FCN Working Paper No. 17/2018

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Publisher: Prof. Dr. Reinhard Madlener
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Combined Vehicle Type and Fuel Type Choices of Private Households: An Empirical Analysis for Germany

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December 2018, revised May 2019

Abstract

This paper examines joint consumer purchasing decisions of vehicle type and fuel type based on a dataset from a Germany-wide survey among 1500 potential car buyers. The goal is to study the buyer segments that are considering to purchase the different types of vehicles and to identify the main determinants influencing the joint choice decision: socio-demographic and household characteristics, attitudes and preferences, as well as vehicle-related attributes. Based on a nested logit model, our results suggest that although German car buyers' are very heterogeneous regarding their preferences, several similarities are found between buyers of specific vehicle types (10 vehicle classes) and specific fuel types (gasoline, diesel, alternative fuel), e.g. smaller cars and alternative fuel vehicles (AFVs) have commonalities regarding individual's environmental awareness/behavior and fuel consumption/costs. Policy-makers, when tailoring their policies, can benefit from making use of the specific insights gained from this particularly comprehensive study, and the comparisons made with the German and international scientific literature on the topic. For instance, the similarities between buyers preferring specific fuel types and specific vehicle types can be used for tailorized measures to incentivize individuals' vehicle type shifting (e.g from larger to smaller vehicles), fuel type switching (e.g. from fossil-fuelled vehicles to AFVs), or both.

Keywords: Discrete choice, Revealed preferences, Stated intentions, Nested logit model, Alternative fuel vehicles, Vehicle segments

JEL Classification: C35, C38, D12, M38, R48

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1 Introduction

Clean air legislation in the EU forces vehicle manufacturers to comply with the legally binding CO_2 emission abatement targets for all newly registered vehicles, which were set at 95 g CO_2/km to be achieved by 2021 (EC, 2014). The pressure to act is strong on the part of manufacturers, as they are threatened with substantial fines in the event of noncompliance with the targets. Furthermore, the average CO_2 emissions of new cars in the EU rose slightly by 0.34% to 118.5 g/km in 2017. In Germany, the situation is even worse compared to the European average, i.e. the average CO_2 emissions of newly registered vehicles not only lie well above the European average but also show a slightly greater increase of 0.39% to 127.9 g/km. This growth connotates a trend reversal of CO_2 emission reductions of past years and is mainly caused by two changes in consumer purchase decisions: Firstly, the share of newly registered diesel-powered passenger cars, whose specific CO_2 emissions are lower than those of comparable vehicles with gasoline engines, decreased by 13.2% to only 38.8% in 2017 in Germany. The main driver behind this sharp decline continues to be the Volkswagen emissions scandal (so-called 'Dieselgate') and its repercussions. Secondly, sports utility vehicles (SUVs) with relatively high fuel consumption and CO_2 emissions (133.2-159.2 g/km on average) continue to enjoy growing popularity among car buyers. With a share of 15.2%, SUVs represent the second-largest vehicle segment in the German market in 2017 and showed an increase of 22.5% compared to the previous year, while the proportion of small vehicles has been steadily declining for years (EEA, 2018; KBA, 2018a).

Besides CO_2 emissions, the popularity of SUVs has further implications for transportation policy: (1) increase in local air pollution from the tailpipe of vehicles due to higher fuel consumption and, usually, greater mileage of larger vehicles, (2) decrease of roadway capacity, since larger vehicles need more space, resulting in traffic congestion and problems with parking spaces in cities, (3) decrease in traffic safety, especially for non-SUV drivers, due to shifts in accident frequencies and injury severity, potentially leading to an 'arms race', i.e. the spiraling up of still larger and heavier vehicles (e.g. van Essen et al., 2019; De Clerck et al., 2018; Liu, 2017; Schmidt, 2016; Yasmin et al., 2014; Jacobsen, 2013; Li, 2012).

Thus, the goal of this research is to determine the buyer segments that are considering to purchase the different vehicle types and fuel types and the factors that influence their joint choice decisions. It is of high relevance to gain a deeper understanding on what can be done to make households adjust their vehicle fleet by incentivizing them to purchase smaller vehicle segments and alternative fuel vehicles (AFVs), instead of 'diesel-guzzling' larger vehicles, such as SUVs, with their higher external costs (e.g. De Clerck et al., 2018). This implies targeting a heterogeneous group of vehicle buyers who differ with respect to their socio-demographic, attitudinal, and household-related characteristics.

For the purpose of our research, we make use of data from a national web-based survey among 1500 new vehicle buyers in Germany, which was conducted in 2011. The participants were sourced from an online panel and had either purchased a vehicle recently or were planning to do so in the upcoming year. We apply a discrete choice model on this combination of revealed preferences and stated preferences data.[1]

Our study builds on a wide range of research that has dealt with the explanation of individuals' intended or actual choices of vehicle types or fuel types[2] in the past. Hackbarth (2020) and Liao et al. (2017) provide comprehensive reviews of the literature that applies a rational choice theoretical approach to assess private households' vehicle purchase decisions – i.e. probabilistic discrete choice analysis based on the assumption of utility maximization – which is also the main basis for the research undertaken in the present study.[3]

While the majority of the reviewed choice-based studies aims at explaining fuel type choice decisions, with a special focus on the adoption of electric vehicles (e.g. Ferguson et al., 2018; Jansson et al., 2017a,b; Rasouli and Timmermans, 2016; Helveston et al., 2015; Mabit et al.,

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[1] Revealed preferences data typically comprises actual vehicle ownership from national registers or household surveys, whereas stated preferences data typically is based on hypothetical vehicle purchase decisions or future purchase intentions gathered in discrete choice experiments or household surveys.

[2] Vehicle type classified by different combinations of size (i.e. small, medium-sized, large cars etc.), body type (i.e. pickup truck, SUV, van etc.), vintage (e.g. year of manufacture), or make and model, depending on the respective study, and fuel type segmented into conventional fuels, such as gasoline and diesel, and alternative fuels, such as natural gas, biofuel, electricity (hybrid, plug-in hybrid, battery electric) or hydrogen.

[3] The review articles of Li et al. (2017) and Rezvani et al. (2015) predominantly focus on psychology-motivated literature – i.e. behavioral theories, such as the theory of planned behaviour, normative theories, and lifestyle theories – which aims at the explanation of interdependencies of psychological constructs and their influence on the purchase intention of specific fuel types, as well as the main motivators and barriers in decisions for specific vehicle/fuel types (e.g. Barth et al., 2016; Nayum et al., 2016; Plötz et al., 2014; Noppers et al., 2014; Nayum and Klöckner, 2014; Schuitema et al., 2013; Egbue and Long, 2012; Graham-Rowe et al., 2012; Skippon and Garwood, 2011).

2015; Hensher et al., 2013, 2017; Beck et al., 2011, 2013), some studies concentrate on the main drivers of the purchase of specific vehicle types or classes (e.g. Biswas et al., 2014; Baltas and Saridakis, 2013; Eluru et al., 2010; Bhat et al, 2009; Chiou et al., 2009; Cao et al., 2006; Choo and Mokhtarian, 2004). However, it is argued that factors influencing fuel type choice are found to vary considerably across vehicle classes (e.g. Mohamed et al., 2018; Higgins et al., 2017). Hence, several studies have jointly considered vehicle type and fuel type choices in their explanatory models in order to account for this heterogeneity in vehicle buyers' preferences (e.g. Habibi et al., 2019; Hahn et al., 2018; Liu and Cirillo, 2018; DeShazo et al., 2017; Higgins et al., 2017; Dumortier et al., 2015; Mabit, 2014; Hess et al., 2012; Potoglou and Kanaroglou, 2007).

A vast amount of factors has been found to significantly influence individuals' vehicle choice decisions and purchase intentions in the empirical literature. Most studies include more than one of the following categories of explanatory variables in their models:

(1) Vehicle attributes, including policy influences, such as taxes or incentives, or the rank of the vehicle in the household vehicle fleet (Jakobsson et al., 2016; Axsen et al., 2016; Prieto and Cammerer, 2013; Link et al., 2012), either specified in discrete choice experiments or derived from real market data;

(2) Socio-demographic characteristics of the decision-maker (e.g. age, gender, education, income), which are controlled for in almost all studies;

(3) Individual (mobility-related) behavior, such as the purpose of vehicle usage (Baltas and Saridakis, 2013, Noblet et al., 2006), usage of carsharing services (Javid and Nejat, 2017), access to and usage of public transportation (e.g. Rudolph, 2016; Jäggi et al., 2013; Spissu et al., 2009), and annual mileage (e.g. Higgins et al., 2017; Shin et al., 2015; Hoen and Koetse, 2014; Kuwano et al., 2013; Ziegler, 2012; Lave and Train, 1979);

(4) Household characteristics, such as household size or number of children in the household (e.g. He et al., 2014; Potoglou and Kanaroglou, 2007; Bhat and Sen, 2006; Choo and Mokhtarian, 2004; Mohammadian and Miller, 2002) and type or number of household vehicles (e.g. Hahn et al., 2018; DeShazo et al., 2017; Helveston et al., 2015; Qian and Soopramanien, 2011; Potoglou, 2008; Cao et al., 2006);

(5) Housing conditions and location and characteristics of the residential neighborhood (Antolín et al., 2018; Liu, 2014; Jäggi et al., 2013; Li et al., 2013; Musti and Kockelman, 2011; Paleti et al., 2011); and

(6) Psychological factors, encompassing attitudes, perceptions, and preferences of the decision-maker – environmental attitude (e.g. Bahamonde-Birke and Hanappi, 2016; Daziano and Bolduc, 2013; Hackbarth and Madlener, 2013; Jensen et al., 2013; Achtnicht et al., 2012; Ewing and Sarigöllü, 2000), technical interest (Soto et al., 2018; Hackbarth and Madlener, 2016; Kim et al., 2014, Hidrue et al., 2011), personal knowledge about AFVs (Hahn et al., 2018), and attitude towards specific vehicle attributes (e.g. Ferguson et al., 2018; Higgins et al., 2017; Biswas et al., 2014; Baltas and Saridakis, 2013; Jäggi et al., 2013) – pre-purchase information sources (Baltas and Saridakis, 2013; Li et al., 2013), as well as signaling (innovativeness, technology-oriented or forward-thinking personality) and societal influences, such as social norms or peer effects (e.g. Cherchi, 2017; Smith et al., 2017; Jansson et al., 2017a,b; Rasouli and Timmermans, 2016; Helveston et al., 2015; Kim et al., 2014).

Generalized results show that individuals preferring smaller vehicles and AFVs, especially battery electric vehicles (BEVs), seem to be younger, better educated, environmentally more aware, living in suburban or more densely populated areas with better access to public transportation, smaller households without children, and have a lower annual mileage. In contrast to buyers of AFVs, individuals preferring smaller vehicles are more likely to be female or have a higher income and are less likely to use the vehicle for commuting or to be home owners. Additionally, personal or social norms and signaling as well as a positive attitude towards or better knowledge about AFVs is shown to positively affect AFV choice probability (see Hackbarth, 2020). However, as indicated by Hackbarth (2020), for most variables either conflicting or insufficient (in the sense of lack of significance of effects, or a lack of sufficing number of studies) evidence concerning their influence on the purchase probability of a specific vehicle type or fuel type can be found. This is mainly due to the fact that their impact is highly dependent on the particularities of the respective studies, i.e. the available data set or applied methodology.

