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Evaluation of the Swedish car fleet model using recent applications

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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 CO_2 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 system. 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 the 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.

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 into the atmosphere by 2050 and have a fossil fuel independent car fleet by 2030. To achieve these goals there is a need to combine different policies. 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 for environmental effects, oil dependence and energy consumption. The Swedish car fleet composition has been affected largely by different policies implemented at the national or local level. Based on statistics, the Swedish fleet has changed from a large, powerful fleet with high CO_2 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 (ex ante) 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 the car fleet in order to evaluate the effect of different implemented policies (see e.g. Berkovec, 1985; Goldberg, 1995; West, 2004; 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 (calculating the number of cars per individual), a scrapping model and a new car purchase model. These sub-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 was first used in a study analysing climate policies for the Swedish Environmental Protection Agency (Naturvårdsverket, 2007). Since then the model system has been used in several prediction studies, e.g. to measure the effects of

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

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introducing a 1000 Euros subsidy for privately bought clean cars, a project carried out for the Swedish Road Administration, and a later forecast for the period 2011–2020. These studies were conducted some years ago, which gives us the possibility to evaluate the performance of the model system to some extent. In these two applications, we compare actual and forecast 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 and Winston, 1985; Brownstone et al., 1998). In the literature there are more sophisticated car ownership and type choice models e.g. dynamic models. For literature reviews read e.g. de Jong et al. (2004), Potoglou and Kanaroglou (2008), de Jong and Kitamura (2009). This paper, however, is about comparing the forecasts from a model system used in practice to actual outcomes. To the best of our knowledge, no study compares predictions to actual outcomes as we do here. The results show that the uncertainty of future technologies are challenging even for the short-term forecast. Few studies exist that deal with new technology production models (see e.g. Berkovec, 1985a, 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. The main contribution of the paper is a comparison of forecast studies carried out using the model system with actual outcome, which is presented 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. The 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 and follows the description in Beser Hugosson and Algers (2012).

2.1. Model system overview

The car fleet model system is a car 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:

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

where,

$V^{vs,t-1}$, is the number of cars of vintage v and type s in the stock at 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 at the end of year t, minus the total number of scrapped cars 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, whose output is $\sum_{vs} V_t^{vs}$.
- A scrapping model, whose output is S_t^{vs}.
- A car type choice model (for new cars), whose output is p_t^s.

Fig. 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 CO_2 emissions, C_t,are calculated. These are calculated as an average over all car types and vintages in the car fleet (Beser Hugosson and Algers, 2012). Thus

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

and

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

where,

f^{vs} is the fuel consumption (in any unit) of cars of vintage v and type s,

C^s is the CO_2 emission per fuel consumption unit 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 (Beser Hugosson and Algers, 2012).

2.2. Car ownership model

To forecast the size of the total car fleet, the Swedish car ownership model is used (VTI, 2002). This cohort model is based on the probabilities for an individual to either become a car owner or stop being one. The calculation of the total amount of car owners is updated yearly. There are mainly socio economic variables included in the model, and the only policy variable included is petrol cost. In the model, the variable for petrol costs is expected to represent driving costs. At the time this model was developed, more than 90% of the cars in the Swedish car fleet were petrol cars, which might have justified this simplification. Today we have a mix of fuel types which means that this variable can cause some inconsistency when the model is used as a part of the car fleet model system (Beser Hugosson and Algers, 2012).

2.3. Scrapping model

To model the scrapping of cars, the Swedish car register is used to provide data. A model that is simple and aggregated is designed on the basis of scrappings from years 2000–2004. It gives the percentage of the stock to be removed each year. The percentage varies depending on the car make and age (Beser Hugosson and Algers, 2012). This model is obviously not policy sensitive at all, but there has been little focus on scrapping policies in Sweden and none at all in the forecasts that we present in this paper. 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).