of new cars added during year t, which is equal to the total fleet size in the end of year t, minus the total number of scrapped cars size during year t: $\sum_{vs} V_t^{vs} - \sum_{vs} S_t^{vs}$.

Therefore, the Swedish car fleet model is composed of different sub-models as follows:

- A total fleet size model, car ownership model, which output is $\sum_{vs} V_t^{vs}$
- A scrapping model, which output is $S^{vs,t}$
- A car type choice model (for new cars), which output is $p^{s,t}$.

Figure 1 schematically shows the Swedish car fleet model with its different sub-models. The result from the model system is the distribution of cars of different vintages and types, using different fuel and different fuel consumption. From this distribution the average fuel consumption, F_t, and average CO2 emissions, C_t, are calculated. These are calculated as an average over all car types and vintages in the car fleet. Thus

$$F_t = \sum_{vs} (V_t^{vs} * f^{vs}) \Big/ \sum_{vs} V_t^{vs}$$

and

$$C_t = \sum_{vs} V_t^{vs} * C^s f^{vs} \Big/ \sum_{vs} V_t^{vs}$$

where,

f^{vs} is the fuel consumption rate of cars of vintage v and type s,

c^S is the fuel cost of cars of type *s*.

To make a forecast with the model system, the car fleet composition is thus calculated yearly from the base year to the forecast year of interest for different forecast years. The year by year calculation is made by subtracting all scrapped cars by type and vintage, and adding all new purchased cars by type to the existing car fleet.

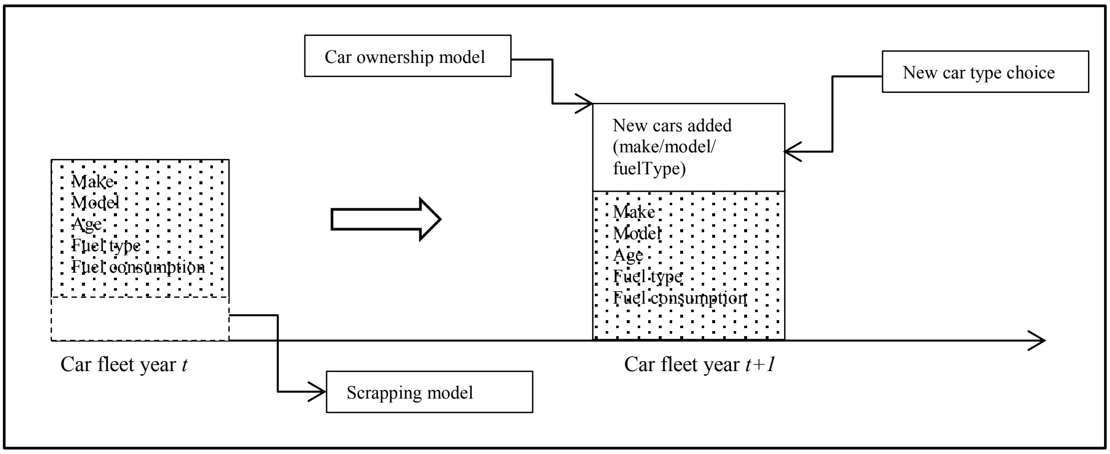


Figure 1. Swedish car fleet model system

2.2 Car ownership model

The total fleet size model is a car ownership model used in the national planning process (VTI, 2002). This model is also a cohort model, based on individual car ownership entry and exit probabilities. The number of car owners is annually updated using models for these probabilities. The models are mainly driven by socio economic variables, and the only policy variable is petrol cost. The variable is meant to represent costs of driving, and might have been justified at the time the model was developed, more than ten years ago when the share of petrol cars was over 90 percent in the Swedish car fleet. When this model is used as a part of the car fleet model some inconsistency may take place as the average cost of driving depend on the mix of car types. This is a subject for future model improvement.

2.3 Scrapping model

The scrapping model is a simple aggregated model, based on the data from the car register from 2000 to 2004. It gives the percentage of the stock to be removed each year. The percentage varies depending on the car make and age. Generally defined, a household will scrap a car when the gained value from scrapping that car will be more than its obtained price in the used car market. Both aggregated and disaggregated models have been discussed in the literature. Aggregated models deal with the changes of the cars with specific ages. These changes can be either the number of scrapped cars or survival rates for cars of different ages. For an extensive review see De Jong et al. (2001).

2.4 New car type choice model

The car type choice model is the one that is responsive to different policies in the car fleet model system. To model what cars that will be added to the car fleet, we employ discrete choice models (Ben-Akiva & Lerman, 1985). Lave & Train's (1979) work on car type choice is the first disaggregate study to use multinomial logit model structure which includes vehicles characteristics as explanatory variables. Since then it has been used to model car type choice in different applications such as Train & Winston (2007), in the EU model system TREMOVE (2006) and, integrated with car use, by Bhat & Sen (2006). Page et al. (2000) study the distribution of the new car purchased to improve the British car market model (VMM) and Mohammadian & Miller (2003) build a model for a car ownership module of ILUTE (Integrated Land-Use, Transportation, and Environment) project which objective is policy analysis in the Greater Toronto Area[2].

Here, we model the choice of the new car type given that the decision to buy a new car is already made. The estimated choice model is of the nested logit type. Nested logit models for car type choice application have been employed in several studies (e.g. Mannering et al., 1991; Berkovec & Rust, 1985). In these models the elasticities among car alternatives within the same nest are larger compared to other alternatives. This means that if a new car alternative is introduced, this will affect the market share of closer car alternatives relatively more than for other car types.

[2] For extensive review about car fleet models refer to (Potoglou & Kanaroglou 2008) and (De Jong et al. 2004)

The new car type model is comprised of three consumer segments to capture the fact that different consumers value car attributes differently. One segment is private buyers, and the other two segments are company cars, with or without a leasing contract. The leased company car segment is typically the fringe benefit car segment although such cars can also be used as a shared car by the company (Beser Hugosson & Algers 2012). The shares of privately bought or company bought cars each year are exogenous in the model. For each of the three segments, a choice set of more than 300 different car alternatives is established.

The register data is the main data source used for estimation which includes the registration of new bought cars in the first half of 2004. This data set contains 162,000 new registrations that year. Each observation in the dataset includes some socioeconomic data of current and previous owners such as age and gender, some car attributes as year model, production year, registration date, date of previous transfers, if the car is privately owned or owned by a company and in case of company cars whether it is leased or not. Table 1 summarizes the number of cars in various categories.

