Electric Vehicle Adoption in the Context of Household Fleet Choice: the Case of the Netherlands

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SHORT SUMMARY

This study uses data from the 2018, 2019 and 2020 Dutch National Travel Surveys and employs a multinomial logit regression model to examine the relationship between the household characteristic and the adoption of different types of electric vehicles (EVs) in the context of the household car fleet. Our results show that battery electric vehicles (BEVs) have the smallest sub-user groups. Internal combustion engine vehicles (ICEVs) and hybrid electric vehicles (HEVs) are more likely to be owned by one-car households, while plug-in hybrid electric vehicles (PHEVs) and BEVs tend to be leased by two-car households. PHEV and BEV adoption mostly occurs in highly urbanized areas. In particular, higher education and higher income are the main factors for BEV adoption in one-car household, respectively. Moreover, a 2020 COVID-19 effect shows that people were inclined to adopt BEVs and HEVs in that year and that BEVs appeal to a wider user group.

Keywords: Household fleet choice, EV, transition, ownership, leasing, the Netherlands

1 INTRODUCTION

Transport electrification and the transition to electric vehicles (EVs) help to realize the decarbonization of the transport sector if electricity is generated in a renewable way (Cano et al., 2018). Understanding households' decisions to adopt EVs as part of the household vehicle fleet is vital to help promote EV diffusion.

Previous studies on household fleet type and size decisions mainly refer to Internal combustion engine vehicles (ICEVs), and rarely involves EVs. These studies find, for example, that larger household fleet sizes are often associated with the number of employed adults, retirees, and license holders (Anowar et al., 2014). Also, households with older, well-educated household heads and higher household incomes are found to own more cars (Rith et al., 2019). Finally, larger vehicles with more seating and luggage space are more likely to be chosen as household size and the number of children increases (Chen et al., 2021).

Previous studies on EV adoption seldom distinguish between all EV types (hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery electric vehicles (BEVs)). For instance, Mandys (2021) used stated preference (SP) data from 2014 and 2015, to suggest that younger, higher educated, married and to a lesser extent higher income groups, and those living in the more southern parts of the UK are more likely to be early EV adopters. Also, previous studies mostly focused on identifying early adopters, without focusing on the dynamics of market diffusion process of different types of EVs. However, it is essential to understand the diffusion process, and Jenn et al. (2020) also suggested that the plug-in electric

vehicles (PEVs, including PHEVs and BEVs) market is moving beyond innovators and early adopters towards mass-market consumers with moderate incomes. This is also in line with the Diffusion of Innovations theory (Rogers, 2003).

Therefore, this study uses recent 2018, 2019 and 2020 data to assess the determinants of the adoption of different EV types in the context of household fleet size and composition choice. Given the fast increase in EV ownership in the 2018-2020 period, we also test to what extent these determinants have changed in this period, as an indicator of the EV market diffusion process.

2 DATA AND METHODS

Data

The data used in this study was derived from the Dutch National Travel Survey (DNTS) and CBS (2019). The DNTS reports the one-day travel behavior of a representative sample of the Dutch population. To increase our sample size, and specifically the number of EV owners, we pooled data from 2018 and 2019. Also, to observe the impact of recent development in the EV market and COVID-19 on car ownership, we compared data from 2018 and 2019 to data from 2020. Due to data availability and few two-car households leasing two cars and owning/leasing three and more cars, we only considered households owning/leasing at most two cars (excluding two-car households with two leasing cars). Because only people over 17 years old can legally hold a driver's license, we only included respondents who were at least 18 years old. After removing the missing values, we were left with data from 125,442 households.

This study investigates the fleet size and composition choice between no-car, one-car and two-car households. Nine household car fleet alternatives are identified (**Table 1**). The car(s) held by the household includes both owned and leased car(s) (this could be a private lease or company lease). We distinguish cars in the following increasing level of electrification: ICEV, HEV, PHEV, BEV.

Table 1 Explanation and definition of households based on fleet size and composition.

Category	Type of Household	Explanation of car ownership	Fleet size	Type of advanced	Sample size				
					2018	2019	2018+2019	2020	Total
Carless households	no car	There is no passenger car in the household.	0	-	6,703	6,542	13,245	8,140	21,385
One-car households	one-ICEV	There is only one passenger car in the household, and this car is an ICEV.	1	ICEV	21,001	20,115	41,116	23,086	64,202
	one-HEV	There is only one passenger car in the household, and this car is an HEV.	1	HEV	573	722	1,295	972	2,267
	one-PHEV	There is only one passenger car in the household, and this car is a PHEV.	1	PHEV	123	115	238	200	438
	one-BEV	There is only one passenger car in the household, and this car is a BEV.	1	BEV	27	76	103	241	344
Two-car households	ICEV+	There are two passenger cars in the household, and these two cars both are ICEVs.	2	ICEV	11,444	10,338	21,782	11,880	33,662
	HEV+	There are two passenger cars in the household, and these two cars at least include one HEV.	2	HEV	452	494	946	681	1,627
	PHEV+	There are two passenger cars in the household, and these two cars at least include one PHEV.	2	PHEV	269	245	514	317	831
	BEV+	There are two passenger cars in the household, and these two cars at least include one BEV.	2	BEV	78	160	238	449	687
Total number of households as the study sample					40,670	38,807	79,477	45,966	125,443

Statistical approach

Our primary focus is to identify the determinants of household fleet choice. First, we conduct

descriptive analysis for categorical household characteristics. Second, we examine the influence of household characteristics on the household fleet composition using a multinomial logit (MNL) discrete choice model. The dependent variables are nine alternatives based on the household fleet size and composition, taking the carless household as the reference category. The independent variables include individual and household socio-economic and demographic characteristics, and residential environmental attributes (**Table 2**). The goodness-of-fit of MNL model is assessed through McFadden's pseudo R square and Log-likelihood.