In that sense, we contribute to the literature in several ways. First, to the best of our knowledge, our work is the first scientific research to study German vehicle buyers' joint vehicle type and fuel type choice decisions by using a unique dataset[4] of revealed preferences and stated intentions.[5]

Secondly, closely related to the vehicle type choice studies of Baltas and Saridakis (2013), Eluru et al. (2010), and Cao et al. (2006), as well as the fuel type choice studies of Jansson et al. (2017a) and Javid and Nejat (2017), we are mainly focusing on car buyers' characteristics, preferences and attitudes as main explanatory factors and less on vehicle-related attributes to explain specific vehicle type and fuel type purchases. However, our work extends on these international studies, in that it combines many of their most relevant and explanatory factors in a single model for analyzing joint vehicle and fuel type choice decisions. Moreover, we integrate several promising but rarely used explanatory factors, such as the source of funding of the vehicle (Ziegler, 2012), individuals usage of carsharing services (Javid and Nejat, 2017), or the premium-quality of the original equipment manufacturer (OEM). The latter information could be peculiarly interesting for German OEMs.

Thirdly, we especially analyze the specifics of buyers of smaller vehicles and their differences to those individuals preferring SUVs, as grasping a better understanding of this issue seems vital in the current market situation of rapidly increasing SUV sales figures.

Finally, we compare our results with the international research in great detail in order to facilitate the commensurability and transferability of our results, recommendations, and conclusions to other use cases.

This paper is, thus, motivated both from a transportation policy and a car manufacturer's perspective alike, as the problems shown above have strategic, behavioral, and marketing implications for both. A more detailed knowledge of the underlying preferences and determinants behind vehicle adoption decisions could help to further accelerate the diffusion of

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[4] The experimental data focusing on discrete fuel type choice gathered in the same survey was already analyzed in detail in Hackbarth and Madlener (2013, 2016). In this study, we now focus on the revealed preferences and stated intentions data of participants and not on the experimental data.

[5] That is, until now regardless of the underlying theoretical approach, scientific studies solely focused on the explanation of fuel type purchase decisions or intentions: rational choice studies (e.g. Jacobs et al., 2016; Bauer, 2015; Hackbarth and Madlener, 2013, 2016; Achtnicht et al., 2012; Ziegler, 2012; Eggers and Eggers, 2011) and behavioral or psychological studies (e.g. Barth et al., 2016; Plötz et al., 2014; Bühler et al., 2014; Petschnig et al., 2014).

smaller and alternatively fueled vehicles[6] by adjusting business models, information, or policies accordingly.

The remainder of this paper is organized as follows. In section 2, we describe the survey generation and the data gathered. In section 3, the methodological approach is introduced. Empirical results are reported and compared to previous research in section 4. In section 5, the recommendations for action are derived. Section 6 concludes.

2 Data

The data, on which our empirical analysis of consumers' vehicle choice is based, stems from a Germany-wide web-based survey that was conducted by the authors in July and August 2011. In total, 1500 respondents completed the survey and were recruited from a probability-based commercial online panel. Potential respondents had to meet two requirements. Firstly, they had to own a driver's license. Secondly, they had to have either purchased their newest vehicle in the last 12 months or they had to be intending to purchase one within the upcoming year.

The sample, which almost perfectly reflects the regional distribution of the population among the 16 German federal states, shows many similarities regarding socio-economic and socio-demographic factors when compared to the general population in Germany. However, also some minor differences can be found (Table 1). For instance, our sample under-represents individuals with low income, while it over-represents younger and highly educated people, which is a common finding in web-based surveys. Moreover, the survey participants are comparatively less often owning a vehicle and living less often in single-person households or rural areas. Slight dissimilarities can also be found concerning vehicle attributes, i.e. our sample over-represents buyers of relatively inexpensive vehicles and AFVs, as well as drivers with high annual mileage. This needs to be taken into account when interpreting the results.

[6] Electrified vehicles considerably increased their market share among newly registered vehicles in Germany over the past year: 25,056 BEVs (+119.6%), 84,675 HEVs (+76.4%), including 29,436 PHEVs (+114.2%). However, the share of gasoline-powered passenger cars is still increasing (+5.6%), and making up for the biggest part (57.7%) of the 3.44 million newly registered passenger cars in 2017 (KBA, 2018a).

Table 1: Household and vehicle characteristics of the sample vs. the population in Germany

Variable	Value	Sample (%)	Population (%)
Household characteristics			
Gender	Female	48.8	50.9
	Male	51.2	49.1
Age	18 to 24	8.9	9.8
	25 to 44	50.0	31.3
	45 to 64	37.1	34.3
	65 or above	4.0	24.6
Education	No form of school leaving qualification	0.4	7.7
	Secondary general school leaving qualification	6.7	37.3
	Intermediate school leaving qualification	29.5	29.0
	Higher education entrance qualification or university (of applied sciences) degree	63.4	26.0
Household income per month	Less than €2,000	17.4	49.5
	€2,000 to €5,999	62.1	40.3
	€6,000 or more	2.6	2.7
	Not stated and others	17.9	7.5
Number of persons in household	1	16.3	40.2
	2	39.7	34.2
	3	22.5	12.6
	4	16.0	9.5
	5 or more	5.5	3.4
Type of location	Urban (central city)	39.8	28.9
	Suburban / subrural	51.6	56.5
	Rural	8.6	14.6
Number of vehicles in household	0	4.7	17.7
	1	52.9	53.0
	2	35.7	24.2
	3	5.1	4.0
	4 or more	1.5	1.0
Vehicle characteristics			
Vehicle purchase	Vehicle purchase in past 12 months	48.0	-
	Vehicle purchase planned within 12 months	52.0	-
Reason for vehicle purchase	Replacement of old vehicle	82.8	81.0
	Additional vehicle	12.5	11.0
	Initial vehicle purchase	4.7	8.0
Purchase price	Less than €20,000	49.8	34.0
	€20,000 to €40,000	41.6	51.0
	€40,000 or more	8.6	15.0
Vehicle type	Mini cars	5.5	5.6
	Small cars	18.6	18.4
	Medium-sized cars	28.1	25.4
	Large cars	19.9	14.7
	Executive cars	6.4	5.2
	Luxury cars	0.9	0.9
	Multi-purpose cars	9.3	11.9
	SUVs	6.4	11.3
	Sport coupés	1.1	1.5
	Others	3.7	5.1
Fuel type	Gasoline	59.3	52.0
	Diesel	29.5	47.1
	Alternative fuel	11.2	0.9
Annual mileage	Less than 10,000 km	29.2	36.7
	10,000 km to 20,000 km	41.3	41.4
	20,000 km or more	29.5	21.9

Source: Own calculations; Population shares for Germany computed on the basis of BBSR (2012), DAT (2012), KBA (2012, 2014), Destatis (2012a, 2012b), and Infas/DLR (2010).

The pre-tested and revised final survey consisted of five main sections. In the first section, respondents had to provide detailed information about existing and planned car ownership, i.e. the vehicle segment (and make/model if possible) and fuel type of the newest/next vehicle, the (expected) driving habits, and the influencing factors before and during vehicle acquisition. The second section retrieved respondents' familiarity with six types of AFVs, followed by a detailed introduction to these alternative propulsion technologies, and a stated preferences discrete choice experiment. The data of the latter is described and explored elsewhere (see Hackbarth and Madlener, 2013, 2016). In the third section, participants had to indicate the magnitude of importance of 16 different vehicle attributes in their purchase decision, while their level of agreement with numerous statements touching environmental concern, environmentally compatible behavior in various fields (shopping, mobility, and energy), and the interest in technology in general, and cars in particular, was gathered in the fourth section. Finally, the fifth section comprised several socio-economic and socio-demographic questions, such as gender, age, income, occupation, and educational level, but also questions regarding specifics of the respondents' household, such as its size and residential environment, as well as respondents' habits concerning public transport utilization.

3 Methodological approach and model specification

3.1 Methodological approach

Our empirical analysis of the joint vehicle type and fuel type choice data is based on a discrete choice model, since the dependent variable indicates (potential) new car buyers' choices out of a finite set of 30 disjoint vehicle alternatives – all possible combinations of 10 different vehicle types and 3 fuel types (see section 3.2).

Since the Hausman-McFadden tests for all possible reduced choice sets showed violations of the very restrictive independence of irrelevant alternatives (IIA) assumption[7], we chose to estimate a less restrictive nested logit model (NL) – in addition to a standard multinomial logit model MNL for comparative reasons. The NL allows correlation in unobserved attributes by

[7] The IIA assumption states that the ratio of choice probabilities of two alternatives is independent from the availability of any other alternative. It directly originates from the assumption that the error terms ε_{nj} are independently and identically extreme value distributed.

grouping similar alternatives into nests (e.g. mini and small cars), while keeping alternatives in different nests uncorrelated.[8]

The methodological approach of such an NL with two levels is described briefly in the following, drawing directly from Silberhorn et al. (2008), Cameron and Trivedi (2005), Train (2003), Hensher and Greene (2002), and Louviere et al. (2000), respectively.

It is assumed that the J elementary choice alternatives on the lower level, so-called twigs, can be clustered into K nests on the upper level, so-called branches, depending on their similarity, depictable in a tree structure.[9] Thus, the overall random utility U_{jk} a decision-maker receives of a specific alternative j now can be decomposed into two parts. First, a marginal utility component $U_k = V_k + \varepsilon_k$ on the branch level, with a deterministic part $V_k = \gamma' Y_k$ – comprising a vector of explanatory variables of the specific branch Y_k and a vector of unknown coefficients γ' – and the stochastic part ε_k. Second, a conditional utility component $U_{j|k} = V_{j|k} + \varepsilon_{j|k}$ on the twig level given that branch k was chosen, with a deterministic part $V_{j|k} = \beta' X_{j|k}$ – comprising a vector of characteristics of the specific vehicle alternatives or the vehicle buyers $X_{j|k}$ and a vector of unknown coefficients β' – and the stochastic part $\varepsilon_{j|k}$.

Taking all this into account, the probability P_{jk} that a utility maximizing decision-maker selects alternative j within nest k results from the product of the marginal choice probability P_k for nest k (upper level) and the conditional probability $P_{j|k}$ for choosing alternative j within nest k (lower level), which are both logit models. Applying RU2 normalization[10], the choice probability is as follows:

[8] That is, while in an NL the IIA assumption still holds regarding alternatives in the same nest (comparably to an MNL), it is relaxed when it comes to alternatives in different nests. Thus, the variances of the random error components in the utility expressions can be different across groups of alternatives. To accommodate these potential variance differences, scale parameters (μ_k and λ_k) have to be introduced into the utility functions.

[9] Note that this tree structure has nothing to do with behavioral reasons or decision trees but is defined by the researcher. In other words, NLs do not portray the decision-making process, but only account for differences in variances in the unobservable utility components. Still, congruency between both might occur (Hensher et al. 2005).

[10] We chose the RU2 normalization on the upper level ($\lambda_k = 1$) and allow the IV parameters to be free between partitions of a nest because of the unrestricted compatibility of this normalization with the necessary conditions for utility maximization (see Hensher and Greene, 2002).

$$P_{jk} = P_k \cdot P_{j|k} = \frac{\exp\left(V_k + \frac{1}{\mu_k} IV_k\right)}{\sum_{l=1}^{K} \exp\left(V_l + \frac{1}{\mu_l} IV_l\right)} \cdot \frac{\exp(\mu_k V_{j|k})}{\sum_{m=1}^{J|k} \exp(\mu_k V_{m|k})}, \quad (1)$$

with $IV_k = ln \sum_{m=1}^{J|k} \exp(\mu_k V_{m|k})$ being the inclusive value, which represents the expected utility for the choice of alternatives within nest m and connects the two decision levels, and scale parameter μ_k, which has to be in the unity interval for consistency with utility maximization (with values closer to unity indicating less correlation).