Table 1. Number of cars in different categories in registry data

	New registration in 2004
No of cars	161529
Private owners	59848
company owners	86882
year model 2002 or earlier	14799

To gain access to additional attributes of cars (such as price, alternative fuel refuelling facilities, resale value and safety), other sources of data are needed. Data sources used to define these attributes as well as car alternatives are; data on performance of the different car models from a data base compiled by a Swedish motor journal (Teknikens värld), traffic safety classification from Folksam insurance company, and attributes for used and new cars from the Swedish Consumer Agency.

When modelling car type choice the possibility to introduce new technologies is of importance. The register data is restricted to already existing technologies; moreover, there may also be strong correlation between variables such as price, size and horsepower etc. To make it possible to vary attributes and include not only already existing attributes, a stated preference study was conducted. It is reasonable to assume that private car owners and company car owners have different values and conditions for buying a car. In order to better identify the various underlying factors that affect these groups, different SP surveys were conducted for each group. From the stated preference survey, it was possible to directly evaluate willingness to pay for different characteristics including environmental values (Transek, 2006). Stated preferences (SP) data has been used in several previous studies (see e.g. Hess et. al., 2009; Batley & Toner, 2003; Golob et al., 1993).

Different models have been estimated for private owners and company car owners (with or without a leasing contract). We choose an aggregation level of make/model/fuel-type. The variables included in the models should be able to describe different characteristics of the car alternatives, including performance, safety, costs etc, without incorporating high correlations in the model.

There are only two variables that are different in these three models. Purchase price is used for private owners, while the net benefit value is used for the company car owners. Running costs include both car tax and fuel consumption per year. It was found necessary to assume that the tax and fuel costs (converted to an annual cost) have the same parameter. Private owners pay both costs out of pocket, but for company car owners, it is assumed that half of the employees pay for the fuel themselves. The results show that the parameters of purchase cost and benefit value are negative and significant. The running cost is as expected significantly negative in all three models. This makes it possible to evaluate the effects on the particular car type choice of various policies such as fuel taxes and vehicle taxes. The hatchback body type is more important for company owned leased cars than for the privately owned cars. Size classification of the data is the same as the classification made by Folksam and NCAP. The Private owners prefer midsized cars, while large cars are preferred among company car owners. The parameter for gas, electric hybrid and diesel cars are significantly negative for private owners. For gas cars this expresses that the environmental benefits of these cars do not outweigh the disadvantages that may be associated with these car types *e.g.* shorter range, limited fuel supply, uncertainty about resale value. It was not possible to estimate a parameter for the variables describing the driving performance i.e. engine power, torque, top speed and acceleration. Instead the results of the SP survey were used. The engine power, has been converted in terms of the purchase price and benefit tax value for different type cars. Therefore, it was required to recalibrate of models estimated on private owners, which affected the constant terms for the different makes. The parameter for crash worthiness (safety class) is significant and positive. The tank volume is significant in all three models, and reflects the value of long range. The variable for number of years with anti-corrosion warranty reflects the vehicle's reliability in the long term, and maybe also the resale value. The positive and significant parameter indicates that this property is important for car type choice. For a more comprehensive description of the model and model result see Transek (2006).

2.5 Model updates

The models were estimated on 2004 data. In order to bring the model up to date for a specific base year, the model for new purchases has been calibrated to that specific base year. The calibration was carried out as an estimation of constants for fuel type and brand into the utility functions, not altering the coefficients for the attributes included in the model. The most recent calibration was performed in 2012 and corresponded to the 2011 situation.

3. Policies and effects on the car market in Sweden

3.1 Policies

In Sweden several policies have been introduced to transform the Swedish car fleet. The measures have been applied at national as well as local levels. It is important to distinguish between policies to prepare the market for changes and policies making the market change. Examples of policies used to prepare the market are green procurement, laws and regulations. An example of this is the law implemented in 2006 that obliged all larger refuelling stations to provide at least one renewable fuel. Examples of policies to force the market to change are clean car purchase subsidies, circulation taxes etc. In this section we give a brief description of some of the policy measures used in Sweden and the development of sales of new cars. Of course regulations at international level also will affect the Swedish car market.

3.1.1 Definition of clean cars

The definition of a clean car has been changed several times over the years, and a full explanation of this is not necessary to do here. The aim of the definitions has been to promote cars with low emissions of CO2 and cars using alternative fuels or has an electric engine as a part of the drive train. Different definitions have been used for different policies.

3.1.2 Company car benefit tax reduction

Employees who are being supplied a car by the employer for private travels are taxed for this benefit according to the purchase price of the car. As a special policy to favour the purchase of clean cars, the benefit values are lowered 20 – 40 percent for some categories of clean cars. Depending on the marginal taxation level, the maximum reduction is worth between 700 – 1 100 Euros per year net after tax.

3.1.3 CO2 based circulation tax

The CO2 based circulation tax consists of two parts – one part is a base tax per car (36 Euros per year), the second part is based on the CO2 emission. The CO2 component is 2 Euros per gram CO2 emission (over 117 g/km) for conventional cars and 1 Euro per gram for alternatively fuelled cars. For diesel cars a supplementary environmental tax is added. From July 2009, clean cars are exempt from this tax the first five years. In figure 2 the actual yearly CO2 based circulation tax is shown.