3 RESULTS

Descriptive analysis

The results suggest that ICEVs and HEVs are predominantly owned, whereas PHEVs and BEVs are more often leased. ICEV+ and HEV+ households usually have two owned cars. PHEV+ and BEV+ households mostly have an owned and a leased car, with the EV being the leased car (**Figure 1**). PEVs are mostly adopted in two-car households (**Table 1**).

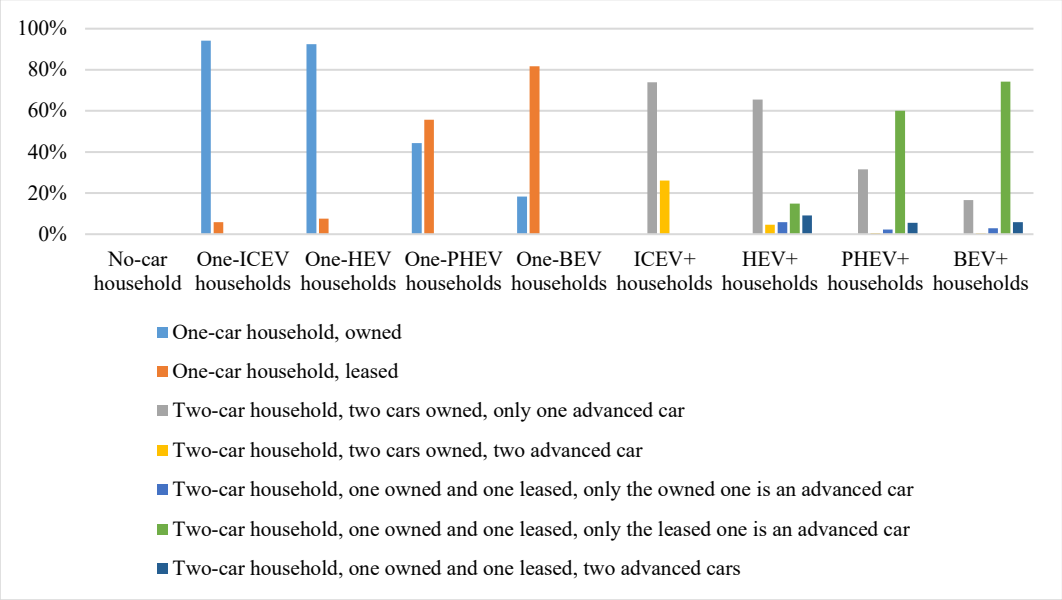

Figure 1 Percentage of households based on car ownership.

PHEV and BEV owning/leasing households (with one and two cars) are relatively younger than ICEV and HEV owning/leasing households. However, this effect is less distinctive for two-car households. For ICEV and HEV owning/leasing households, we find that two-car households tend to be relatively younger. For PHEV and BEV owning/leasing households, two-car households are relatively older than one-car households (**Figure 2**).

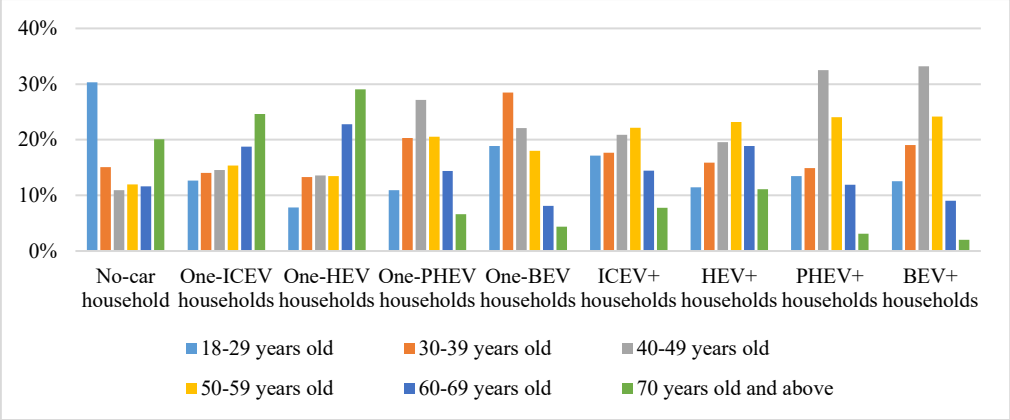

Figure 2 Percentage of households based on age classes.

We find that HEV, PHEV and BEV owning/leasing households are increasingly highly educated. One-car households with a PHEV or BEV include the highest share of highly educated households (**Figure 3**).