We tested and compared an exhaustive range of NL models with two- or three-level nesting structures as to vehicle type, fuel type, or a combination of both. We found, however, that the nesting structures compatible with identification requirements under the utility maximization paradigm were predominantly those in which the alternatives were jointly grouped based on vehicle and fuel type, with best results obtained by a two-level structure. From the many NL partition structures evaluated, the tree structure presented in Figure A1 in the Appendix showed the best statistical model fit and, thus, was chosen for our final empirical analysis. In this final structure, the 30 vehicle alternatives were clustered into six nests: a nest comprising of all mini, small, and medium-sized vehicle options irrespective of their fuel type; a nest containing all comparably spaceous gasoline-fueled vehicles, i.e. large, executive, luxury, and sports cars, as well as SUVs, MPVs, and other vehicles; two nests comprising the first four of these more spaceous vehicles (large, executive, luxury, and sports cars) each, separated regarding the two fuel types diesel and alternative fuel; and, finally, two nests containing the remaining three spaceous vehicles (SUVs, MPVs, and other vehicles) each, again segmented with regard to fuel type (diesel and alternative fuel).

3.2 Model specification

The specification of the utility functions, i.e. the dependent and the explanatory variables that were included in our final vehicle type and fuel type choice model, are explained in more detail in the following.

3.2.1 Dependent variables

The dependent variables of our choice model are the new vehicles that respondents either purchased recently (i.e. the latest household vehicle acquired within the preceding 12 months – revealed preference) or were about to purchase in the upcoming year (stated intention).

Table 2: Variables used in the model

Variable	Definition	Mean	Std. dev.	Min	Max
Individual and household characteristics					
Demographics					
Age	Age of the respondent in years	41.615	12.678	18	84
Female	1 if respondent is female, 0 otherwise	0.488	0.500	0	1
Attitudes and behavior					
Environmental awareness	Respondent's environmental awareness (average of the seven 5-point Likert scale[1] item scores)	3.468	0.757	1	5
Technophilia	Respondent's technophilia (average of the three 5-point Likert scale[1] item scores)	3.199	0.913	1	5
Environmental behavior 1	Respondent's environmental purchase and donation behavior (average of the three 5-point Likert scale[1] item scores)	2.680	0.930	1	5
Environmental mobility	Respondent's environmental mobility (average of the three 5-point Likert scale[1] item scores)	3.408	0.966	1	5
Knowledge about AFVs	Respondent's knowledge about alternative fuel vehicles (average of the six 5-point Likert scale[2] item scores)	2.809	1.046	1	5
Importance of vehicle attributes					
Fuel consumption and fuel cost	Importance of vehicle's fuel consumption and fuel cost in purchase decision (5-point Likert scale[3])	4.223	0.971	1	5
Motor vehicle tax	Importance of vehicle's annual tax in purchase decision (5-point Likert scale[3])	3.840	0.973	1	5
Size and spaciousness	Importance of vehicle's size and spaciousness in purchase decision (5-point Likert scale[3])	3.755	1.004	1	5
Horsepower	Importance of vehicle's horsepower in purchase decision (5-point Likert scale[3])	3.460	0.993	1	5
Uniqueness and rarity	Importance of vehicle's uniqueness and rarity in purchase decision (5-point Likert scale[3])	2.660	1.174	1	5
Appearance and design	Importance of vehicle's appearance and designe in purchase decision (5-point Likert scale[3])	3.561	1.067	1	5
Driving range	Importance of vehicle's driving range on full tank or battery in purchase decision (5-point Likert scale[3])	3.921	0.967	1	5
Fuel type	Importance of vehicle's fuel type in purchase decision (5-point Likert scale[3])	3.524	1.023	1	5
Household characteristics					
Without children	1 if household is without children, 0 otherwise	0.655	0.476	0	1
No. of automobiles	5-point scale of household's number of automobiles, ranging from '0 = without vehicle' to '4 = four or above'	1.457	0.732		
User of carsharing services	1 if respondent uses carsharing services, 0 otherwise	0.041	0.198	0	1
Residential location	4-point scale of household's residential location, ranging from '1 = central city' to '4 = rural area'	1.877	0.914	1	4
Vehicle characteristics					
Utilization					
Main purpose of vehicle use: commute	1 if main purpose of vehicle use is commuting to work, 0 otherwise	0.513	0.492	0	1
Household's main vehicle	1 if vehicle is household's main vehicle, 0 otherwise	0.411	0.492	0	1
Annual mileage	6-point scale of vehicle's annual mileage, ranging from '1 = up to 5000 km' to '6 = 40,000 km and above'	3.079	1.095	1	6
Purchase					
Recent vehicle purchase	1 if vehicle was purchased in past year, 0 otherwise	0.480	0.500	0	1
Purchase price	7-point scale of vehicle's purchase price range, ranging from '1 = up to €10,000' to '7 = €70,000 and above'	2.741	1.225	1	7
Company car	1 if vehicle is a company car, 0 otherwise	0.039	0.194	0	1
Premium OEM	1 if vehicle manufacturer is BMW, Mercedes, Lexus, Infinity, Porsche, Aston Martin, Audi, Jaguar, or Ferrari, 0 otherwise	0.221	0.415	0	1
Alternative-specific constants					
Mini gasoline	1 if vehicle type is mini and fuel type is gasoline, 0 otherwise	0.042	0.201	0	1
Mini diesel	1 if vehicle type is mini and fuel type is diesel, 0 otherwise	0.007	0.085	0	1
Mini altern. fuel	1 if vehicle type is mini and fuel type is alternative, 0 otherwise	0.006	0.077	0	1

Table 2 *(continued)*

Variable	Definition	Mean	Std. dev.	Min	Max
Small gasoline	1 if vehicle type is small and fuel type is gasoline, 0 otherwise	0.142	0.349	0	1
Small diesel	1 if vehicle type is small and fuel type is diesel, 0 otherwise	0.023	0.151	0	1
Small altern. fuel	1 if vehicle type is small and fuel type is alternative, 0 otherwise	0.021	0.142	0	1
Medium gasoline	1 if vehicle type is medium-sized and fuel type is gasoline, 0 otherwise	0.182	0.386	0	1
Medium diesel	1 if vehicle type is medium-sized and fuel type is diesel, 0 otherwise	0.067	0.249	0	1
Medium altern. fuel	1 if vehicle type is medium-sized and fuel type is alternative, 0 otherwise	0.032	0.176	0	1
Large gasoline	1 if vehicle type is large and fuel type is gasoline, 0 otherwise	0.091	0.287	0	1
Large diesel	1 if vehicle type is large and fuel type is diesel, 0 otherwise	0.085	0.279	0	1
Large altern. fuel	1 if vehicle type is large and fuel type is alternative, 0 otherwise	0.023	0.151	0	1
Executive gasoline	1 if vehicle type is executive and fuel type is gasoline, 0 otherwise	0.030	0.171	0	1
Executive diesel	1 if vehicle type is executive and fuel type is diesel, 0 otherwise	0.029	0.169	0	1
Executive altern. fuel	1 if vehicle type is executive and fuel type is alternative, 0 otherwise	0.005	0.068	0	1
Luxury gasoline	1 if vehicle type is luxury and fuel type is gasoline, 0 otherwise	0.005	0.073	0	1
Luxury diesel	1 if vehicle type is luxury and fuel type is diesel, 0 otherwise	0.002	0.045	0	1
Luxury altern. fuel	1 if vehicle type is luxury and fuel type is alternative, 0 otherwise	0.002	0.045	0	1
Sport coupé gasoline	1 if vehicle type is sports car or roadster and fuel type is gasoline, 0 otherwise	0.008	0.089	0	1
Sport coupé diesel	1 if vehicle type is sports car or roadster and fuel type is diesel, 0 otherwise	0.001	0.036	0	1
Sport coupé altern. fuel	1 if vehicle type is sports car or roadster and fuel type is alternative, 0 otherwise	0.002	0.045	0	1
SUV diesel	1 if vehicle type is sports utility vehicle and fuel type is diesel, 0 otherwise	0.031	0.172	0	1
SUV altern. fuel	1 if vehicle type is sports utility vehicle and fuel type is alternative, 0 otherwise	0.004	0.063	0	1
MPV gasoline	1 if vehicle type is multi-purpose vehicle and fuel type is gasoline, 0 otherwise	0.045	0.208	0	1
MPV diesel	1 if vehicle type is multi-purpose vehicle and fuel type is diesel, 0 otherwise	0.033	0.180	0	1
MPV altern. fuel	1 if vehicle type is multi-purpose vehicle and fuel type is alternative, 0 otherwise	0.014	0.117	0	1
Others gasoline	1 if vehicle type is pickup truck, camper van, light commercial vehicle, leisure activity vehicle, etc. and fuel type is gasoline, 0 otherwise	0.018	0.133	0	1
Others diesel	1 if vehicle type is pickup truck, camper van, light commercial vehicle, leisure activity vehicle, etc. and fuel type is diesel, 0 otherwise	0.016	0.125	0	1
Others altern. fuel	1 if vehicle type is pickup truck, camper van, light commercial vehicle, leisure activity vehicle, etc. and fuel type is alternative, 0 otherwise	0.003	0.058	0	1

Notes: 1 = The 5-point Likert scale ranges from '1 = strongly disagree' to '5 = strongly agree'; 2 = The 5-point Likert scale ranges from '1 = I could not explain it at all' to '5 = I could explain it well '; 3 = The 5-point Likert scale ranges from '1 = not at all important' to '5 = very [1]important'.

The possible vehicle alternatives are defined by vehicle type, classified into 10 categories, and three fuel types, leading to 30 distinct choice options. The 10 vehicle categories used in the present study are mainly classified in terms of their size and body type according to the segmentation scheme set by the German Federal Motor Transport Authority (e.g. KBA, 2018a): mini cars, small cars, medium-sized cars, large cars, executive cars, luxury cars, sport coupés, multi-purpose vehicles (MPVs), i.e. minivans and vans, SUVs (including off-road vehicles), and others (summarizing the segments labeled 'utilities', 'camping vans', and 'others'). The three fuel types used to categorize the vehicle alternatives in our study are gasoline, diesel, and alternative fuels, the latter containing all kinds of partially or fully electrified vehicles – i.e. hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs) – and those running on natural gas. The shares of and preferences for the different vehicle types and fuel types in our sample are presented in Table 2.

Finally, we chose gasoline SUV as base alternative (parameter set to zero) in our model, as, firstly, determinants of SUV purchase and their differences to other segments are one of the main research goals of our study, and, secondly, most vehicles run on gasoline, so that this specific fuel type is a natural candidate as a base category. Thus, the estimated coefficients will have to be interpreted with respect to that category.

3.2.2 Explanatory variables

The variables entering the deterministic part of utility in our vehicle choice model are given in Table 2, and can roughly be classified into decision-maker/household characteristics and vehicle characteristics. The former can further be arranged into 4 subgroups, i.e. (1) socio-demographic characteristics, (2) attitudes and behavior, (3) importance of vehicle attributes, and (4) household characteristics, while the latter comprise 3 subgroups: (1) vehicle utilization, (2) vehicle purchase, and (3) alternative-specific constants.