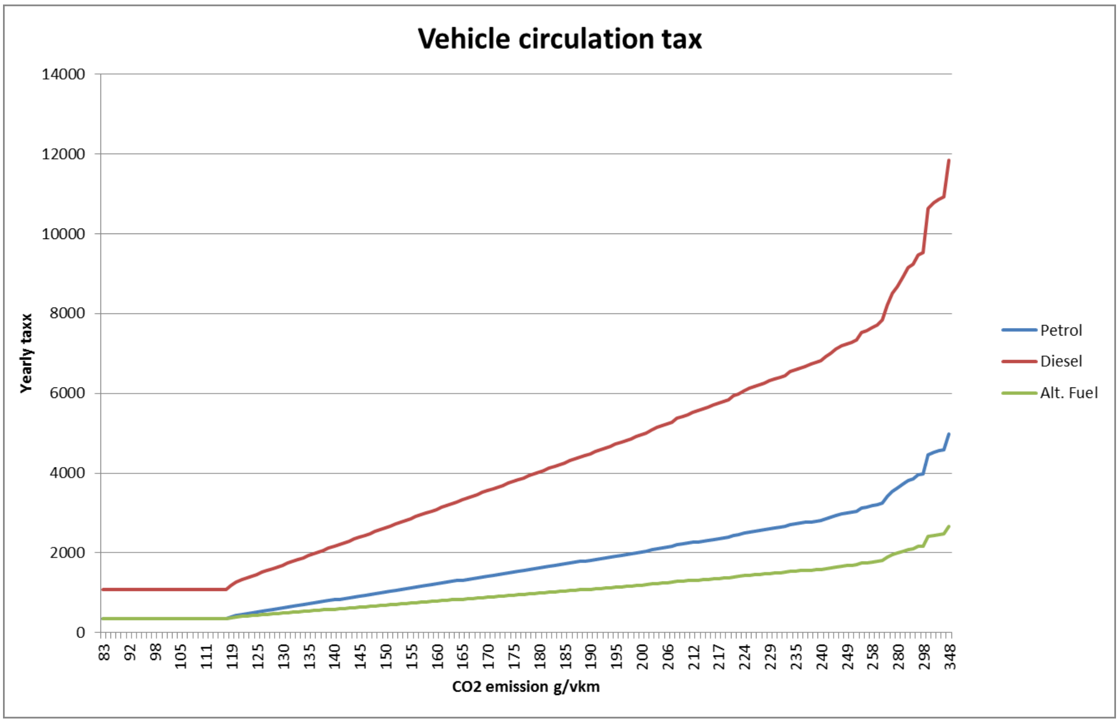


Figure 2. The CO2 based circulation tax in 2013.

3.1.4 Subsidy for purchase of new clean car (privately bought)

A subsidy for clean cars was introduced in April 2007. A rebate of 10 000 SEK (~ 1 100 Euros) was available if a new clean car was purchased by households (not companies). The subsidy ended in July 2009.

3.1.5 EU regulation on CO2 emission of new cars

The EU regulation (Regulation (EC) No 443/2009) sets emission performance standards for new passenger cars. The average CO2 emission from new cars should not exceed 130 g/km in 2015 and 95 g/km in 2020.

3.1.6 Congestion charge exempt and free city residential parking for alternatively fuelled cars

Alternatively fuelled cars were exempt from congestion charges in Stockholm from 2006 until 2012 for the car registered before January 2009 (this policy ended in 2009). The charge is differentiated during the day and varies between 1 to 2 Euros. The maximum fee is 6 Euros per day. The exempt may be worth up to 900 Euros per year for regular car commuters. Some municipalities introduced free residential parking for clean cars. In central Stockholm this subsidy was worth about 70 Euros per month (this policy ended in 2009).

3.1.7 Premium for purchase of new 'super-green-car'

A premium of maximum 40 000 SEK (~4 300 Euros) is available for a purchase of a 'super-green-car'. A 'super-green-car' is defined as a car that meets the Euro 5 and 6 regulations and emits maximum 50 grams CO2 per kilometre. The premium was introduced in January 2012.

3.2 Effects on the Swedish car market

In this section, we use statistics to observe actual changes of the Swedish car market. The statistics shows the development of fuel consumption, car sales and the development of car supply. The different fuel types we are observing are petrol and diesel car, low emission petrol and diesel cars (CO2-emission less than 120 g/km before 2013), gas cars running on natural or biogas, ethanol cars running on a mix of ethanol and petrol, electric cars, hybrids and plug-in hybrids.

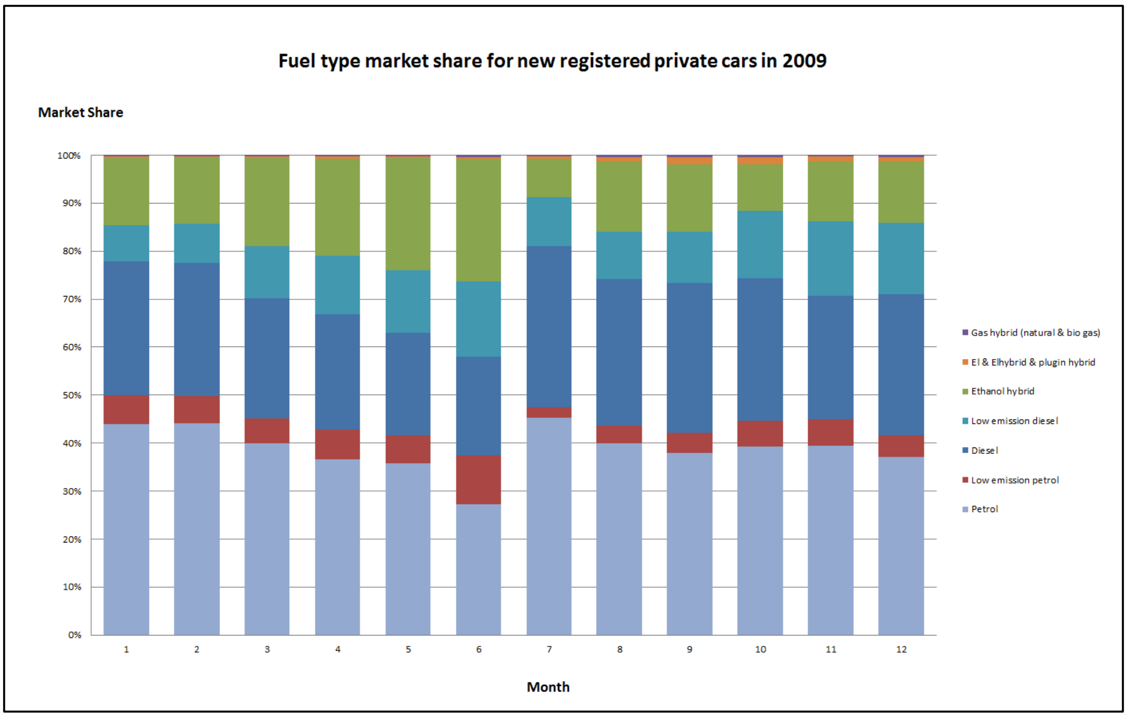


Figure 3. Fuel type market shares for new cars in 2009

The 1 000 Euros clean car subsidy was abolished in July and replaced by the exempt from CO2 based circulation tax (first five years) for clean cars[3]. The figure 3 illustrates

[3] In fact the tax exemption policy was introduced in January 2010 but implemented rectroactively from 1st July 2009.

the immediate effect of that policy change on new car sales. After the policy change in July 2009, the share of new low emission petrol and diesel cars as well as ethanol cars was reduced. Instead the share of petrol and diesel cars with higher emissions increased.

