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Title **Evaluating of Bonus-Malus system in Sweden**

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Recently, the Swedish government has started to investigate a policy package aiming at a fossil free fleet by the year 2030. This policy package is in accordance with the vision of climate neutral transport in 2050. One objective in this investigation (the so called FFF-investigation) is to design a Bonus-Malus system that pushes the Swedish fleet composition towards the EU objectives of CO2 emissions which is on the average 130 gr/km by 2015 and 95 gr/km by2020. In this paper, we evaluate whether it is possible to reach this goal or not, and what level of Bonus-Malus system is necessary.

The system is designed to reward (bonus) car buyers who choose to purchase a car with lower CO2 emissions and penalize (malus) the buyer who choose a car with higher CO2 emissions. The idea is that the system would pay for itself in that those who choose to buy a car with higher CO2 emissions subsidize the purchase of those who choose a car with lower CO2 emissions. In this research project we evaluate different scenarios for Bonus-Malus based on the FFF package. The Bonus-Malus system has been widely used in insurance companies to adjust the premium paid by a customer based on his/her claim history. It is also applied in France as a car taxation system and it is being stricter each year to reach the desired effect. Different consumer segments have different sensitivity to purchasing and operating costs and consequently the Bonus-Malus system affect them differently. Therefore, we need to use a model that accounts for this heterogeneity. We use Swedish car fleet model that was previously developed and calibrate it based on the recent data. The Swedish car fleet accounts for different private and company car segments as well as make, model and fuel type of each car type. The model is a cohort model, updating the stock of cars by subtracting scrapped cars and adding new cars. Our aim is to model the evolution of the car fleet on the yearly basis. Cars can be added to the fleet either by being purchased by a private person or an organization from a car dealer or being imported directly by a person or an organization. These two groups may have different choice behavior and choice sets. For the last group, we assume that the import pattern is constant in terms of share of import and its distribution over age. Also, cars can exit from the car fleet either by scrappage or being exported. The output of the model is the numbers of vehicles of different types, average fuel consumption rates and average fuel costs. These are calculated as an average over all car types and vintages in the car fleet. To make a forecast with the model, the car fleet composition is thus calculated yearly from the base year to the forecast year of interest.

On the demand side we have Swedish registry data from 2004-2013. Each observation in the dataset includes some socio-demographic data of current and previous owners such as age and gender, some car’s attributes and some data on cars’ date such as year model, production year, registration date, date of previous transfers, data on if the car is privately owned or owned by a company and in case of company cars whether it is leased or not. On the supply hand we have detailed data on all cars available in the market from 1999-2014.

We need the supply data to include some of the important cars' characteristics that are missing from the registry data such as price. There are over 2500 alternatives for each year in the supply data. The supply data is very detailed down to a specific version of a model. Since the supply data is more detailed than the register, several alternatives from supply can therefore correspond to a given observation from the registry. For calibration, we aggregate the alternatives from supply to the level of make/model/fuel-type which are observed from the register data. For calibration, we use data on total fleet in 2012 as well as 2013 new car addition and scrappage data to calibrate the model and prepare it to be used for prediction for the year 2014 under different scenarios for Bonus-Malus. There exist 5,600,668 cars in the Swedish fleet in 2012. In 2013, 221,781cars were added to the fleet and 297,897 were scrapped. Also, it should be mentioned that the Swedish car fleet has been the target of many policies in the recent years. The car fleet model also should be updated regarding the policies that continue to be in effect and also the ones that have been shut down.
The Swedish car fleet model consists of three components: car ownership model, scrappage model and new car type choice model. The scrappage model calculates the share of cars that will be scrapped during a year depending on vehicle age and make. The total fleet size model is a car ownership model. This model is also a cohort model, based on individual car ownership entry and exit probabilities (Hugosson and Algers, 2012). The car type choice model is the disaggregate model which is the most sensitive one to policy changes. To model what types of cars will be added to the car fleet, we use discrete choice model to model consumer behavior (Ben-Akiva and Lerman, 1985). Such models have been estimated in different applications such as Train and Winston, 2007, and integrated with car use in Bhat and Sen, 2006. Here, we model the choice of the new car type given that the decision to buy a new car is already made. The model is based on observed choices in the Swedish car register among about 300 different car alternatives aggregated at make/model/fuel-type level. The car type choice model is the one that is responsive to different policies in the car fleet model system. The choice model includes a number of attributes related to different aspects of car preferences, such as price, running costs, safety, size and maintenance. Policies that can be formulated in these attributes - like a Bonus Malus system - are suited for evaluation with this model. There are three separate models for the three segments of the market for new cars - the private market, the leased company car market and the self-owned company car market. The sensitivity to variations in the different characteristics differs among these segments. The estimated choice model is of the nested logit type. The reason for the nesting is that the elasticities between models of the same model family are larger than that between cars of different brands. 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 models. This characteristic violates the assumption of independence of irrelevant alternatives (IIA) which is a main assumption of multinomial logit (MNL). The nested logit model for car type choice application has been employed in studies e.g. Mannering et al., 1991and Berkovec and Rust, 1985. The calibration has been in the form of estimating constants for fuel type and brand into the utility functions, not altering the coefficients for the attributes included in the model.

This is ongoing research; we are now in the process of calibrating the model. Next wewill use different scenarios based on the FFF investigation to evaluate the effect of each ofthem and choose the optimal one or propose a combination of different introduced systems. A comprehensive analysis of the results will be reported in the final paper.

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