Note that numerous explanatory variables which were found to exert a significant influence on vehicle choice in previous research were tested in the course of model specification. However, not all of them were found to have a statistically significant impact on the choice decision of at least one alternative in our sample, and, thus, were discarded in our final model.[11] The remaining 26 key explanatory variables that entered the vehicle choice model are:

- *Socio-demographic characteristics:* The demographic variables that were found to significantly influence vehicle purchase decisions include the age and gender of the primary driver.
- *Attitudes and behavior:* Our survey contained 22 statements adopted from the literature and adapted where needed (e.g. Karrer et al., 2009; Kuckartz, 2000; Preisendörfer, 1999), measuring the underlying subject of environmental concern, environmental behavior and interest in cars or new technologies. In order to extract the slightly correlated fundamental attitudes and behaviors and, thus, to reduce the dimensions of variation, we applied a principal component analysis (PCA) using Promax rotation as the extraction method on these 22 items. As can be seen in Tables A1 and A2 in the Appendix, six[12] underlying components with eigenvalues greater than unity were identified, accounting for 64.05% of the overall variance. Of the six extracted components only four – environmental awareness, environmental mobility, environmental (purchase and donation) behavior, and technophilia – had an impact on vehicle choice and, hence, were used in our final model by averaging the item scores into sum scales for each factor. Furthermore, respondents were asked to rate their familiarity with different alternative propulsion technologies. The scores for the single AFVs were then added up and averaged for each respondent in order to obtain a unidimensional scale as an indicator for their general knowledge about alternatively fueled vehicles. As shown in Table 2, on average respondents evaluate themselves as being rather inexperienced with regard to alternatively fueled vehicles.

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[11] We derived our final model comprising solely significant explanatory variables from exhaustive tests applying backward elimination. The deleted variables include: pre-purchase information sources, utilization of other means of transportation, availability of public transportation, current job, education, income, and the importance of some vehicle attributes (e.g. safety, reliability, driving range, emissions, service, fuel availability).

[12] A PCA is suitable for our data, as indicated by the Kaiser-Meyer-Olkin statistic (0.887) and the highly significant Bartlett test of sphericity ($p < 0.0001$). Furthermore, the number of items (≥3) and the reliability (Cronbach's alpha ≥ 0.66) for each of the six extracted factors is sufficient, i.e. exceeding the proposed critical threshold values of 0.60-0.70 (Peterson, 1994). All of the items had factor loadings greater than (or close to) 0.6, and generally loaded strongly on a single factor in the six-factor solution. Finally, a content-related label could easily be assigned to each of the six components, due to their great intra-component item homogeneity.

- *Importance of vehicle attributes:* The importance that vehicle buyers' ascribe to 16 different vehicle attributes was measured in the questionnaire, of which only 8 were found to significantly influence the vehicle purchase decision: fuel consumption and fuel cost, motor vehicle tax, size and spaciousness, horsepower, uniqueness and rarity, appearance and design, driving range, and fuel type.[13]
- *Household characteristics:* Four household-related variables were significant in our final model: number of automobiles, residential location (categorizing the German districts with regard to population density, see BBSR, 2012), and two variables indicating the absence of children and the usage of car-sharing services, respectively. As shown in Table 2, the latter household characteristic is comparatively rare.
- *Vehicle utilization:* The survey contained several questions related to vehicle usage, which resulted in only three statistically significant variables: indicators for commuting as main intended vehicle use[14], main vehicle (as can be seen in Table 2, around 41% of the (intended) vehicle purchases are concerning the principal vehicle of the household), and annual mileage.
- *Vehicle purchase:* The significant variables entering our final model indicated whether the vehicle was funded by the employer (company car)[15], built by one of the nine premium manufacturers (BMW, Mercedes, Lexus, Infinity, Porsche, Aston Martin, Audi, Jaguar, or Ferrari) defined by Rosengarten and Stürmer (2005), or already and actually purchased in the year prior to the survey participation, respectively. Respondents further had to indicate their budget constraint, i.e. the stated price range of their last/next vehicle purchase.

[13] Multi-collinearity between the 8 remaining items measuring the importance of vehicle attributes was tested for. Since in our final model the slightly correlated vehicle attributes never enter the utility functions of the same vehicle alternative, multi-collinearity is not an issue.

[14] In our sample, the indicated main purposes of vehicle usage were commute to work (51%), private affairs (35%), business-related (9%), recreation and vacation (4%), and others (1%).

[15] The means of vehicle financing of survey participants were cash payment (52%), personal credit (21%), leasing (12%), funded by employer (4%), and others (11%).

4 Empirical Results

The impact of driver, household, and vehicle characteristics on the choice probability of the 30 distinct vehicle alternatives, described by vehicle and fuel type, was assessed by estimating an MNL and NL. Although the estimation results of the MNL and NL (see Table 3) are comparably similar, small differences can be found particularly regarding the size of coefficients and the statistical significance of some variables. For instance, while one parameter is insignificant in the NL but not in the MNL (luxury gasoline vehicle constant), a greater number of variables are insignificant in the MNL compared to the NL (medium class alternative fuel vehicle constant, user of carsharing services*medium class vehicle, and premium OEM*luxury vehicle). Differences in the sign of parameters between the two models are only observed for three insignificant alternative specific constants (large diesel vehicle, MPV diesel, and other diesel) and, thus, negligible.

However, as indicated by the goodness-of-fit test statistics (LL values, McFadden's ρ^2), the final NL shows significant statistical improvement compared to the MNL specification, i.e. the final NL more precisely explains individuals' vehicle choice behavior.[16]

This result is accentuated by the six inclusive value parameters which are found to be significantly different from zero and one, respectively (see *p*-values and Wald test statistic in Table 3), implying that the utility maximization requirement is met, alternatives belonging to the specific nests actually are sharing unobserved attributes, and the nesting structure does not necessarily have to be changed.[17] Further, the $\rho^2(c)$ value of 0.21 of the final NL compared to the model containing constant terms alone falls within the range of other models found in the literature. Therefore, in the following detailed discussion of the estimation results, we focus on the NL model parameters only.

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[16] The result of the likelihood ratio test between MNL and NL illustrates the statistically highly significant superiority of the NL: $55.06 > \chi^2_{\alpha=0.99}(6) = 16.81$.

[17] That is, although the difference between some of the parameters (e.g. the IV parameters of the two nests containing larger alternatively fueled vehicles) is quite small, collapsing these two nests into one single branch results in a deterioration of the model's goodness-of-fit indicators.

Table 3: Estimation results

	MNL		NL	
	Coefficient	**Std. error**	**Coefficient**	**Std. error**
Alternative-specific constants				
Mini gasoline	7.37233***	1.12238	6.25585***	0.75301
Mini diesel	4.96998***	1.24543	4.86024***	0.86004
Mini altern. fuel	3.06719**	1.36743	3.42986***	0.94627
Small gasoline	7.43790***	0.78667	6.28745***	0.60101
Small diesel	4.76997***	0.93020	4.71374***	0.69891
Small altern. fuel	3.10097***	1.05439	3.43020***	0.76884
Medium gasoline	5.18599***	0.59918	5.01613***	0.55909
Medium diesel	2.93983***	0.76376	3.58716***	0.68028
Medium altern. fuel	0.89271	0.92295	2.13517***	0.82702
Large gasoline	2.08411***	0.57446	0.96929**	0.43958
Large diesel	0.38203	0.74322	-0.50810	0.59023
Large altern. fuel	-1.96125**	0.94152	-2.57674***	0.73200
Executive gasoline	-3.91154***	0.77882	-2.32076***	0.68534
Executive diesel	-6.19701***	0.96222	-3.96737***	0.83899
Executive altern. fuel	-8.75466***	1.18099	-5.92831***	0.97445
Luxury gasoline	-3.77145**	1.63603	-2.28834	1.40515
Luxury diesel	-7.39398***	1.90543	-4.34484***	1.64018
Luxury altern. fuel	-8.47697***	1.94421	-5.43298***	1.44638
Sport coupé gasoline	-9.33926***	2.40899	-6.16261***	2.11365
Sport coupé diesel	-13.9271***	2.64646	-9.09170***	2.34563
Sport coupé altern. fuel	-14.1556***	2.63389	-9.65693***	2.15538
SUV diesel	-1.70121***	0.51192	-1.43767***	0.40630
SUV altern. fuel	-5.00972***	0.85687	-3.92143***	0.67318
MPV gasoline	2.09056***	0.73901	1.29730***	0.45258
MPV diesel	0.09773	0.87345	-0.24676	0.62657
MPV altern. fuel	-2.22747**	1.04437	-2.39309***	0.74961
Others gasoline	2.08964**	0.92716	1.02428**	0.52230
Others diesel	0.55721	1.04654	-0.14378	0.70961
Others altern. fuel	-2.47280**	1.25639	-2.61471***	0.78136
Mini				
Female	0.56598**	0.27884	0.33945**	0.15397
Environmental awareness	0.59905***	0.19940	0.47541***	0.13808
Importance of fuel consumption and cost	0.42043***	0.15958	0.18377**	0.08597
Importance of size and spaciousness	-0.89750***	0.15532	-0.68244***	0.10834
Household without children	0.96374***	0.32952	0.90813***	0.21745
User of carsharing services	2.09869***	0.60766	1.43205***	0.43990
Household's main vehicle	-1.58027***	0.32260	-1.04446***	0.23557
Annual mileage	-0.78128***	0.14921	-0.39986***	0.09025
Purchase price	-2.85028***	0.23955	-2.17794***	0.16264
Small				
Age	-0.01279**	0.00592	-0.00703**	0.00330
Female	0.50451***	0.16305	0.30084***	0.09767
Environmental awareness	0.39528***	0.13029	0.37195***	0.10319
Importance of fuel consumption and cost	0.26855***	0.09569	0.10522*	0.05388
Importance of size and spaciousness	-0.62789***	0.11116	-0.54397***	0.08888
Household without children	0.81958***	0.20950	0.81865***	0.16994
User of carsharing services	1.09656**	0.48126	0.92434**	0.39321
Household's main vehicle	-1.04842***	0.21455	-0.75865***	0.17849
Annual mileage	-0.30254***	0.08490	-0.15385***	0.04761
Purchase price	-2.21317***	0.16063	-1.83228***	0.11560
Medium				
Environmental awareness	0.33911***	0.09841	0.33382***	0.09403
Importance of size and spaciousness	-0.34511***	0.08613	-0.40544***	0.07816
Importance of uniqueness and rarity	-0.14270**	0.06019	-0.06697*	0.03598
Household without children	0.58285***	0.15990	0.68395***	0.15251
User of carsharing services	0.61994	0.38931	0.64215*	0.35776
Household's main vehicle	-0.67693***	0.17426	-0.55076***	0.15903
Purchase price	-1.17741***	0.11049	-1.28560***	0.09827
Premium OEM	0.90119***	0.23368	0.65072***	0.17642
Large				
Technophilia	0.16008*	0.08507	0.11321*	0.06243
Importance of uniqueness and rarity	-0.21204***	0.06895	-0.13631***	0.04981
Importance of driving range	0.17389**	0.08213	0.12642**	0.05780
No. of automobiles	-0.26700**	0.10600	-0.14605*	0.07726
Household's main vehicle	-0.65139***	0.17317	-0.37401***	0.12482
Purchase price	-0.32829***	0.09560	-0.18549**	0.07815
Premium OEM	1.18722***	0.23537	0.92113***	0.19338

