Dynamic simulation of the German vehicle market

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Extended Abstract

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Introduction

Vehicle purchase decisions of today by households determine not only the short-term mode choice behavior but also the size and composition of the national vehicle fleet for long periods. Modeling these decisions accurately is therefore a key factor to secure sustainable transport planning and policy setting. The information about car availability and usage is not only crucial for transportation models as car ownership deeply influences all levels of travel behavior (i.e. trip generation, destination and mode choice); it is also a prerequisite for monitoring energy consumption and for capturing the resulting emission levels correctly.

In the literature – apart from aggregated models, which, e.g., aim to predict the total number of cars in a country as a function of its GDP – there exist disaggregated models, which aim to explain the behavioral driving forces behind vehicle-related decisions. These models can be differentiated by their respective approach[1]: (i) static vehicle holding/ownership (and use) models, and (ii) dynamic vehicle transaction (and use) models. The static models minimally predict, for a given point in time, the discrete number of vehicles owned by a household as a function of the explanatory variables. More sophisticated models additionally provide information on the vehicle type mix and the continuous number of kilometers traveled by each vehicle (see, e.g., Bhat and Sen (2006)). Nonetheless, their goal is not to replicate the dynamics involved in the vehicle purchase/selling decisions. Therefore, they are only appropriate to model end-state conditions and fail to replicate the impact of changing exogenous conditions and/or policy measures that have a continuous impact over time.

[1] For a comprehensive review of car ownership models and a more detailed classification, please refer to de Jong, G., J. Fox, A. Daly, M. Pieters and R. Smit (2004). "A comparison of car ownership models." Transport Reviews **24**(4): 379-408.

In contrast, dynamic vehicle transaction models explicitly predict – for every year of the simulation – vehicle transactions over time where households add, replace, dispose of vehicles, or maintain their current state (see, e.g., Mohammadian and Miller (2003)). Some of these models try to link the decisions to so-called life-course events, such as the birth of a child, residential relocation, or a change in employment status (see, e.g., Yamamoto (2008), Chen, Takami et al. (2013), Fatmi and Habib (2017)). These models were often criticized as too data-intensive as they are usually built on panel data, which in many cases do not exist (Bunch, Brownstone et al. (1995), Bhat and Sen (2006)). However, dynamic models are needed to capture the transition phase, especially in situations where major disruptions in the mobility market are expected, be it through the introduction of alternative powertrains or autonomous vehicles including the resulting new business opportunities of Mobility as a Service (MaaS) and their potential impact on vehicle ownership.

In this paper, we therefore propose a dynamic vehicle transaction model, similar to the one by Mohammadian and Miller (2003). Our approach, however, differs from their model, as we do not only aim at modeling vehicle transactions by households (as done by Mohammadian and Miller (2003)), but additionally the entire vehicle market, including both new and used vehicles. This implies modeling not only the household decisions, but also the entire vehicle fleet. This approach is compulsory to model the German vehicle market. In Germany, given the tax incentives in place, a large proportion of vehicles used for private purposes are user-chooser company cars, which are part of the employee's remuneration.[2] It represents 60% of the total vehicle transactions. It seems therefore essential to consider the used vehicle market in any vehicle market model, as changes in it would have large implications on the development of the entire fleet, affecting the demand for new vehicles upstream, be it through direct competition or through resale prices.

While our extension of the model by Mohammadian and Miller (2003) is especially important to capture the particularities of the German market, it is a valuable addition to any vehicle market model, as new vehicles sales are presumably affected by the dynamics of the used vehicle market. Hence, not considering the used vehicle market or the impact of certain policy measures on it, may lead to misleading recommendations.

Model Structure

The model is based upon a dynamic simulation of household vehicle transactions and a longitudinal model, which makes it possible to follow every vehicle entering the market over its entire life span. This way, every active decision (i.e. buying or selling) by a given household in the vehicle market is associated with a particular vehicle being assigned to or removed from the household. This allows monitoring the entire fleet, including vehicles in possession of a given household being available for sale on the used vehicle market.

Given this setup, the key foundation of the dynamic simulation is provided by a behavioral model of the households in the vehicles market. This model, estimated on the basis of revealed preferences, allows establishing purchase probabilities for the households opting for new vehicles, new user-chooser company vehicles (mainly used for private purposes), or second-hand vehicles. Furthermore,

[2] Private use of a vehicle owned by the employer may reduce an employee's income tax due to German tax regulations and, hence, might be less expensive than a privately owned vehicle.

the behavioral model allows establishing probabilities for the size class (small, medium, large) and powertrain (diesel vs gasoline) of the vehicles to be acquired. These probabilities are a function of the characteristics of the household as well as of the acquisition price and the operational costs. The decision of selling a giving vehicle as well as the end of the life span is based on an independent stochastic model (see Kickhöfer and Brokate (2017), who use a function of the vehicle age and mileage as well as of the number of years that the vehicle has been in possession of the same household).

Finally, in every step of the simulation (representing one year), purchases, sellings and vehicles leaving the market are generated on the basis of the aforementioned probabilities. Vehicles are then assigned to households in function of their availability. For this purpose it is assumed that the availability of new vehicles is unlimited, while in the second-hand market it is limited by the vehicles sold in the current year and in the previous years.

Illustrative examples

For illustrative purposes, we consider five different scenarios over a time horizon of 30 years. The considered scenarios are the following:

a) Base-case scenario (business as usual).
b) Increment of fuel prices by 20%.
c) Increment of the diesel tax by 50%.
d) Increment of the vehicle tax for diesel vehicles produced before 2015 by 100% (i.e. not complying with the emissions standard EURO 6).
e) Increment of fuel taxes by 50% starting at the end of 2025.

The illustrative examples exhibit the model’s capability to react to changes in the current conditions and exhibit the transition phase before a stationary state is reached. Furthermore, they confirm that, given the long replacement times of the vehicle market in Germany, the effect of policy measures on the vehicle fleet are not immediate and that long transition times are necessary.

Conclusions

The availability of vehicles is a key element in the analysis of travel behavior, as it deeply affects transport demand at every possible level. Nonetheless, the analysis of vehicle purchase decisions (or most long-term decisions associated with mobility tools) by households has not played a major role in transport modeling yet. We propose and successfully test a simulation tool that allows considering the availability of vehicles at the level of households taking market constraints into account (especially the respective long replacement times).

While the model has been developed for vehicle purchases in Germany, it is possible to adapt it for other markets or different mobility tools, such as public transport monthly cards or carsharing membership decisions. Furthermore, it is also possible to extend the model to analyze the adoption of electric powertrains or autonomous vehicles and their potential impact on vehicle ownership over time. Moreover, it offers a powerful way to assess the impact of different policy measures on car ownership.

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