Both implemented policies and technology development aims to reduce average fuel consumption. When observing the fuel consumption from 2005 to 2011 a strong reduction of average consumption can be noticed. See table 2.

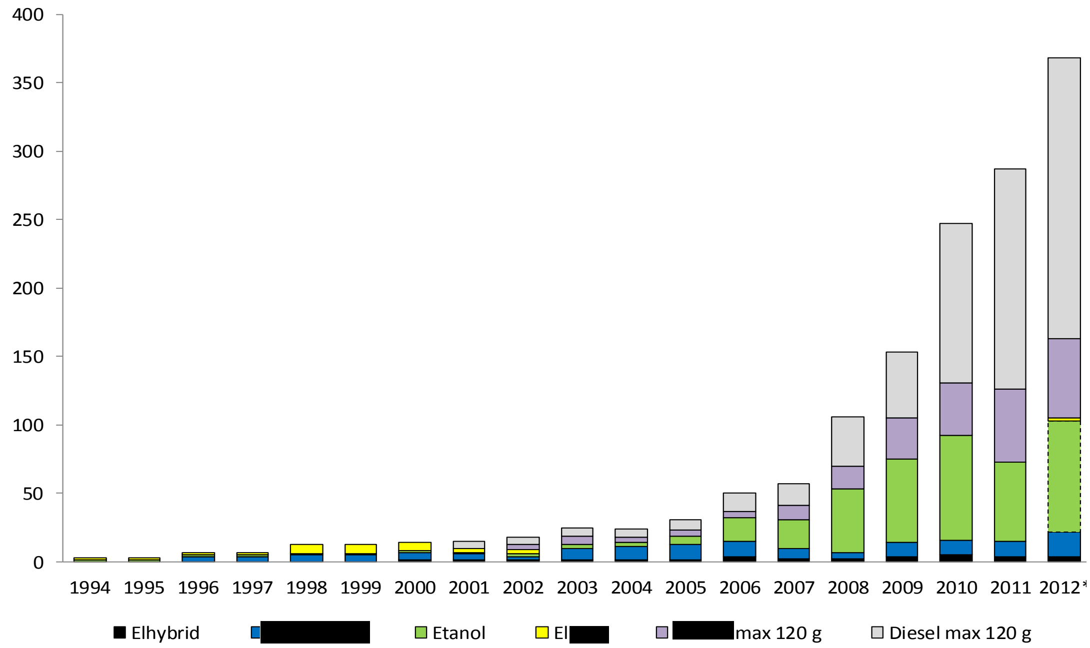
Table 2. Average fuel consumption in Sweden for new cars. *Source: Swedish Transport Administration*

Average fuel consumption						
Year	2005	2006	2007	2008	2010	2011
l/100 km	8.0	7.8	7.3	7.1	6.2	5.8

Several measures used in Sweden have had the purpose to support clean cars. In figure 4 the development of the supply of clean car models 1994-2012 is shown. We can notice a fast and powerful increase in available clean car models. The ethanol car models dominated among clean car models available from 2006 until 2010. After 2010 a reduction of ethanol models can be seen. The supply of biogas car models has been rather constant. After 2009 the low CO2 fossil fuel cars (in particular the diesel cars) dominate the supply of clean car models. The available hybrid models are still quite small.

In figure 5 we can follow the development of the fuel type market shares of new registered cars and when important policies were introduced. The highest share of ethanol cars can be noticed in 2008 and 2009. In 2006, only 19 percent of the market share was diesel cars in Sweden. In 2011 this share has increased to 61 percent. The most rapid increase is the share of low emitting fossil cars. This follows the observed effect on the supply, where the models available of diesel and petrol cars with low emissions have increased dramatically, see figure 4. Before 2013, the low emission petrol and diesel were defined to have emissions less than 120 gram/km. In 2013, the requirement became stricter. Many of the cars that are classified as clean car in 2012 do not meet the new requirements. This explains why the share of low emission petrol and diesel is decreased in 2013.

From the examples above, it is clear that the Swedish car market has undergone dramatic changes during the last 10 years. The supply of clean car models available for the customers has increased substantially. Moreover, the average fuel consumption of new cars has dropped considerably. Different incentives to promote clean cars have been introduced and some of them have been abolished. It is quite evident that the policies affect the sales of new cars, but there are several other factors that also must be taken into account. Such factors are technological breakthrough, consumer attitudes and confidence in new technology, media reporting of biofuels and car industry strategies to cope with a changing world. Altogether, these circumstances make the modelling of the car fleet composition a challenging task. In the next chapter, we will look at the success of some applications of the model system that has been done during the last years. By comparing the forecasts with the actual fleet or sales, important conclusions can be drawn regarding the need for improvement of the model system.



Note: The number of ethanol models has increased between 2011 and 2012. One reason is that Saab ethanol remains in the "guide for new cars" for 2012. Although Saab is no longer manufactured, according to "BIL Sweden" almost 400 Saab 9-3 BioPower and Saab 9-5 Biopower has been registered during January-July 2012.