Table 3 *(continued)*

	MNL		NL	
	Coefficient	**Std. error**	**Coefficient**	**Std. error**
Executive				
Environmental awareness	0.32024**	0.16049	0.18908*	0.10554
Purchase price	0.57883***	0.12592	0.32594***	0.10751
Premium OEM	1.78611***	0.32000	1.23650***	0.25222
Luxury				
No. of automobiles	-1.82321***	0.59225	-0.83184**	0.37244
Purchase price	1.41243***	0.26442	0.72236***	0.24661
Premium OEM	1.10593	0.70691	0.80507**	0.35899
Sport coupé				
Technophilia	0.91198**	0.38175	0.65055**	0.27899
Importance of size and spaciousness	-1.25687***	0.25412	-0.76655***	0.22505
Importance of appearance and design	0.99116***	0.33297	0.61301**	0.25891
Purchase price	1.29479***	0.24561	0.81473***	0.20454
MPV				
Importance of size and spaciousness	0.34653***	0.12937	0.20623***	0.07260
Importance of horsepower	-0.45397***	0.11493	-0.28112***	0.08104
Importance of uniqueness and rarity	-0.24127**	0.09888	-0.13545**	0.05825
Household without children	-0.62590***	0.20854	-0.30441***	0.11578
No. of automobiles	-0.36171**	0.15270	-0.22021**	0.09516
Residential location	0.24397**	0.09955	0.10465*	0.05542
Premium OEM	-0.82813**	0.37449	-0.46456**	0.20066
Others				
Importance of size and spaciousness	0.52642***	0.18244	0.31498***	0.10618
Importance of horsepower	-0.30206*	0.16863	-0.27053***	0.09711
Importance of appearance and design	-0.46072***	0.14517	-0.21864**	0.09685
Main purpose of use: commuting	-0.76175**	0.31062	-0.31238**	0.15484
Household's main vehicle	-0.79281**	0.32015	-0.27259*	0.16119
Annual mileage	-0.45989***	0.14551	-0.20486***	0.07905
Premium OEM	-1.70001**	0.75333	-0.73722**	0.36186
Diesel				
Environmental mobility	-0.14326**	0.06603	-0.08817*	0.04702
Importance of motor vehicle tax	-0.12890*	0.07157	-0.08919*	0.05338
Importance of uniqueness and rarity	-0.14636**	0.05698	-0.12220***	0.04157
Importance of fuel type	0.20331***	0.07179	0.15103***	0.05537
Household without children	-0.37608***	0.13234	-0.29829***	0.09676
Household's main vehicle	0.39696***	0.13327	0.28290***	0.09819
Annual mileage	0.58979***	0.08010	0.42776***	0.06799
Purchase price	0.40219***	0.07205	0.27717***	0.05579
Company car	1.71979***	0.35403	1.21556***	0.27214
Alternative fuel				
Environmental behavior: purchase/donation	0.22402**	0.10234	0.14054**	0.07035
Knowledge about AFVs	0.20469**	0.09078	0.15295**	0.06952
Importance of fuel consumption and cost	0.27928**	0.11350	0.17994**	0.07645
Importance of horsepower	-0.45886***	0.09613	-0.33640***	0.07762
Importance of fuel type	0.24572**	0.10413	0.20030***	0.07087
Residential location	-0.24348**	0.10527	-0.13437*	0.07735
Annual mileage	0.52960***	0.11827	0.36114***	0.08345
Recent vehicle purchase	-2.05931***	0.23405	-1.43778***	0.21006
Purchase price	0.53409***	0.11191	0.40954***	0.09050
Premium OEM	-1.24493***	0.29383	-0.96411***	0.23744
Inclusive value (IV) parameters[1]				
Mini/small/medium			0.50784***	0.06412
Large/Executive/Luxury/Sport–Diesel			0.47347***	0.13468
Large/Executive/Luxury/Sport–Altern. fuel			0.32826*	0.17341
SUV/MPV/Other–Diesel			0.30472***	0.08318
SUV/MPV/Other–Altern. fuel			0.31801*	0.18072
Spacious vehicles–Gasoline			0.57299***	0.11008
Estimation statistics				
No. of observations	1500		1500	
Log likelihood at zero LL(0)	-5101.41		-5101.41	
Log likelihood at constants LL(c)	-4216.18		-4216.18	
Log likelihood at convergence	-3356.54		-3329.01	
$\rho^2(0)$	0.342		0.347	
$\rho^2(c)$	0.204		0.210	

Notes: ***, **, * indicate significance at the 1%, 5%, 10% level; Base alternative: Gasoline SUV; 1 = Wald statistics against unity are (top-down) -7.68, -3.91, -3.87, -8.36, -3.77, and -3.88, respectively (i.e. all being greater than the critical value of ±1.96 at α=0.05).

4.1 Results ordered by vehicle alternative

First, we analyze the statistically significant key influencing factors by vehicle type to gain better knowledge about the characteristics of typical buyers of each vehicle segment and fuel type. Most of the 29 alternative-specific constants are significant, except for gasoline-fueled luxury cars, and three diesel-fueled vehicles (large cars, MPVs, ‘others’). Mini (all fuel types), small (all fuel types), medium-sized (gasoline and diesel), and large gasoline cars as well as gasoline MPVs have a positive sign compared to gasoline-fueled SUVs, the base category, suggesting that the average effect of all unmeasured variables tends to increase the probability of choosing these vehicle alternatives. In contrast, the alternative-specific constants of executive (all fuel types) and luxury (diesel and alternative fuel) cars, sport coupés (all fuel types), SUVs (diesel and alternative fuel) as well as alternatively fueled large cars, MPVs, and ‘others’ are negative compared to gasoline SUVs, suggesting that the average effect of all unmeasured variables tends to decrease the choice probability of these vehicles. Furthermore, the comparably large alternative-specific constants for sport coupés as well as the alternatively fueled vehicles in general suggest that the choice probability of these vehicle types are least well-explained by the variables included in the model.

Mini: Buyers of mini cars are more likely to be female and more environmentally aware and tend to place more emphasis on the vehicles’ fuel consumption and fuel costs in the purchase decision. On the other hand, individuals perceiving vehicle size and spaciousness as being an important vehicle attribute are less likely to purchase mini cars. Smaller households without children and users of carsharing services are overrepresented among buyers of mini cars. Finally, mini vehicles are less likely to be household’s main vehicle and less likely to be chosen by car buyers willing to spend greater amounts for their new vehicle and individuals with high annual mileage.

Small: Likewise, the probability of purchasing a small car is higher for younger, female vehicle buyers, and individuals with stronger environmental attitude or living in childless households. It is less likely for drivers with high annual mileage and car buyers deciding about the household’s main vehicle to buy a small car. Interested consumers tend to have a smaller budget for the purchase and place less emphasis on vehicle size and spaciousness, while placing stronger emphasis on fuel consumption and fuel costs.

Medium: The propensity to prefer a vehicle from the medium class is higher for individuals who are more environmentally aware, user of carsharing services, or those who live in households without children. Medium class vehicles are less likely to be the household's main car but more likely to be manufactured by a premium OEM. Individuals placing weaker emphasis on vehicles' size and spaciousness or uniqueness and rarity in their purchase decision and spending smaller amounts on their vehicle have a higher than average probability of purchasing a medium class vehicle.

Large: Being technically interested increases the likelihood of choosing a large vehicle, while the purchase probability decreases with the number of automobiles already available in the household and the purchase price of the vehicle. If the vehicle is intended to be the household's main vehicle, car buyers are also less likely to purchase a large vehicle. However, large vehicles are more likely to be from a premium brand. Finally, individuals placing less emphasis on the importance of a vehicle's uniqueness and rarity but more importance on its driving range tend to purchase large vehicles more often.

Executive: Executive vehicle buyers tend to be more environmentally aware, pay greater amounts for their vehicle, and are more likely to purchase a vehicle from a premium manufacturer.

Luxury: Similarly to the executive vehicle segment, luxury vehicles are more likely to be manufactured by a premium OEM and, on average, tend to have a greater purchase price. The number of automobiles in the buyer's household, however, decreases the purchase probability of luxury vehicles.

MPV: Compared to buyers of SUVs, individuals interested in MPVs are less likely to place higher importance on horsepower or uniqueness and rarity, but greater emphasis on vehicles' size and spaciousness. They tend to live in more rural areas, in households without children, or households with a smaller number of available vehicles. Finally, MPVs are less likely purchased from a premium manufacturer.

Sport coupé: The likelihood of purchasing a sport coupé is higher for individuals who have stronger technical interest or rate vehicles' appearance and design as being more important during the purchase decision. Vehicle size and spaciousness, on the other hand, tend to be comparably unimportant for individuals being more likely to purchase a sport coupé. Compared to SUVs the purchase price is likely to be higher.

Others: Conversely, car buyers placing more emphasis on vehicle size and spaciousness and less emphasis on horsepower or appearance and design purchase vehicles from the 'others' segment more often. It is, however, less likely to be chosen if it is the main vehicle in a household or from a premium manufacturer. A high annual mileage and work-related usage as the main vehicle purpose also has a negative effect on the likelihood of purchasing an 'other' vehicle.

Diesel: Diesel is more likely to be chosen as the household's main vehicle, if it is a company vehicle (i.e. entirely or co-fincanced by the employer) and if the acquisition budget is higher. Furthermore, individuals with a weaker environmental mobility attitude and a greater annual mileage are also more likely to purchase diesel vehicles, whereas living in a household without children decreases the purchase probability. Car buyers placing more emphasis on motor vehicle taxes and vehicles' uniqueness and rarity are less likely to purchase a diesel-fueled vehicle, while its likelihood of being chosen increases with the importance of fuel type in the decision process.

AFV: Individuals with greater annual mileage, living in more urban areas, with greater environmental behavior, or knowledge about AFVs in general tend to be more open towards alternative fuels, while those having purchased a vehicle recently are less likely to have chosen an AFV. AFVs are also found to have higher purchase prices but are less likely to be from a premium manufacturer. Vehicle buyers placing more emphasis on fuel consumption and fuel cost and fuel type tend to prefer AFVs, while alternative fuel is less likely to be chosen if horsepower is valued as more important.

4.2 Results ordered by explanatory variables

Second, we describe the results according to the type of explanatory variable, i.e. individual and household characteristics as well as attributes of the vehicle options, assess their impact on the choice probability of the different vehicle alternatives, and compare our results to findings from previous research.

4.2.1 Individual and household characteristics

Demographics: Our results indicate that socio-demographics only have a comparably small impact on vehicle choice, as only age and gender show a significant influence. Age has a negative impact on the choice probability of small cars, i.e. older car buyers are less likely to choose this car type compared to (gasoline) SUVs, while, all else equal, women are more likely to choose mini and small cars. This finding is, on the one hand, in contrast to previous studies, often showing an impact of various further socio-demographic variables, such as education, income, marital status, or employment, on vehicle choice decisions and especially the choice probability of AFVs (e.g. Cirillo et al., 2017; Higgins et al., 2017; Rasouli and Timmermans, 2016; Nayum et al., 2016, Mabit et al., 2015; Peters and Dütschke, 2014; Plötz et al., 2014). On the other hand, our results corroborate previous research stating that the effects of socio-demographic characteristics greatly decrease when other explanatory variables, especially psychological factors, are accounted for (e.g. Mohamed et al., 2018; Axsen et al., 2016; Nordlund et al., 2016; Rezvani et al., 2015; Nayum and Klöckner, 2014).