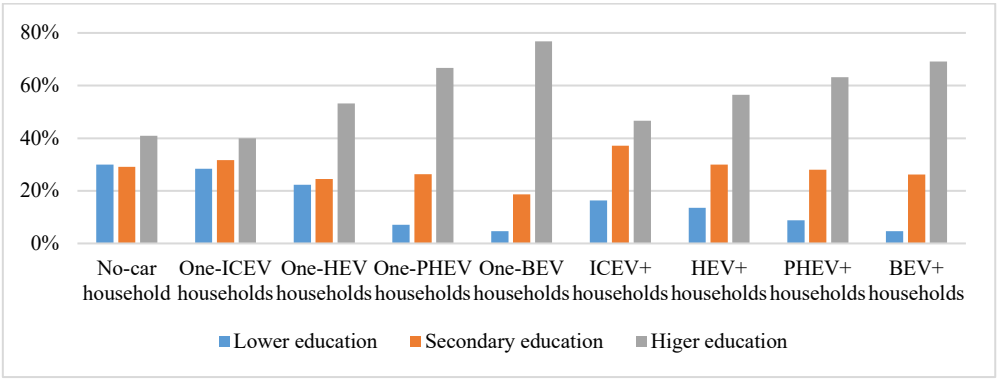

Figure 3 Percentage of households based on different education levels.

Compared with car-using households, the majority of no-car households have one adult (**Figure 4**). Two-car households relative to one-car households are more likely to have two adults.

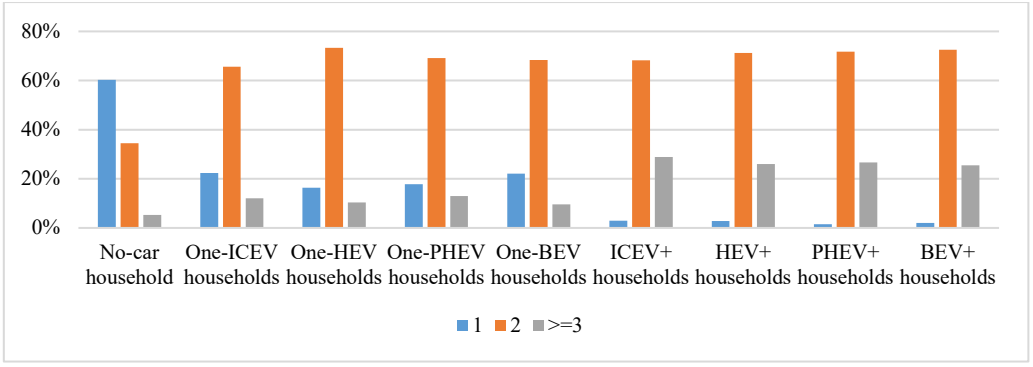

Figure 4 Percentage of households based on the number of adults.

We also find that compared to no-car households, households with a car(s) are more likely to have a younger child(ren)(**Figure 5).**

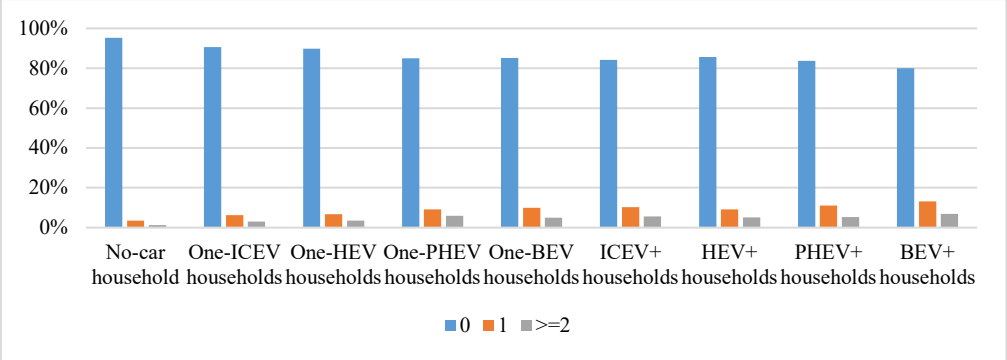

Figure 5 Percentage of households based on the number of younger children (under six years old).

Compared with no-car households, households with a car(s) are more likely to have older children. Moreover, two-car households are more likely to have at least two children relative to one-car households (**Figure 6**).

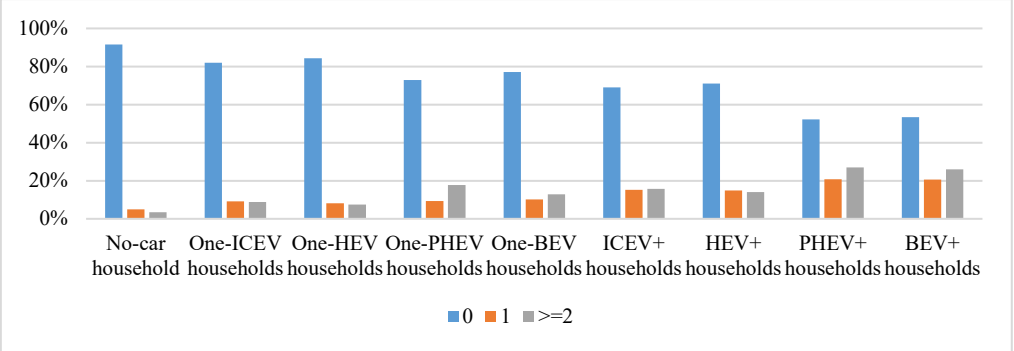

Figure 6 Percentage of households based on the number of older children (aged six to 17 years old).