Figure 4. Development of the supply of clean cars 1994-2012. (Pädam et al., 2012)

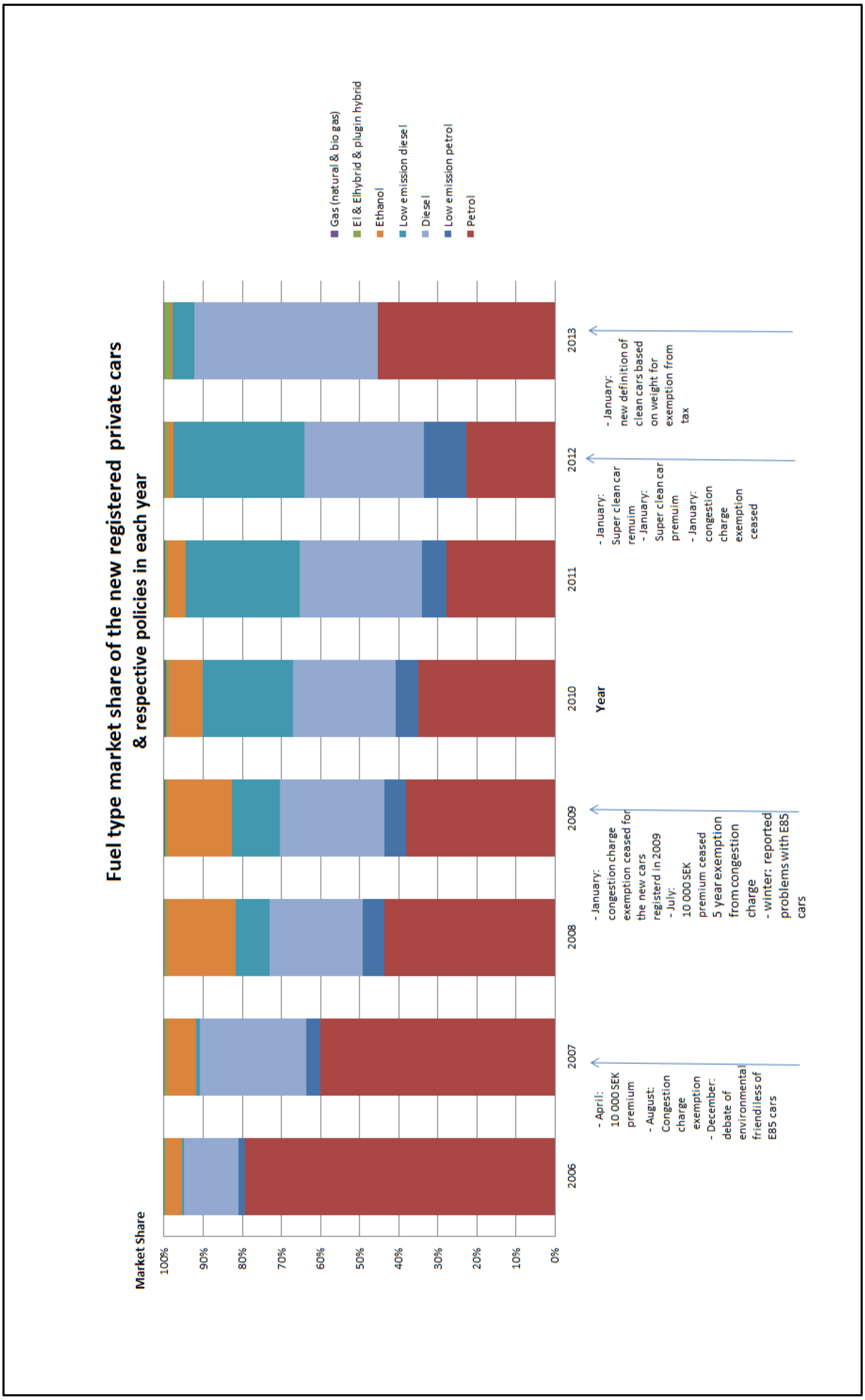


Figure5. Development of fuel type market shares of new cars and implemented policies

4. Model system application – forecasts and actual outcome

4.1 Introducing a 1 000 Euros subsidy for private purchase of a new clean car

The model has been used to forecast the effects of the 1 000 Euros purchase subsidy for clean cars that was introduced in 2007. The results are shown in table 3. When the actual car registrations became available in 2008, two additional forecasts were performed to validate the new car type choice model. Table 3 shows a comparison between the actual outcome and the forecast. As can be seen in the table the model underestimated the share of clean cars (10 percent instead of 18 percent).

Table 3. Comparison actual outcome and forecasting results

Make	Actual outcome		Forecast		Forecast 2		Forecast 3	
	Total	Clean car	Total	Clean car	Total	Clean car	Total	clean car
VOLVO	26741	6169	17926	2601	12302	2828	19068	4383
FORD	8617	3882	5526	1808	5526	1670	8565	2589
SAAB	6321	3823	4130	1004	4118	1195	6382	1852
OPEL	5619	53	3104	2	3251	130	5039	202
VOLKSWAGEN	11255	1929	7715	455	8220	1008	12740	1562
TOYOTA	13709	1352	7219	276	6666	613	10332	949
MAZDA	3094	0	2043	0	2092	0	3243	0
NISSAN	2848	0	1633	0	1672	0	2592	0
MERCEDES-BENZ	5272	3	3528	14	3614	16	5601	24
AUDI	6311	0	3415	0	3498	0	5421	0
BMW	6801	0	3988	0	4084	0	6330	0
PEUGEOT	11522	3080	7628	1907	8438	3019	13079	4679
FIAT	1827	1232	923	4	2398	1697	3716	2631
RENAULT	4953	447	5240	0	5813	806	9010	1249
HONDA	4369	273	1723	20	1769	28	2741	44
MITSUBISHI	1602	0	1832	0	1877	0	2909	0
CITROEN	7872	2568	3583	290	3623	784	5615	1215
SUZUKI	1469	120	1066	92	1092	95	1693	146
SUBARU	1687	0	1171	0	1199	0	1859	0
ALFAROMEO	248	0	233	0	238	0	369	0
Others	22863	3096	16375	1126	18513	2510	28695	3890
Total	155000	28027	100000	9600	100000	16397	155000	25416
Share of clean cars		18%		10%		16%		16%
Relative deviation				-66%		-41%		-9%
Absolute deviation				8427		-1630		-2612

In the first additional forecast, the exogenous assumption on supply was corrected to actual outcome (forecast 2 in table 3). In the second additional forecast, the total number of new cars was also corrected to the actual outcome (forecast 3 in table 3). By correcting the supply assumption, we get a reasonable share of clean cars, 16 percent, compared to the actual share, 18 percent. In that forecast the total number of new clean cars is still underestimated due to the wrong assumption on the total sale to private buyers

(100 000 cars instead of 155 000 cars). When both supply and the total number of new cars in the private segment are corrected, the model forecasts the total number of new clean cars reasonably well. Having access to registration data, it was also possible to compare the forecast and the outcomes on a more disaggregate level. In figure 6, forecast and actual numbers of new cars in the private segment by brand are shown. The model was calibrated on registration data for 2006 to match totals on brand and fuel type. It is reasonable to expect some inertia with respect to brand, due to brand loyalty. In figure 7, forecast and actual numbers of new clean cars in the private segment are shown.

