

# Modelling determinants of vehicle ownership transitions: advances in modeling inter-temporal choice

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## Abstract

**Motivation** The car market offers a unique forecasting problem to solve. A multitude of vehicles at different stages of technology innovation cycles are available to consumers in any given time. On the consumer side, the choice of vehicle involves a significant expenditure that forms a durable possession, entails lengthy planning as well as being influenced by past choices and expectations about future market developments. Arguably the study of vehicle acquisition behavior is increasingly complex given recent diffusion of innovative technologies such as hybrid power trains, emergence of alternative fuel engines and appearance of new car body styles. These phenomena are likely to increase uncertainty where consumers are forced to also consider fluctuation in complementary goods such as fuel prices and infrastructure availability. Hence, future market developments as well as the value of the acquired vehicle is exceedingly difficult to predict. The challenge of understanding consumer behavior in this context is given further relevance in view of the sizable institutional investments to promote alternative vehicle markets with a final aim to improve energy efficiency in the transportation sector.

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The delineated context underlines the need to consider the inter temporal evolution of car transactions when formulating models of vehicle choice. Indeed, it is increasingly clear that vehicle choice models need to accommodate complex substitution patterns both across products and over time. Simultaneously, a fuller understanding of vehicle fleet evolution requires consideration not only of traditional features characterizing vehicle choice, such as individuals' socio-demographics, but also prompt us to examine a wealth of time-dependent factors that modulate the acquisition process.

**Methodological contribution** This paper aims to provide an alternative to the one-shot decision models that have come to dominate vehicle choice analysis for the last decades. A model of vehicle transition, that is accounting for the passage between the most recent previous and the newly acquired vehicle, is developed. Revealed preference data on new vehicle acquisition provides the testbed for the model development. A vehicle choice is treated as a realization occurring in each time period (in this case yearly) and the model accounts for a large set of time-varying contingencies (e.g. incentives/policies, vehicle-performance variation across years, vehicle market launches). The model framework represents the aggregate market evolution of vehicle choices focusing on linking the time-varying events to vehicle fleet adjustments over time. The vehicle choice is modeled as a discrete choice process. The decision is formulated as such; population segments shift across different vehicle classes based on utility evaluation. Utility depends on  $u_{ijt} = U(\beta_1 \text{personal features}_{it}, \beta_2 \text{previous car features}_{it}, \beta_3 \text{new car features}_j, \beta_4 \text{market events}_t)$ , for individual  $i$ , time  $t$  and vehicle  $j$ . The structure can be enriched to consider dynamic determinants, such as policy incentives, occurring in different time-periods. In this dynamic vehicle transition model probability of transition is made dependent on the previous market state,  $pr(S_{t+1}|S_t)$ , that is, the acquisitions behavior in the vehicle market  $S$ , evolves according to a first-order Markov process from time  $t$  to  $t + 1$ . The essential feature here is that the transition probability matrix is derived empirically from decades of aggregate vehicle acquisition data. The proposed framework allows us to shed light on the timing and type of vehicle ownership and illustrates the benefits of taking the first steps away from a static approach. The application allows us to identify the relevant factors that explicates how different consumers trade various vehicles features against each other in a dynamic market setting. Such findings will aid the prediction of consumer behavior with regard to critical policy variables such as incentives and aid the understanding of diffusion of novel technologies. Such understanding is essential from the perspective of a society trying to manage the transition towards alternative mobility patterns.

**Data** The project benefits from empirical testing drawing on a unique database recording new car purchases. The data derives from a large-scale

disaggregate survey with a representative sample of new car buyers in major European markets. The dataset contains rich information on recently acquired vehicles, personal socio-demographics, buyer attitudes and motivations, household characteristics and vehicle fleet. At the disaggregate level the data contains detailed information on the current and past vehicles of each respondent. Treated as an aggregate dataset it contains cross-sectional records of new vehicle acquisition for over two decades. In addition, supplementary vehicle market, policy and economic data is incorporated in line with the objective to link vehicle market segment transitions to external dynamic events.

**Results and outlook** Modeling results from the aggregate model of vehicle transition propensity allows the identification of the main determinants of vehicle type 'switching' over time. In particular the empirical results allow us to trace the role of policies such as scrapping, alongside supply dynamics in the vehicle market and quantify their relative role in favoring specific behavior such as: shifting fuel-type, downsizing, lowering the vehicle class. Moreover, estimations on filtered data allow us to delineate a detailed transition-matrix, distinguishing the behavior of different sub-groups. Inserted in a forecasting setting we gain unique insight into why and when acquisitions occur and trace the future development in the presence of different policy scenarios. Further developments will focus on finding the motivational determinants of the timing/type of vehicle transactions as well as trace the dynamics of vehicle holding duration and new technology diffusion cycles.

*Keywords:* *vehicle decisions, market evolution, discrete choice*