Two-car households are more likely to be wealthier than one-car households. In addition, both one- and two-car households with PHEV(s) and BEV(s) mainly consist of the most affluent households, compared with households with HEV and then ICEV (**Figure 7**).

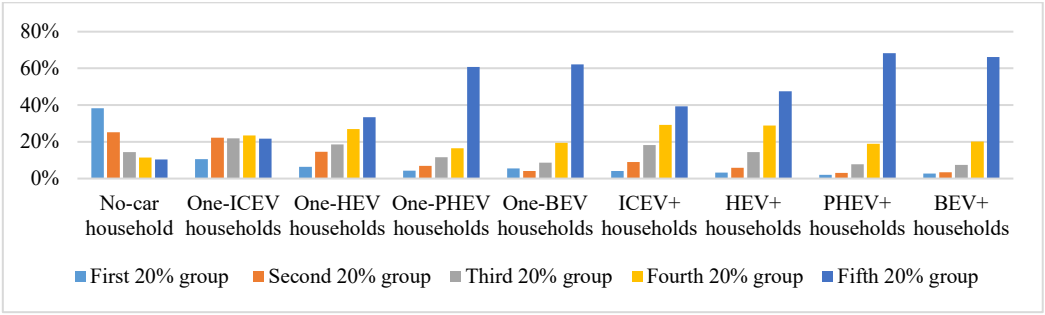

Figure 7 Percentage of households based on disposable household income level.

One-car households are more likely to live in highly urbanized areas, compared with two-car households (**Figure 8**). The largest share of BEV users live in the highly urbanized area, followed by PHEV users, compared with HEV users and ICEV users in households with the same car holding level.

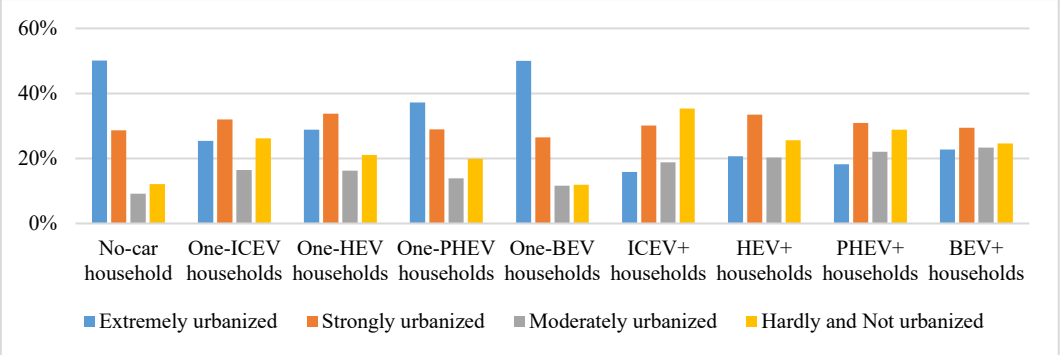

Figure 8 Percentage of households based on urbanization degree.

Multinomial logit model results

Individual socio-demographic characteristics

The MNL results (**Table 2**) indicate that with increasing age, households are more likely to own ICEVs and HEVs, both as a single car or combined with another car. For one-PHEV and one-BEV households, this trend peaks at 50-59 years old and 60-69 years old, respectively. People in the age cohort 40-59 are most likely to have fleet composition PHEV+. For BEV+, the cohorts are 40 years old and above, and 50-59 are most likely to have this fleet composition. Education effect is strongest for single BEV.

Household socio-economic and demographic characteristics

Compared with no-car households, larger households (with more adults, younger children and older children) are more likely to own/lease a car, and even more to own/lease two cars although this effect is less strong than for BEVs.

Higher household income levels increase the probability of car ownership for any type of car, and for one- and two-car fleets. The highest income level in particular increases the probability of owning two cars. Income effect is strongest for single PHEV.

Residential environmental attributes

With increasing urban density, decreasing number of convenience facilities and lower transit accessibility, the probability of car ownership statistically decreases in general. This negative urbanization effect plays out stronger for two-car fleets. In addition, the effect size seems to be less strong for HEV, PHEV including fleets, and especially BEVs, suggesting that EV ownership is a more urban phenomenon than ICEV ownership.

2020 effect on household fleet choice

We find that Dutch households are more likely to have HEV and BEV as a single car or combined car in 2020 (**Table 2**). Due to the word limit, this conference paper cut down part of our works. See other MNL models in our full paper, where taking categorical household characteristics as the interaction terms respectively. For example, the MNL model with residential environmental attributes as interaction terms is shown in **Table 3.**

Table 2 MNL result for household fleet choice.