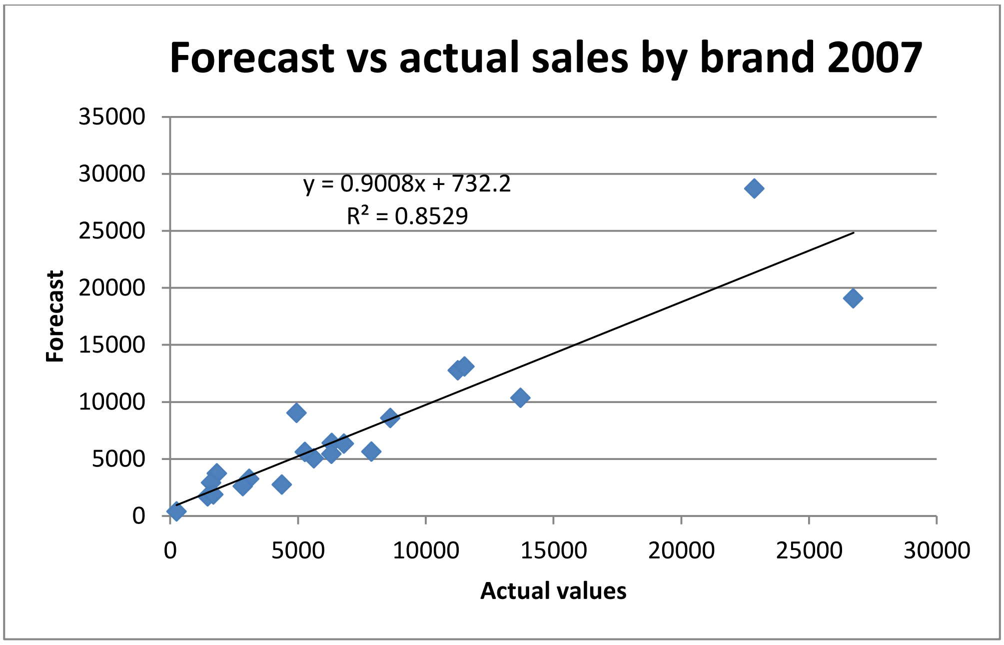


Figure 6. Forecast and actual sales of new cars to private buyers by brands

The forecast of clean cars is not as accurate as the forecast on all cars. This is partly due to the fact that new cars are introduced on the market, which cannot be accounted for in detail in the calibration process. Aggregated to clean car total the model predicts reasonably well however. This validation shows that supply assumptions are crucial for a reasonable forecast, as well as the size of the new cars addition, including its exogenously given distribution on buyer segments (particularly when evaluating segment specific policies). Improvements in these respects are discussed in section 5.

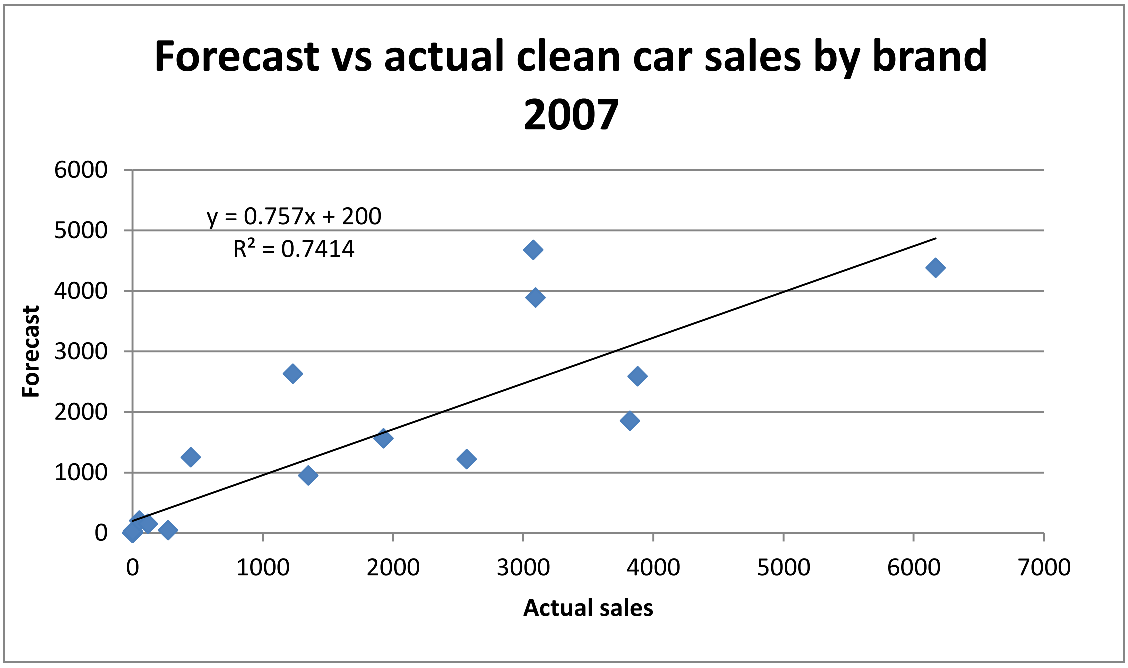


Figure 7. Forecast and actual sales of new clean cars to private buyers by brand 2007

4.2 2011 – 2020 forecast

In another project undertaken in 2012, a car fleet forecast for the period 2011 – 2020 was made. The focus of the project was to forecast fuel demand, based on the development of the car fleet. Here we will focus on the new car sales. There is now registration data available up to 2013 so that a comparison can be made between these and the forecast. In this project, the choice model for new car types was first calibrated to registration data for 2011. The calibration targets were the segment specific distributions on 30 brands and 10 fuel types. The forecast then calculates the yearly fuel demand development between 2012 and 2020. Table 4 shows the predicted new cars sales by fuel type together with actual registration data from Transport Analysis (Swedish government agency for transport policy analysis). As can be seen in the table 4, the differences are quite significant except for diesel. For petrol the difference between predicted and actual outcome is 20 percent, and the differences for the other fuel types are even larger. The registration data did not allow for a more detailed comparison of different hybrids. The total number of new cars is overestimated by 4 percent. The total new car sales is decided by the car ownership model and the scrapping model, see section 2. Correcting for the total does not change the picture much – underestimated number will increase somewhat, and overestimated numbers will decrease somewhat. Another aspect is the share of new cars bought privately or by a company. Correcting for this does also not change the picture much, either.