Moreover, the results that younger and female vehicle buyers are buying smaller vehicles is broadly in line with the literature and the reported negative impact of age (Adjemian et al., 2010; Bhat et al., 2009; Choo and Mokhtarian, 2004) or being male (e.g. Jäggi et al., 2013; Prieto and Cammerer, 2013; Chiou et al., 2009; Spissu et al., 2009; Bhat and Sen, 2006; Cao et al., 2006; Choo and Mokhtarian, 2004) on the probability of purchasing mini, small, or medium class vehicles in relation to larger or more massive vehicles (e.g. pickup trucks).

Attitudes and behavior: Environmental awareness has a positive impact on the choice probability of mini, small, and medium-sized cars. Hence, buyers of larger (such as SUVs) or more sportive vehicles generally are less environmentally aware than buyers of smaller vehicle types, which was expected – as they, on average, are heavier, more powerful, less fuel-efficient and, thus, less environmentally friendly – and corroborates previous findings (Mohamed et al., 2018; Kahn, 2007; Choo and Mokhtarian, 2004). Interesting, however, is that environmental awareness also exerts a positive influence on the purchase probability of executive vehicles, which is only comparable to the results of Higgins et al. (2017), who find that prospective luxury car buyers seem to make greener decisions.

Consumers donating to environmental organizations or paying attention to environmental attributes in their purchase decisions are more likely to choose AFVs.[18] This result corroborates the general findings from other studies regarding the impact of environmental concern on fuel type choice, especially regarding electrified vehicles (e.g. Nordlund et al., 2016; Krause et al., 2016; Helveston et al., 2015; Krupa et al., 2014; Noppers et al., 2014; Petschnig et al., 2014; Hackbarth and Madlener, 2013; Daziano and Bolduc, 2013; Axsen et al.; 2013; Carley et al., 2013; Schuitema et al., 2013; Daziano and Chiew, 2012; Hidrue et al., 2011). Finally,

[18] Regarding fuel type choice, factors measuring environmental behavior and attitudes towards environmental mobility were more informative than the environmental awareness scale.

respondents putting much emphasis on environmentally-friendly mobility are less likely to buy diesel-fueled cars – a finding which opposes the result of Soto et al. (2018) for Columbian data.

Car buyers who are interested in (new) technologies are more likely to buy large cars and sport coupés (compared to SUVs), which especially regarding the latter makes sense. Our finding is broadly in line with the studies of Baltas and Saridakis (2013) concerning sport coupés as well as Higgins et al. (2017) for the case of (electrified) large vehicles. However, unlike previous studies (e.g. Soto et al., 2018; Axsen et al., 2016; Hackbarth and Madlener, 2016; Egbue and Long, 2012; Hidrue et al., 2011), we did not find a significant positive impact of technical interest on fuel type choice, especially concerning electrified vehicles. This, however, may be caused by the fact that we explicitly tested for individuals' specific knowledge about all kinds of AFVs, which in our model is found to increase a car buyer's likelihood of choosing such an alternatively propelled vehicle. This result also supports the studies reporting that personal knowledge and experience increase BEV acceptance (e.g. Hahn et al., 2018; Schmalfuß et al., 2017; Barth et al., 2016; Krause et al., 2013; Egbue and Long, 2012; Graham-Rowe et al., 2012).

Importance of vehicle attributes: Fuel consumption and the according fuel costs have a positive impact on the choice of mini and small cars, i.e. car buyers who rate fuel costs as being important are more likely to choose mini and small cars. Furthermore, respondents for whom fuel costs are important also tend to more likely choose alternatively fueled cars. Both results, especially the latter, are in line with previous findings (e.g. Higgins et al., 2017; Jäggi et al., 2013; Link et al., 2012) and were expected, since smaller vehicles tend to be more fuel-efficient and alternative fuels generally are less expensive (mainly due to lower tax rates).

We further find that respondents who place more emphasis on the motor vehicle tax during new car purchase decisions are less likely to buy vehicles that run on diesel, which is in line with Habibi et al. (2019). Our result makes sense, as in Germany this tax for diesel vehicles is higher, compared to gasoline vehicles and AFVs.[19]

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[19] The annual circulation tax in Germany is calculated depending on the fuel type (BMF, 2018), so that newly registered conventionally-fueled vehicles are burdened on the basis of the engine displacement (base tax rates of €2/100 ccm for gasoline and €9.5/100 ccm for diesel engines) and, additionally, the CO_2 emissions (tax rate of €2 per gCO_2/km for every gram above 95 gCO_2/km). Electric vehicles are exempted from the tax for 10 years. After the expiration of that term, they are assessed by their total weight (€5.63-6.39/200 kg, increasing with weight).

Car buyers who place more emphasis on vehicle size and spaciousness are, as expected, less likely to choose mini, small, and medium-sized cars, as well as sport coupés and are more likely to buy MPVs and ‘other’ vehicles, compared to SUVs, which is also broadly in line with the literature (Mohammadian and Miller, 2002; Beggs and Cardell, 1980).

However, if a vehicle’s horsepower is considered to be an important vehicle feature, MPVs and ‘other’ vehicles as well as AFVs in general are less likely to be chosen. The latter result is in line with the finding of Biresselioglu et al. (2018), who describe the lack of trust in BEVs’ performance as a major barrier for their adoption, while our former result is broadly in line with the finding of Baltas and Saridakis (2013), who report a positive impact of horsepower on the purchase probability of large vehicles, sport coupés and station wagons, also compared to SUVs.

Car buyers who place more emphasis on vehicle uniqueness and rarity are less likely to choose medium-sized and large cars, as well as MPVs. Regarding the choice of fuel type, diesel cars are chosen less often by consumers who value uniqueness and rarity as being more important. Sport coupés are more likely to be chosen by car buyers who put more emphasis on vehicles’ appearance and design, while those consumers are less likely to choose ‘other’ vehicles, which is absolutely reasonable given the highly different and unique characteristics and application areas of both vehicle types. The results of Baltas and Saridakis (2013) are pointing in the same direction concerning sport coupés, while they additionally report that individuals putting more importance on vehicles’ image in their purchase decision are more likely to purchase mini or luxury vehicles compared to SUVs.

In contrast to the literature, we did not find a positive effect of these more image-related vehicle features on the choice probability of AFVs (e.g. Schuitema et al., 2013; Graham-Rowe et al., 2012; Skippon and Garwood, 2011).

Consumers who are more interested in driving range are more likely to choose large cars, suggesting that they are used more frequently for longer trips than SUVs, as the annual mileage does not seem to be significantly different between both vehicle types. Our finding generally supports the results of Hahn et al. (2018), who report medium-sized and executive vehicles to be preferred by individuals valuing driving range as being more important.

Finally, car buyers who place more importance on the fuel type of the new vehicle are more likely to choose diesel and alternatively fueled cars compared to the base model (gasoline car).

The implication is that buyers of non-gasoline vehicles (diesel and AFVs) are making this decision very intentionally and, thus, potentially are also better informed.

Household characteristics: Households without children are more likely to choose mini, small and medium-sized cars, and are less likely to purchase MPVs. Also diesel-fueled vehicles are less likely to be purchased by childless households. This is in line with the literature, which reports a positive impact of household size on the purchase probability of diesel vehicles (e.g. Knockaert, 2010), MPVs (e.g. Xu et al., 2015; Eluru et al., 2010; Spissu et al., 2009; Potoglou and Kanaroglou, 2007; Bhat and Sen, 2006), or SUVs compared to smaller vehicles (Musti and Kockelman, 2011; Bhat et al. 2009; Mannering et al., 2002), as well as a negative impact on medium-sized vehicles (Xu et al., 2015; Adjemian et al., 2010; Eluru et al., 2010). Additionally, the presence of children in a household in particular is found to exert a positive influence on the choice of MPVs (He et al., 2014; Mabit, 2014; Potoglou, 2008; Spissu et al., 2009; Choo and Mokhtarian, 2004; Mohammadian and Miller, 2002) and SUVs (Paleti et al., 2011; Spissu et al., 2009; Bhat and Sen, 2006; Cao et al., 2006), while a negative impact is reported for small (Antolín et al., 2018) and medium-sized cars (Paleti et al., 2011).

The number of automobiles has a negative impact on large and luxury cars, as well as MPVs. Put differently, multi-vehicle households are less likely to choose these vehicle types, suggesting that they are also more likely to be the households' main vehicle. Other studies find a generally negative impact on large vehicles (Adjemian et al., 2010), MPVs and passenger cars (Liu et al., 2014), and a positive impact on luxury vehicles (Antolín et al., 2018), sport coupés (DeShazo et al., 2017; Liu et al., 2014; Adjemian et al., 2010; Lave and Train, 1979) and pickup trucks (Liu et al., 2014; Adjemian et al., 2010; Potoglou, 2008; Cao et al., 2006) when compared to smaller vehicles, which is partially contrary to our results.[20]

Individuals using car-sharing services are more likely to buy mini, small, and medium-sized vehicles. This finding makes sense, as larger cars, which might be needed only occasionally (e.g. for transporting bulky goods), could then be rented easily from the car-sharing company.

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[20] In contrast to our study, in the literature significant impacts are found concerning the different fuel types, e.g. negative effects for NGVs, HEVs, and PHEVs (Antolín et al., 2018; Higgins et al., 2017; Musti and Kockelman, 2011) as well as positive effects for BEVs (Higgins et al., 2017; Helveston et al., 2015; Jensen et al., 2013; Qian and Soopramanien, 2011).

Individuals that do not live in the city center but in suburbs or in rural areas are more likely to choose MPVs and are less likely to choose AFVs. This finding is contrary to the result of Baltas and Saridakis (2013) that MPVs are more likely to be chosen by more urban households, compared to SUVs. The findings from previous research concerning the impact of household location on preferences for all kinds of AFVs is also rather mixed, i.e. both a positive impact (Antolín et al., 2018; Liu, 2014; Egbue and Long, 2012; Musti and Kockelman, 2011; Skippon and Garwood, 2011) as well as a negative impact (Antolín et al., 2018; Plötz et al., 2014; Paleti et al., 2011) of urban location on AFV choice probability is described.

4.2.2 Vehicle characteristics

Utilization: Those who mainly use a vehicle for commuting are significantly less likely to purchase vehicles from the 'others' segment. Thus, we do not find a specifically positive effect of commuting as the main vehicle use on the likelihood of purchasing larger passenger cars or SUVs, in contrast to other literature (Baltas and Saridakis, 2013, Noblet et al., 2006).

Mini, small, medium-sized, and large cars as well as 'others' tend to be chosen less often, when looking for the main household vehicle compared to more massive SUVs. On the other hand, vehicles running on diesel are more likely to be the main vehicle of the household. These findings are in line with our expectations, as the main household vehicle is driven more frequently and used for a broader number of purposes. Our results are expanding the findings from previous studies which report a greater probability of larger vehicles having a higher rank in the vehicle fleet (Prieto and Cammerer, 2013) and HEVs or gasoline vehicles being the main household vehicles as well as BEVs being the second or an additional car (Jakobsson et al., 2016; Axsen et al., 2016; Link et al., 2012).