Variable Name	One-ICEV households Coef. (Std. Err)	One-HEV households Coef. (Std. Err)	One-PHEV households Coef. (Std. Err)	One-BEV households Coef. (Std. Err)	ICEV+ households Coef. (Std. Err)	HEV+ households Coef. (Std. Err)	PHEV+ households Coef. (Std. Err)	BEV+ households Coef. (Std. Err)
(Intercept)	-2.088 ***	-6.655 ***	-7.268 ***	-7.525 ***	-5.851 ***	-8.072 ***	-6.942 ***	-7.222 ***
	(-0.046)	(-0.147)	(-0.231)	(-0.218)	(-0.071)	(-0.201)	(-0.215)	(-0.188)
Year								
2018+2019 (ref.)								
2020	-0.021	0.36 ***	0.12	0.532 ***	-0.02	0.188 ***	-0.062	0.62 ***
	(-0.02)	(-0.045)	(-0.076)	(-0.069)	(-0.024)	(-0.053)	(-0.067)	(-0.064)
Individual socio-demographic characteristics								
Age								
18-29 years old (ref.)								
30-39 years old	0.422 ***	0.779 ***	0.734 ***	1.892 ***	0.555 ***	0.465 ***	-0.066	-0.033
	(-0.034)	(-0.099)	(-0.17)	(-0.173)	(-0.042)	(-0.106)	(-0.123)	(-0.132)
40-49 years old	0.814 ***	1.027 ***	1.516 ***	2.728 ***	0.924 ***	1.095 ***	0.552 ***	0.916 ***
	(-0.038)	(-0.104)	(-0.164)	(-0.168)	(-0.044)	(-0.103)	(-0.113)	(-0.119)
50-59 years old	0.895 ***	1.209 ***	1.649 ***	2.51 ***	0.992 ***	1.112 ***	0.32 **	1.114 ***
	(-0.035)	(-0.096)	(-0.154)	(-0.163)	(-0.041)	(-0.094)	(-0.11)	(-0.109)
60-69 years old	1.177 ***	1.633 ***	1.822 ***	2.168 ***	0.863 ***	1.254 ***	0.087	0.784 ***
	(-0.035)	(-0.093)	(-0.158)	(-0.175)	(-0.043)	(-0.098)	(-0.133)	(-0.13)
70 years old and above	0.937 ***	1.342 ***	1.44 ***	2.013 ***	0.018	0.282 *	-0.59 ***	0.667 ***
	(-0.033)	(-0.093)	(-0.163)	(-0.176)	(-0.044)	(-0.117)	(-0.156)	(-0.129)
Education								
Low education (ref.)								
Medium education	0.355 ***	0.033	0.459 ***	1.129 ***	0.596 ***	0.398 ***	-0.234 *	0.405 ***
	(-0.027)	(-0.067)	(-0.111)	(-0.11)	(-0.033)	(-0.084)	(-0.096)	(-0.1)
High education	0.321 ***	0.49 ***	0.453 ***	1.027 ***	0.461 ***	0.636 ***	-0.134	0.466 ***
	(-0.027)	(-0.062)	(-0.111)	(-0.112)	(-0.033)	(-0.081)	(-0.093)	(-0.098)
Household socio-economic and demographic characteristics								
Number of adults								
1 (ref.)								
2	1.543 ***	1.801 ***	1.443 ***	1.412 ***	3.486 ***	2.616 ***	2.505 ***	1.743 ***
	(-0.021)	(-0.06)	(-0.097)	(-0.083)	(-0.042)	(-0.101)	(-0.132)	(-0.094)
>=3	2.036 ***	2.073 ***	2.303 ***	2.258 ***	4.751 ***	3.51 ***	3.153 ***	2.594 ***
	(-0.041)	(-0.096)	(-0.136)	(-0.12)	(-0.055)	(-0.118)	(-0.152)	(-0.119)
Number of younger children								
0 (ref.)								
1	0.215 ***	0.638 ***	0.481 **	0.056	0.55 ***	0.872 ***	0.635 ***	1.045 ***
	(-0.049)	(-0.095)	(-0.172)	(-0.156)	(-0.053)	(-0.098)	(-0.116)	(-0.117)
>=2	1.146 ***	0.76 ***	2.463 ***	0.133	1.724 ***	1.103 ***	1.592 ***	1.644 ***
	(-0.089)	(-0.171)	(-0.178)	(-0.295)	(-0.093)	(-0.174)	(-0.181)	(-0.196)
Number of older children								
0 (ref.)								
1	0.526 ***	0.674 ***	0.026	-0.078	0.686 ***	0.524 ***	1.213 ***	0.978 ***
	(-0.043)	(-0.087)	(-0.16)	(-0.137)	(-0.047)	(-0.091)	(-0.1)	(-0.102)
>=2	0.524 ***	0.54 ***	0.771 ***	-0.241	0.955 ***	0.688 ***	1.621 ***	0.894 ***
	(-0.047)	(-0.097)	(-0.138)	(-0.146)	(-0.051)	(-0.097)	(-0.102)	(-0.116)
Income level								
First 20% group (ref.)								
Second 20% group	0.875 ***	1.305 ***	0.982 ***	-0.216	0.891 ***	1.219 ***	0.233	0.55 ***
	(-0.027)	(-0.102)	(-0.159)	(-0.118)	(-0.044)	(-0.159)	(-0.174)	(-0.126)
Third 20% group	1.493 ***	1.872 ***	1.745 ***	0.357 **	2.063 ***	2.231 ***	1.582 ***	1.045 ***
	(-0.03)	(-0.103)	(-0.155)	(-0.115)	(-0.043)	(-0.15)	(-0.147)	(-0.127)
Fourth 20% group	1.863 ***	2.551 ***	1.703 ***	0.689 ***	2.868 ***	3.023 ***	2.519 ***	1.423 ***
	(-0.032)	(-0.101)	(-0.163)	(-0.112)	(-0.044)	(-0.146)	(-0.139)	(-0.127)
Fifth 20% group	2.104 ***	2.81 ***	2.872 ***	1.274 ***	3.573 ***	3.771 ***	3.574 ***	2.698 ***
	(-0.035)	(-0.103)	(-0.151)	(-0.106)	(-0.046)	(-0.145)	(-0.137)	(-0.115)
Residential environmental factors								
Urbanization degree								
Extremely urbanized (ref.)								
Strongly urbanized	0.538 ***	0.853 ***	0.042	0.429 ***	0.926 ***	0.483 ***	0.472 ***	0.691 ***
	(-0.025)	(-0.062)	(-0.098)	(-0.091)	(-0.032)	(-0.074)	(-0.094)	(-0.09)
Moderately urbanized	0.848 ***	1.071 ***	-0.05	0.386 **	1.327 ***	1.028 ***	1.11 ***	1.11 ***
	(-0.034)	(-0.075)	(-0.14)	(-0.128)	(-0.041)	(-0.085)	(-0.105)	(-0.108)
Not and hardly urbanized	0.967 ***	0.683 ***	0.576 ***	0.665 ***	1.654 ***	1.066 ***	1.217 ***	1.109 ***
	(-0.033)	(-0.08)	(-0.115)	(-0.117)	(-0.039)	(-0.085)	(-0.104)	(-0.11)
Number of supermarkets and daily grocery stores	-0.015 ***	-0.019 ***	-0.012 ***	0	-0.037 ***	-0.026 ***	-0.036 ***	-0.001
	(-0.001)	(-0.002)	(-0.002)	(-0.002)	(-0.001)	(-0.002)	(-0.004)	(-0.002)
Walkability of train stations	-0.321 ***	-0.273 **	-0.464 **	-0.133	-0.619 ***	-0.443 ***	-0.105	-0.271 *
	(-0.036)	(-0.092)	(-0.163)	(-0.131)	(-0.048)	(-0.118)	(-0.136)	(-0.129)
Cycling accessibility of train stations	-0.142 ***	-0.113 *	0.041	-0.013	-0.279 ***	-0.057	-0.084	0.015
	(-0.024)	(-0.053)	(-0.091)	(-0.088)	(-0.028)	(-0.061)	(-0.075)	(-0.079)
Model Fit								
McFadden's pseudo R^2	0.1919							
Log-likelihood	-124067.7							