Table 4. Forecasts and statistics for new car sales.

	Forecast	Registration data	Difference	
Fuel type	2012-2013	2012-2013	Absolute	Percent
Petrol	155155	193416	-38261	-20
Gas	14606	9308	5298	57
Diesel	356201	370857	-14656	-4
Hybrids/Electric	68556	10695	57861	541
Ethanol	20999	9147	11852	130
Total	615518	593423	22095	4

Hybrid, ethanol and gas cars are strongly overestimated. This could imply that the assumed supply of such cars does not exist on the market yet and/or that the preferences for such cars are not correctly described in the new car type model. After corrections for differences in the distribution of fuel types in the supply data for 2013 and for the total number of new cars, the picture changed a bit (see table 5).

Table 5. Comparison actual outcome and forecasting results

	Forecast	Registration data	Difference	
Fuel type	2012-2013	2012-2013	Absolute	Percent
Petrol	154164	193416	-39252	-20
Gas	18355	9308	9047	97
Diesel	331418	370857	-39439	-11
Hybrids/Electric	77836	10695	67141	628
Ethanol	11650	9147	2503	27
Total	593423	593423	0	0

The main supply difference was the number of ethanol cars, which were overestimated more than twice in the forecast. The demand for ethanol cars is still overestimated in spite of the correction, The supply of gas and hybrid cars was underestimated, hence the increased over prediction.

The remaining prediction error is then likely to be caused by preferences not captured in the model. A reason for over predicting hybrids (most of which are plug in hybrids) is that some of the drawbacks are not included in the model. The most obvious factor is the charging requirements, implying range constraints as well as charging post availability. While range is accounted for to some extent (a variable in the model), the additional requirement of charging post availability is not. This requirement severely constrains the usefulness of electrical or plug in hybrid cars for household not having an electrical outlet close to the parking place, which is the case for many households in densely populated areas.

In addition, requirements for charging facilities at travel destinations are also a constraint, also for households having charging facilities at their dwelling. Effects of fuelling infrastructure was subject to the SP survey during the development of the new car choice model in 2005, showing an important impact of the share of fuel stations having ethanol or gas capability (Transek, 2006).

The model system overestimates the demand for ethanol cars as well. This could be an effect of changes in policies and attitudes towards ethanol cars that have been implemented since the model was estimated, such as the abolition of the exempt of congestion charges for alternatively fuelled cars. It may also be the result of some attitudinal changes. One of them is caused by the debate on using food to produce ethanol, creating doubt on the environmental effects of ethanol use. Another one is reported technical problems when using ethanol, which introduces uncertainty of using ethanol. The estimated share of ethanol used by ethanol cars is now around 40 percent, even though there is no fuel price disadvantage of using ethanol.

Gas cars are also over predicted, although the total number of gas cars is small. The gas car share may be especially difficult to predict, as almost half of the gas cars was sold to taxi companies (45 percent in 2013). As the number is small, prediction is not affecting the other fuel types much.

The petrol and diesel shares are of course affected by the prediction errors for the other fuel types. If the large over prediction for hybrid and electrical cars could be overcome, the shift of demand would be forecast proportional to the market shares for the other fuel types (a logit model property). Then the number of new petrol cars would be under - predicted by 10 percent, and the number of new diesel cars would be over predicted by 1 percent.

The reader may ask why we assume that the main errors are associated with the alternative fuels and not with petrol and diesel. The answer is that petrol and diesel were dominating in the estimation data, which means that they are well known by car buyers and therefore also car buyers' preferences for petrol and diesel car attributes are better known. These are of course not perfectly captured in the model (estimated in 2004), and there is also reason for updating the model parameters with regard to petrol and diesel car attributes.

5. Discussion

A main issue is to inform the model of preferences for alternative fuel types. This is often done by using Stated Preference experiments (as was also done when developing the current model). Such an effort has not yet been undertaken after the initial development of the model. Today, a larger number of cars using alternative technology has been added to the market, and shows up in registration data. This means that the model can be calibrated using information on actual demand for these fuel types. Such a calibration has been performed on registration data for 2013.

Other issues in the car fleet model are related to the exogenous assumptions on market share segments. Some policies that have been analysed imply severe reductions of the benefit of having a company car. Such reductions may make employees less interested in having such a (reduced) benefit. Therefore, a model of the choice between company car benefit and private car ownership should be modelled. Recently, such a project was initiated at CTS[4].

Another issue is the choice process for company cars. The employee may have more or less severe constraints on prices, brands and fuel types imposed by the employer. In the current model, such constraints are implicit in the model parameters. In order to model policies affecting companies' policies regarding company car benefits, such constraints need to be modelled more explicit. This is also intended to be done in the new project mentioned above.

The current model is mainly estimated on car register data. This means that there are no variables describing the household in the model, which means that effects of demographic and economic changes cannot be captured. Therefore, it is also planned to estimate a new version of the model including socioeconomic variables, obtained in data from the new project.

One of the properties in the current model is the sensitivity to supply assumptions for future years. Although this sensitivity in the current model may be associated also with the ability to capture preferences of new technology, it is clear that we need not only information on consumer preferences, but also on technology development. Previous experience shows that it is hard to make such assumptions also in the short run.

If supply assumptions are difficult even in the short run, they will be even more difficult in the long run. The ability of the model to predict demand can be improved to a certain level, which will reduce the forecasting error. The development of supply is depending on technological innovation and economic production conditions which are much harder to predict. There may also be an interdependence between policies and supply. EU and regulations imposed elsewhere are specifically aiming towards this. It is less likely that Swedish regulations will have an impact on car technology, but there may be

[4] Center of Transport Studies (www.cts.kth.se/)

dependencies between Swedish policies and what car types that are imported to the Swedish market (the 1 000 Euros subsidy triggered increased import of small petrol and diesel cars). Depending on the use of the forecasts – be it car sales, emissions or fuel demand – it may be necessary to use different supply scenarios to get an idea of the robustness of the forecast result.