The annual mileage has a negative influence on the choice probability of mini and small cars as well as 'others'. This result is in line with the positive effect found in the literature on the choice probability of larger vehicles (Shin et al., 2015; Kuwano et al., 2013; Lave and Train, 1979), On the other hand, annual mileage positively influences the purchase probability of diesel and alternative fuel vehicles in our sample. While the former result corroborates previous findings (Shin et al., 2015; Ziegler, 2012), the latter result is in contrast to the predominant finding in the literature of a negative impact of annual mileage on the choice probability of AFVs (e.g. Higgins et al., 2017; Hoen and Koetse, 2014; Li et al., 2013; Achtnicht et al., 2012).

Purchase: The amount of money car buyers (are willing to) spend for their vehicle has a negative impact on the choice probability of mini, small, medium-sized and large cars, and a positive influence on the choice probability of more exclusive cars, i.e. executive and luxury cars as well as sport coupés when compared to SUVs. Also, diesel and alternative fuel vehicles are more likely to be chosen with greater budget or income.[21] These results are reflecting the fact that more exclusive and larger vehicles, diesel vehicles, as well as generally all types of AFVs tend to cost more than their gasoline counterpart (ICCT, 2018).[22]

If the vehicle is funded by the employer it is more likely to be diesel-fueled, which was expected, as company vehicles usually are also larger vehicles (large, executive, luxury), and which also is totally in line with vehicle license data in Germany (KBA, 2018b).

If the vehicle was purchased recently, i.e. during the year prior to our survey, individuals were less likely to have chosen an AFV. This result makes sense, as at the time the survey was conducted, the supply of AFVs was still rather limited (early diffusion stage) so that an AFV as newest/next household vehicle for the most part was intended and not already purchased.

If the new vehicle is from a premium OEM, it is also more likely to be a medium-sized, large, executive, or luxury car, while it is less likely to be an MPV or 'other' vehicle. Further, when the vehicle manufacturer is a premium OEM, the choice of an AFV is less likely. Interestingly, in our sample, sport coupés do not seem to significantly differ from SUVs regarding premium manufacturers. Generally, this attribute is not considered in the literature, whereas the influence of specific brands on the purchase probability of the different vehicles is studied occasionally. For instance, Bauer (2015) finds that VW and BMW have a negative effect on AFV purchase attitude in Germany, while Kia has a positive impact. Habibi et al. (2019) observe a positive impact of Ferrari and Bentley and a negative effect of all other brands, with Volvo being the base manufacturer in this Swedish case. Both findings thus roughly point in the same direction as our results, whereas the majority of studies do not show any clear-cut effect regarding premium OEMs (e.g. Ito et al., 2019; Østil et al., 2017; Xu et al., 2015; Bhat et al., 2009; Mannering et al., 2002).

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[21] As income and purchase price are correlated ($r = 0.44$), purchase price can serve as a proxy for household income.

[22] Exactly this higher purchase price of AFVs is one of the main barriers to their adoption consistently found in the literature (e.g. Axsen et al., 2013; Egbue and Long, 2012; Daziano and Chiew, 2012; Graham-Rowe et al. 2012; Lane and Potter, 2007).

5 Discussion and policy implications

5.1 Discussion of results

As shown in our study mini, small, and medium-sized vehicles are remarkably similar with regard to the influence of observable factors on their purchase probability – environmental awareness, importance of fuel consumption and fuel costs, importance of size and spaciousness, number of children in the household, usage of carsharing services, main household vehicle, purchase price – but also concerning the impact of unobservable attributes, as is shown by the tree structure of our final NL model. This means, on the contrary, that smaller vehicles are in many respects very different to larger or more massive vehicles, such as SUVs (our base model). For instance, compared to SUVs mini, small, medium-sized, and large vehicles are more likely to be chosen by childless households and driven less far throughout the year (annual mileage of mini and small vehicles), as well as less likely to be households' main vehicle.

SUVs, however, seem to be more similar to MPVs and 'others' (predominantly utility vehicles/cargo vans) and to be correlated in unobserved attributes, as again reflected by the nesting structure of our model. A finding also supported by previous studies is that already owning SUVs, MPVs or pickup trucks decreases the likelihood of purchasing a further SUV (Paleti et al., 2011; Eluru et al., 2010). However, although related, MPVs are not perfect substitutes for SUVs, as their target groups are mainly suburban or rural families for whom vehicles' size and spaciousness is particularly important and horsepower as well as uniqueness and rarity is comparably unimportant in purchase decisions, respectively. In other words, SUVs are aiming at a much broader range of consumer segments, especially compared to MPVs but also smaller vehicles. For instance, as documented by Kim et al. (2006), elderly individuals with health problems prefer to purchase SUVs due to their favorable features, such as increased visibility, ease of entry and exit, and comfort, and not primarily because of their spaciousness or off-road capabilities. Moreover, safety is often referred to as an influencing factor for the choice and success of heavier vehicles such as SUVs (e.g. Hoen and Koetse, 2014; Cao et al., 2006), although this finding is not supported by our results. However, safety and reliability can be interpreted as a prerequisite in vehicle choice, independent of vehicle size or fuel type, as both factors seem to be very important in the whole sample.[23]

Unfortunately, this fact could potentially increase reluctance towards the new propulsion technologies, especially fuel cell electric vehicles (FCEVs) and BEVs, as due to their novelty and car buyers' lack of familiarity they are potentially perceived as being more unsafe, unreliable, and risky (e.g. Orlov and Kallbekken et al., 2019; Wang et al., 2018; Krause et al., 2013; Egbue and Long, 2012; Lane and Potter, 2007).

Fortunately, however, several similarities between buyers of specific fuel types and those of specific vehicle types can be found. For instance, smaller vehicles show connecting points to AFVs in two major aspects: those car buyers with a higher environmental attitude and placing greater emphasis on vehicles' fuel consumption and fuel cost are more likely to prefer mini, small, and medium-sized vehicles as well as AFVs. As economic and environmental reasons are found to be the major motivators to purchase an AFV (e.g. Biresselioglou et al., 2018; Li et al., 2017), buyers of small vehicles seem to be the most promising target group for switching to an alternative fuel.

Concerning their impact on CO_2 emissions, buyers of larger vehicles are the second and potentially even more important target group for actions taken by climate policy-makers and vehicle manufacturers to increase the adoption of alternative propulsion technologies. Individuals preferring larger vehicles are comparable to individuals who (intend to) chose an alternative fuel when it comes to the purchase price (SUVs). This is particularly important, as purchase price explains the greatest part of variance in our model and, thus, can be labeled as the most decisive factor in respondents' vehicle choice decisions – a result which is in line with the findings in Biresselioglou et al. (2018). Furthermore, MPVs as potential SUV substitutes and AFVs are less likely to be from a premium OEM, while medium-sized, large, executive, and luxury vehicles are more likely to be from one. Both results indicate that alternatively fueled

[23] Average stated importance of vehicle attributes (standard deviation in parentheses) in descending order: Reliability 4.43 (0.950), safety 4.30 (0.975), fuel consumption and fuel costs 4.22 (0.971), purchase price 4.15 (0.970), driving range on full tank/battery 3.92 (0.967), fuel availability (density of infrastructure) 3.89 (0.958), comfort 3.89 (0.916), motor vehicle tax 3.84 (0.973), size and spaciousness 3.75 (1.004), environmental friendliness 3.59 (1.000), appearance and design 3.56 (1.067), service station density 3.56 (0.987), fuel type 3.52 (1.023), horsepower 3.46 (0.993), image and design 3.01 (std. dev. 1.141), and uniqueness and rarity 2.66 (1.174).

larger vehicles can be successful but currently are receiving little attention from premium manufacturers. Finally, besides diesel cars, AFVs are potentially more likely to be purchased by individuals with higher annual mileage who are not purchasing the smallest vehicle types.

While the simultaneous accomplishment of both goals – adoption of AFVs and move to smaller vehicles – should be the first-best option, especially regarding environmental benefits, crash safety, or parking spaces, it could be prohibitive for individuals who rate size and spaciousness of the vehicle as very important or actually need a large vehicle (e.g. due to household size, i.e. the presence of children or mobility-challenged persons in the household). Thus, the second-best option for reaching the goal of sustainable mobility should be to enforce car buyers' switch from fossil to alternative fuels, when purchasing a large vehicle.

5.2 Policy implications

To accomplish these goals, based on the results of our study and previous findings, first and foremost comparably easy-to-realize policy measures should be introduced, such as information campaigns (including energy labels), trials, or carsharing options for AFVs organized by manufacturers or municipalities, to promote them as environmentally friendly and cost-effective solutions for individual road transport – and to allow individuals to gain practical experience especially with BEVs. Such information campaigns would not only resonate with potential buyers of smaller cars as 'natural' target group of BEVs, but presumably also with buyers of larger vehicles. For instance, Mohamed et al. (2018), Higgins et al. (2017), and Hardman et al. (2016) emphasize that such 'high-end' customers should be targeted as early adopters of electrified vehicles, as they are more likely able and willing to pay the higher purchase prices of AFVs. Furthermore, this consumer segment is susceptible to the potential economic and environmental benefits of electric propulsion, as these large vehicles suffer from higher fuel consumption.[24] Our results also show that 'high-end' SUV buyers put more emphasis on vehicles' uniqueness and rarity in their purchase decisions, indicating that in the near future manufacturers could promote AFVs by using unique and innovative designs.

[24] In line with this, Teisl et al. (2008) indicate that although environmental information shows little influence on vehicle type choice, it can exert a significant impact on fuel type choice within a specific vehicle segment (e.g. choosing an electric instead of a fossil-fueled SUV).

An information and trialability strategy which takes all these aspects into account could lead to behavioral change, as knowledge about and familiarity with AFVs, as well as an increase in the importance of the propulsion technology in vehicle choice decisions, are all found to boost the likelihood of purchasing an AFV (see also e.g. Schlüter and Weyer, 2019; Jensen et al. 2013; van Rijnsoever et al., 2009). That is, communication efforts and trials should focus on the main barriers for AFV adoption and aim at allaying the notion of AFVs as being unsafe or unreliable, as well as establishing confidence in recharging infrastructure, driving range, but also superiority regarding environmental impact and total cost of ownership (Haustein and Jensen, 2018). The latter is important, as a considerable amount of households is found to be unaware or unsure with regard to the monetary (Orlov and Kallbekken, 2019) and environmental (Graham-Rowe et al., 2012) savings potentials of energy-efficient vehicles. Moreover, the information should be distributed via a broad variety of media channels to increase its penetration, as the bandwidth of pre-purchase information sources car buyers rely on is diverse[25]. However, particularly peer or neighbor effects (social norm, signaling) should be accounted for, as they are consistently found to play a very important role in the decision-making process[26] (e.g. Bobeth and Matthies, 2018; Jansson et al., 2017b; Barth et al., 2016; Schuitema et al., 2013; Graham-Rowe et al., 2012).

Since vehicle buyers' motivation to adopt AFVs across all vehicle classes has been comparably low until today[27], communication efforts alone could be insufficient and should be accompanied by strong government policy, e.g. financial measures to stop the steady increase

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[25] In our sample, potential car buyers' preferred pre-purchase information sources are websites of car manufacturers (62%), (local) car sellers (57%), test reports in car magazines (48%), friends, relatives, colleagues (31%), blogs, web forums (14%), automobile clubs (7%), vehicle conventions (2%), and others (8%).