Note: * p<0.05, ** p<0.01, *** p<0.001

Table 3 MNL with residential environmental factors as the interaction terms.

	One-ICEV households	One-HEV households	One-PHEV households	One-BEV households	ICEV+ households	HEV+ households	PHEV+ households	BEV+ households
Variable Name	Coef. (Std. Err)	Coef. (Std. Err)	Coef. (Std. Err)	Coef. (Std. Err)	Coef. (Std. Err)	Coef. (Std. Err)	Coef. (Std. Err)	Coef. (Std. Err)
(Intercept)	-1.309 ***	-7.759 ***	-4.113 ***	-3.741 ***	-5.091 ***	-5.73 ***	-4.961 ***	-5.077 ***
	(-0.048)	(-0.19)	(-0.169)	(-0.178)	(-0.075)	(-0.156)	(-0.169)	(-0.164)
Year								
2018+2019 (ref.)								
2020	-1.04 ***	-1.561 ***	-2.425 ***	-2.875 ***	-1.251 ***	-1.539 ***	-2.03 ***	-1.344 ***
	(-0.056)	(-0.143)	(-0.197)	(-0.216)	(-0.072)	(-0.153)	(-0.18)	(-0.173)
Individual socio-demographic characteristics								
Age								
18-29 years old (ref.)								
30-39 years old	0.549 ***	2.217 ***	0.192	0.659 ***	0.699 ***	0.761 ***	0.066	0.024
	(-0.033)	(-0.143)	(-0.117)	(-0.108)	(-0.041)	(-0.094)	(-0.112)	(-0.106)
40-49 years old	0.789 ***	2.67 ***	0.673 ***	0.544 ***	0.938 ***	0.938 ***	0.759 ***	0.678 ***
	(-0.036)	(-0.14)	(-0.114)	(-0.121)	(-0.043)	(-0.092)	(-0.103)	(-0.099)
50-59 years old	0.925 ***	2.824 ***	0.743 ***	0.184	0.957 ***	1.037 ***	0.778 ***	0.851 ***
	(-0.033)	(-0.135)	(-0.106)	(-0.119)	(-0.039)	(-0.082)	(-0.099)	(-0.09)
60-69 years old	1.243 ***	3.308 ***	0.702 ***	0.087	0.848 ***	1.298 ***	0.924 ***	0.575 ***
	(-0.033)	(-0.136)	(-0.116)	(-0.131)	(-0.041)	(-0.088)	(-0.107)	(-0.105)
70 years old and above	1.003 ***	3.245 ***	0.282 *	-0.052	-0.035	0.75 ***	0.11	0.292 **
	(-0.032)	(-0.136)	(-0.121)	(-0.13)	(-0.043)	(-0.097)	(-0.124)	(-0.108)
Education								
Low education (ref.)								
Medium education	0.378 ***	0.449 ***	0.709 ***	0.372 **	0.596 ***	0.488 ***	0.429 ***	0.542 ***
	(-0.026)	(-0.065)	(-0.095)	(-0.116)	(-0.032)	(-0.073)	(-0.088)	(-0.086)
High education	0.325 ***	0.776 ***	0.505 ***	0.838 ***	0.494 ***	0.615 ***	0.477 ***	0.701 ***
	(-0.026)	(-0.062)	(-0.098)	(-0.109)	(-0.032)	(-0.071)	(-0.087)	(-0.084)
Household socio-economic and demographic characteristics								
Number of adults								
1 (ref.)								
2	1.22 ***	1.377 ***	0.823 ***	1.393 ***	3.301 ***	1.712 ***	1.481 ***	1.489 ***
	(-0.02)	(-0.057)	(-0.075)	(-0.085)	(-0.043)	(-0.076)	(-0.085)	(-0.08)
>=3	1.6 ***	2.467 ***	1.14 ***	1.726 ***	4.437 ***	2.997 ***	2.069 ***	2.275 ***
	(-0.037)	(-0.079)	(-0.116)	(-0.126)	(-0.054)	(-0.09)	(-0.109)	(-0.101)
Number of younger children								
0 (ref.)								
1	0.229 ***	0.647 ***	-0.131	-0.826 ***	0.5 ***	0.625 ***	0.81 ***	0.724 ***
	(-0.046)	(-0.095)	(-0.161)	(-0.176)	(-0.051)	(-0.097)	(-0.105)	(-0.106)
>=2	1.744 ***	2.277 ***	2.627 ***	-0.375	2.176 ***	2.308 ***	2.729 ***	2.631 ***
	(-0.106)	(-0.152)	(-0.169)	(-0.39)	(-0.109)	(-0.151)	(-0.16)	(-0.158)
Number of older children								
0 (ref.)								
1	0.49 ***	0.331 ***	0.343 **	0.243	0.511 ***	0.374 ***	0.685 ***	0.516 ***
	(-0.04)	(-0.084)	(-0.121)	(-0.134)	(-0.044)	(-0.083)	(-0.097)	(-0.094)
>=2	0.653 ***	0.929 ***	0.986 ***	0.516 ***	0.955 ***	0.754 ***	1.505 ***	1.124 ***
	(-0.046)	(-0.085)	(-0.115)	(-0.131)	(-0.049)	(-0.092)	(-0.093)	(-0.095)
Income level								