6. Conclusions

We have presented the Swedish car fleet model system which has been developed for evaluation of effects of car fleet policy measures. We have also presented such measures implemented in recent years and how the Swedish car fleet has developed during these years. We have specifically focussed on comparisons between forecasts and actual developments regarding sales of new cars by fuel type.

The comparisons concern only the short run (1-2 years), for which data was available. In total, the comparisons show that forecasts and actual data may differ quite significantly. We have also analysed the reasons behind to learn from the experience.

The forecast is the result of three sub models – scrapping, total car ownership (fleet size) and car type choice for new cars. The total number of new cars is determined by the first two models. Variations between years are typically badly accounted for in these models that are fed with long term assumptions. If errors in the total number of new cars are accounted for, it appears that the new car type choice model predicts reasonably well when the share of clean cars was forecast (for the private segment only), and still quite unsatisfactorily when newer technology is introduced.

Two issues need to be recognised – one is the issue of the model being correct, and the other is the issue of making short term forecasts.

While the first issue can be solved by improving the car type choice model, results will always be depending on yearly variations in the total of new cars. There is also some uncertainty as to when in a year different policies are implemented and when in a year different car types are put on the market.

For the Swedish car fleet model, a project has been initiated to improve the model system, aiming at refining the separate sub models using new data including socioeconomic data and also improving the model structure by accounting for choice of company car or private car ownership and constraints imposed by employers on company car beneficiaries.

References

Batley, R., & Toner, J. (2003). Elimination-by-aspects and advanced logit models of stated preferences for alternative-fuel vehicles. *In Proceedings of the European Transport Conference, Strasbourg.*

Ben-Akiva M, Lerman SR (1985) Discrete choice analysis: theory and application to travel demand. London.

Berkovec, J. (1985a). Forecasting automobile demand using disaggregate choice models, *Transportation Research Part B* **19B**(4): 315–329.

Berkovec, J. (1985b). New car sales and used car stocks: a model of automobile market, *Rand Journal of Economics* 16(2).

Berkovec, J. & Rust, J. (1985). A nested logit model of automobile holdings for one car households, *Transportation Research Part B* **19B**(4): 275–285.

Beser Hugosson, M. & Algers, S. (2012). Accelerated Introduction of Clean Cars in Sweden, *in* T. I. Zachariadis (ed.), *Cars and Carbon SE - 11*, Springer Netherlands, pp. 247–268.

Bhat, C. R. & Sen, S. (2006). Household car type holdings and usage: an application of the multiple discerete-continous extreme value (MDCEV) model, *Transportation Research Part B* **40**: 35–53.

Brownstone, D. and Train, K. (1998). Forecasting new product penetration with flexible substitution patterns, Journal of Econometrics 89: 109–129. PII: S0304-4076(98)00057-8.

De Jong, G., Fox, J., Pieters, M., Daly, A. J. & Smit, R. (2004). A comparison of car ownership models, *Transport Reviews* **24**(4): 379–408.

De Jong, G., Vellay, C. & James Fox, R. E. N. (2001). Car scrapping: literature and a new stated preference survey, *European Transport Conference 2001 proceedings*, Association for European Transport.

Fang, H. A. (2008). A discrete-continuous model of households' car choice and usage, with an application to the effects of residential densityl, *Transportation Research Part B* **42**: 736–758.

Goldberg, P. K. (1995). Product Differentiation and Oligopoly in International Markets: The Case of the U.S. Automobile Industry, *Econometrica* **63**(4): 891–951.

Golob, T. F., Kitamura, R., Bradley, M. & Bunch, D. S. (1993). Predicting the market penetration of electric and clean-fuel cars, *Science of The Total Environment* **134**(1-3): 371–381.

Hess, S., Fowler, M., Adler, T. & Bahreinian, A. (2009). A joint model for car type and fuel type, *European Transport Conference 2009*, Association for European Transport and Contributors 2009, Leeuwenhorst Conference Centre, The Netherlands.

Lave, C. A. & Train, K. (1979). A disaggregate model of auto-type choice, *Transportation Research Part A: General* **13**(1): 1–9.

Mannering, F., and Winston, C. (1985). A Dynamic Empirical Analysis of Household Vehicle Ownership and Utilization. The RAND Journal of Economics , Vol. 16, No. 2, pp. 215-236

Mannering, F., Winston, C., Griliches, Z. V. I. & Schmalensee, R. (1991). Brand Loyalty and the Decline of American automobile Firms, *Brookings Papers on Economic Activity. Microeconometrics* **1991**: 67–114.

Mohammadian, A. K. & Miller, E. J. (2003). Dynamic Modeling of Household Automobile Transactions, *Transportation Research Record* (1831): 98–105.

Naturvårdsverket (2007). Drivkrafter till bilars minskade koldioxidutsläpp (Driving forces to reduce CO2 emissions for cars, in Sedish with summary in English), report 5755, November 2007.

Page, M., Whelan, G. & Daly, A. (2000). Modelling The Factors which Influence New Car Purchasing, *European Transport Conference 2001 proceedings*, Association for European Transport, Homerton College, Cambridge.

Pädam, S., Sundbergh, P. & Strömblad, E. (2012). Andelen miljöbilar i nybilsförsäljningen i stockholms län - hur har utvecklingen sett ut och hur kan andelen ökas? (the percentage of green cars in new car sales in stockholm city - how have the developments been in this area and how can this share be increased?), *Technical report*, WSP AB, Sweden.

Potoglou, D. & Kanaroglou, P. S. (2008). Disaggregate Demand Analyses for Conventional and Alternative Fueled Automobiles: A Review, *International Journal of Sustainable Transportation* **2**(4): 234–259.

Train, K. E. & Winston, C. (2007). Car Choice Behavior and the Declining Market Share of U.S. Automakers, *International Economic Review* **48**(4): 1469–1496.

Trafikverket (2012). Minskade utsläpp av koldioxid från vägtrafiken (Reduced CO2 emissions from road traffic), Memo, Swedish Transport Administration, Sweden.

Transek (2006). Bilparksmodell (car fleet model), *Technical report*, Transek AB, Sweden.

TREMOVE (2006). http://www.tmleuven.be/methode/tremove/home.htm

VTI (2002). Modeller och prognoser för regionalt bilinnehav i sverige (models and forecasts for regional car ownership in sweden, *VTI rapport* **476**.

West, S. E. (2004). Distributional effects of alternative car pollution control policies, *Journal of Public Economics* **88**: 735–757.