[26] Regarding the decision on which vehicle to purchase next, 44% of the respondents in our sample state that they decide by themselves, while 51% decide with the partner or family, and 11% are additionally influenced by others (friends or colleagues 5%, experts or sellers 3%, and employers (company cars) 3%).

[27] One reason for this lack of motivation, besides the unfamiliarity with the new propulsion technologies or a lack of environmental awareness especially among buyers of SUVs, is assumed to be the individuals' expectation that BEVs will technologically improve in the near future, making a present purchase economically more questionable (Egbue and Long, 2012).

in SUV sales or initiate the change to an alternative fuel (Turcksin et al., 2013).[28] For instance, Langbroek et al. (2016) find that use-based incentives are relatively effective in increasing sales of electrified vehicles, as the lower running costs of AFVs are one of the main drivers of their adoption (e.g. Biresselioglu et al., 2018; Li et al., 2017; Barth et al., 2016), which is in line with our findings. That is, increasing the prices of conventional fuels or subsidizing alternative fuels and electricity could boost AFV sales.[29] However, as Dumortier et al. (2015) indicate, consumers underrate the long-term savings of AFVs compared to their up-front costs. Thus, since AFVs have higher purchase prices compared to their fossil-fueled counterparts and purchase price is also found to be the most decisive factor in our study, additional purchase incentives could increase the adoption of AFVs (e.g. Bjerkan et al., 2016).

Finally, as motor vehicle taxes are found to decrease the purchase probability of diesel vehicles, these taxes could be increased to accelerate switching behavior in favor of AFVs, especially for larger vehicle types (as the tax is currently based on fuel type and engine displacement). Additionally, the possibilities to write-off taxes should be reduced for diesel-fueled company cars and instead increased for AFVs, as the dominance of diesel vehicles in fleets in Germany remains unchanged at a very high level of 84% (DAT, 2019).

6 Conclusion

Clean air legislations on the European and national level force car manufacturers to either diminish the fuel consumption of their conventionally-fueled vehicle fleet through downsizing or to increase the sales figures of AFVs, or both. However, the steadily increasing sales figures of SUVs and unabated dominance of fossil-fueled vehicles indicate that current measures (especially on the side of vehicle manufacturers) are not having the desired effect. It is therefore necessary to investigate what drives German car buyers’ preferences for specific vehicle types and fuel types in order to adjust supporting measures accordingly. Our study is based on

[28] A combination of measures seems to be the means of choice, as incentives alone are also found to have little influence on potential adopters of BEVs who are lacking conviction or knowledge with regard to the technology (Egbue and Long, 2012).

[29] While the latter approach presumably is politically easier to implement, the former measure would be more in line with the ‘polluter pays’ principle, less vulnerable to rebound effects, and also more in line with the current debate regarding the introduction of a national or European CO_2 emissions tax.

revealed and stated preferences data, gathered in a nation-wide survey among 1500 respondents conducted in the summer of 2011. It extends previous studies focusing on the German market, by not solely focusing on fuel type choice but rather investigating the joint choice of vehicle types and fuel types, thus accounting for heterogeneity between buyers of different vehicle classes. Two model specifications were used, a standard MNL and an NL, with the results of the latter suggesting that buyers of smaller vehicles and those preferring larger vehicles, e.g. SUVs, as well as buyers preferring gasoline or diesel vehicles compared to those favoring AFVs, differ significantly regarding: socio-demographic, household, and neighborhood characteristics, as well as attitudes, preferences, and vehicle-related attributes. However, our results also indicate that connecting points between these consumer groups do exist, which could be used as starting points to either switch demand from larger vehicles to smaller vehicle types or from fossil fuel vehicles to AFVs – or both.

Based on our results and findings from previous studies, we discuss the prospects of information campaigns, vehicle trials (especially for BEVs) and (financial) policy incentives and conclude that several measures should be combined to increase their effectiveness. This study thus delivers useful information and results for political decision-makers and car manufacturers in order to review their strategic decisions on how the acceptance of and the demand for AFVs and non-SUVs could be raised effectively in the near future. However, at the same time, attention should be paid to the potential adverse effects of these different information and policy measures on vehicle design[30] as well as the usage frequency of vehicles and other means of transportation (possibility of a rebound effect if usage becomes less expensive or is labeled as environmentally harmless, leading to moral licensing).

Over time, the increase of AFV alternatives available in the market will exert a positive impact on AFV diffusion, as it becomes more likely that vehicle buyers will find a specific alternatively fueled vehicle that fits their needs (Hoen and Koetse, 2014; Mabit, 2014; Liu et al., 2014), so that the supporting measures could be reduced.

Our results are informative for other countries and vehicle markets as well, as we compare our results in great detail with the existing international literature, and highlight the respective

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[30] For instance, under the current legislation, electrically driven kilometers are counted as emission-free in order to support the diffusion of BEVs. However, this ‘greenwashing’ especially of (plug-in) hybrid SUVs has led to a detrimental trend towards even larger, heavier, more powerful, and more expensive vehicles in this segment.

similarities and differences in results. Furthermore, as stated in the introduction, the problems of increasing SUV sales and a slow uptake of AFVs exist throughout the entire EU and beyond.

However, our study also has its limitations. First and foremost, our data was gathered several years back, so that preferences for vehicle types and especially fuel types might have evolved. For instance, in the past few years the so-called ‘Dieselgate’ has negatively influenced preferences for this fuel type not only in Germany. At the same time SUV sales have taken off, and BEVs have seen many developments: increase in vehicle supply (more available variants) and demand, technological progress (battery reliability, driving range), increase in charging infrastructure, monetary and non-monetary incentives, and most importantly, social change (attitudes, knowledge and familiarity regarding BEVs through own experience, neighbor effects or media coverage). However, even today sales figures of AFVs in general and BEVs in particular are still very low, as until now diesel vehicles have been predominantly substituted by gasoline vehicles and not AFVs, so that from that point of view, our data are still remarkably representative. This may also be due to the fact that our sample contains many respondents who intended to buy an AFV or actually had bought one and, thus, were ahead of their time. Nonetheless, a follow-up study with more recent data would be desirable.

Second, a separation of the different AFVs in subsequent research should be aimed at, which would allow for specific findings for BEVs, as BEVs have incommensurable characteristics compared to the other (alternative) fuel types.

Finally, in our study we focused on buyers of new vehicles only. Investigating the specifics of the used vehicles market, particularly with regard to BEVs and the importance and uncertainty of battery lifetime, seems to be a fruitful avenue for future research as well.

Acknowledgments

This study was enabled by a research grant from the E.ON ERC foundation (Project No. 02-02/04-19), which is gratefully acknowledged.

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Appendix

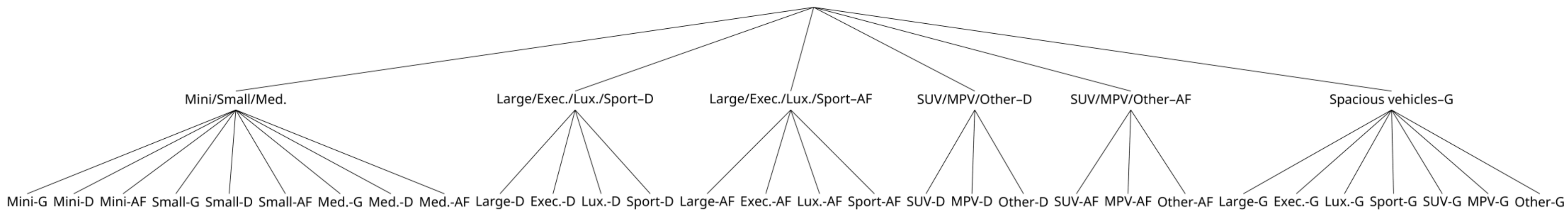

Figure A1: Structure of the estimated NL models

Table A1: PCA results

No.	Component	Cronbach's alpha	Statement	Mean	Std.dev.	Loading	h^2
1	Environmental awareness	0.861	Without additional policy measures, the environmental situation will worsen dramatically.	3.51	1.042	0.791	0.607
			If we continue with business as usual, we are heading for an environmental catastrophe.	3.51	1.078	0.772	0.664
			Currently, it is still the case that the majority of the population behaves environmentally unconscious.	3.71	0.948	0.770	0.515
			There are limits to growth, which have already been exceeded by our industrialized world or which will be reached very soon.	3.50	1.006	0.734	0.528
			It worries me when I think of the environmental conditions our children and grandchildren will probably have to live in.	3.46	1.056	0.715	0.622
			When I read newspaper reports or see TV shows about environmental problems, I'm often disgusted and angry.	3.21	1.014	0.702	0.512
			For the sake of the environment, we should all be willing to limit our current standard of living.	3.37	1.024	0.614	0.604
2	Technophilia	0.784	I am very interested in cars.	3.22	1.123	0.873	0.773
			I often talk with friends, colleagues or my family about cars.	2.99	1.071	0.817	0.716
			I like to keep busy with the operation of new technologies.	3.39	1.082	0.798	0.642
3	Environmental behavior 1 (purchase and donation)	0.747	I donate money to an environmental organization (e.g. Greenpeace, BUND, WWF, etc.) or am involved actively in an environmental organization.	2.23	1.271	0.847	0.679
			I pay attention for products with the 'Blue Angel' certificate, when I'm shopping.	2.74	1.125	0.821	0.700
			I specifically buy products that pollute the environment only slightly in their manufacture and use.	3.08	1.016	0.677	0.684
4	Environmental scepticism	0.718	The role of the car as a polluter is exaggerated.	3.10	1.127	0.821	0.690
			In my estimation, the environmental problem is greatly exaggerated in its importance by many environmentalists.	2.76	1.156	0.809	0.728
			Science and technology will solve many environmental problems, without us having to change our way of life.	3.03	1.035	0.729	0.559
5	Environmental behavior 2 (energy saving)	0.663	I pay attention to a low energy consumption, when I'm buying household appliances.	4.08	0.948	0.780	0.622
			I make sure that electronic devices are switched off completely, i.e. not left in stand-by mode.	3.78	1.103	0.763	0.617
			I throttle my heating in winter, when I leave my apartment for more than 4 hours.	3.75	1.167	0.704	0.537
6	Environmental mobility	0.733	If I have the chance, I use the public transport or bicycle instead of the car.	3.27	1.248	0.888	0.785
			At shorter distances (up to 2 km) I leave the car at home and go by bicycle or walk instead.	3.61	1.154	0.867	0.762
			I am in favor of limiting car traffic in the inner cities and recreational areas, if good public transport lines and cycle path networks are created in return.	3.34	1.185	0.578	0.544

Notes: Extraction method: Principal component analysis; Rotation method: Promax with Kaiser normalization; Loading = Degree of association between the statement and the factor; h^2 = Communality.

Table A2: Correlation matrix for extracted components

	Environmental awareness	Technophilia	Environmental behavior 1	Environmental scepticism	Environmental behavior 2	Environmental mobility
Environmental awareness	1.000	0.140	0.413	-0.341	0.353	0.450
Technophilia	0.140	1.000	0.193	0.287	0.126	0.034
Environmental behavior 1	0.413	0.193	1.000	-0.114	0.227	0.381
Environmental scepticism	-0.341	0.287	-0.114	1.000	-0.138	-0.270
Environmental behavior 2	0.353	0.126	0.227	-0.138	1.000	0.361
Environmental mobility	0.450	0.034	0.381	-0.270	0.361	1.000

Notes: Extraction method: Principal component analysis; Rotation method: Promax with Kaiser normalization.

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