First 20% group (ref.)								
Second 20% group	0.915 ***	1.121 ***	0.664 ***	0.291 *	1.106 ***	0.456 ***	0.428 ***	0.389 ***
	(-0.027)	(-0.112)	(-0.108)	(-0.12)	(-0.044)	(-0.11)	(-0.115)	(-0.104)
Third 20% group	1.37 ***	1.859 ***	0.761 ***	0.404 **	2.084 ***	1.392 ***	0.9 ***	0.648 ***
	(-0.029)	(-0.109)	(-0.115)	(-0.127)	(-0.044)	(-0.1)	(-0.112)	(-0.106)
Fourth 20% group	1.664 ***	2.51 ***	1.074 ***	0.855 ***	2.731 ***	1.972 ***	1.471 ***	1.293 ***
	(-0.031)	(-0.106)	(-0.113)	(-0.118)	(-0.044)	(-0.096)	(-0.107)	(-0.098)
Fifth 20% group	1.658 ***	3.099 ***	1.874 ***	1.547 ***	3.173 ***	2.485 ***	2.39 ***	2.059 ***
	(-0.032)	(-0.105)	(-0.103)	(-0.106)	(-0.045)	(-0.095)	(-0.1)	(-0.092)
Residential environmental factors								
Urbanization degree								
Extremely urbanized (ref.)								
Strongly urbanized	-0.063 *	0.438 ***	-0.839 ***	-0.815 ***	0.266 ***	-0.025	-0.325 ***	-0.5 ***
	(-0.031)	(-0.076)	(-0.112)	(-0.12)	(-0.04)	(-0.085)	(-0.098)	(-0.109)
Moderately urbanized	0.15 ***	0.017	-0.61 ***	-0.905 ***	0.564 ***	0.202 *	-0.055	-0.285 *
	(-0.04)	(-0.099)	(-0.14)	(-0.163)	(-0.049)	(-0.101)	(-0.116)	(-0.134)
Not and hardly urbanized	0.346 ***	-0.368 ***	-0.686 ***	-1.093 ***	0.92 ***	-0.046	-0.211	0.177
	(-0.04)	(-0.106)	(-0.135)	(-0.153)	(-0.048)	(-0.105)	(-0.118)	(-0.119)
Number of supermarkets and daily grocery stores	-0.021 ***	-0.039 ***	-0.014 ***	-0.01 ***	-0.045 ***	-0.03 ***	-0.03 ***	-0.013 ***
	(-0.001)	(-0.003)	(-0.002)	(-0.002)	(-0.001)	(-0.003)	(-0.003)	(-0.002)
Walkability of train station	-0.482 ***	-0.791 ***	-0.936 ***	-2.442 ***	-0.519 ***	-0.611 ***	-1.017 ***	-0.438 **
	(-0.045)	(-0.144)	(-0.165)	(-0.237)	(-0.058)	(-0.137)	(-0.172)	(-0.14)
Cycling accessibility of train stations	-0.312 ***	-0.107	-0.745 ***	-1.389 ***	-0.497 ***	-0.351 ***	-0.556 ***	-0.763 ***
	(-0.03)	(-0.067)	(-0.099)	(-0.105)	(-0.034)	(-0.072)	(-0.083)	(-0.092)
Interaction Terms								
2020 * Residential environmental factors								
2020 * Urbanization degree								
2020 * Strongly urbanized	0.718 ***	1.193 ***	1.493 ***	1.203 ***	0.832 ***	1.126 ***	1.306 ***	1.422 ***
	(-0.049)	(-0.113)	(-0.174)	(-0.18)	(-0.064)	(-0.131)	(-0.166)	(-0.167)
2020 * Moderately urbanized	0.867 ***	1.254 ***	2.082 ***	1.933 ***	1.049 ***	1.352 ***	1.851 ***	2.221 ***
	(-0.067)	(-0.15)	(-0.208)	(-0.236)	(-0.081)	(-0.157)	(-0.189)	(-0.19)
2020 * Not and hardly urbanized	0.938 ***	1.483 ***	2.555 ***	2.57 ***	1.077 ***	1.587 ***	2.326 ***	2.244 ***
	(-0.065)	(-0.161)	(-0.203)	(-0.227)	(-0.079)	(-0.163)	(-0.189)	(-0.177)
2020 * Number of supermarkets and daily grocery stores	0.006 ***	-0.001	0.003	-0.002	0.003	0.003	0.021 ***	-0.008
	(-0.001)	(-0.005)	(-0.004)	(-0.004)	(-0.002)	(-0.004)	(-0.005)	(-0.004)
2020 * Walkability of train station	0.719 ***	2.432 ***	1.995 ***	4.313 ***	0.755 ***	0.961 ***	1.305 ***	0.979 ***
	(-0.073)	(-0.19)	(-0.261)	(-0.312)	(-0.096)	(-0.226)	(-0.26)	(-0.213)
2020 * Cycling accessibility of train stations	0.509 ***	1.329 ***	1.948 ***	2.814 ***	0.642 ***	1.209 ***	0.972 ***	0.999 ***
	(-0.048)	(-0.108)	(-0.162)	(-0.195)	(-0.056)	(-0.115)	(-0.134)	(-0.128)
Model Fit								
McFadden R2: 0.1809978								
Note: * p<0.05, ** p<0.01, *** p<0.001								

4 DISCUSSION AND CONCLUSION

Car ownership and PEV adoption

The market share of PEVs of new passenger car sales increased from 14.8% in 2019 to 24.8% in 2020 in the Netherlands (RVO.nl, 2021), although the annual sales of that have dropped from 450 thousand in 2019 to 360 thousand in 2020 (Statista, 2021) during the COVID-19 pandemic. In our sample, the number of adopters of both BEVs and PHEVs increased from 2018 and 2019 to 2020, which is in line with the general Dutch trends; PEVs are mostly leased, which is consistent with the fact that 55% of Dutch motorists drive second-hand cars (ANWB.nl, 2021). This may be because, firstly, since the technological improvement of PEVs (i.e., battery life and mileage range) is still in a period of rapid development and thus the resale value of PEVs is uncertain. Secondly, the subsidies for both private and company leasing a PEV encourage individuals to lease a PEV (Wallbox.nl, 2021). Thirdly, the purchase price remains the biggest barrier to EV adoption (ANWB.nl, 2021). Besides, PEVs are almost exclusively for sale new and the second-hand EV market is insufficient yet. Thus, leasing a PEV appears to be a promising choice for those people who intend to use an EV but do not purchase one.

Individual socio-demographic characteristics

Young people show an inclination towards PEV adoption both in one- and two-car households, which is partly in line with the finding by Plötz et al. (2014). These authors found that BEV adopters in Germany tended to be between 30-50 years old. By distinguishing the PEV users from one-car households and two-car households, we also find that narrower sub-user groups tend to be one-BEV households in terms of age distribution, compared with one-PHEV households.

With increasing education levels, people are more likely to own additional cars. Rith et al. (2019) similarly confirmed that highly educated household heads are found to be willing to acquire more ICEVs in the Philippines. Previous studies also confirmed that highly educated people are more likely to be PEV users in the Netherlands (Peters et al., 2018), Canada (Erutku, 2020), and Ireland (Mukherjee & Ryan, 2020). Nevertheless, our MNL models indicate that PEVs are especially preferred by the highest educated adults in two-car households, whereas they are marginally more likely to be chosen in one-car households. This may be because in most cases, highly educated people are highly correlated with environmental concerns (White & Sintov, 2017).

Household socio-economic and demographic characteristics

We find that households with more adults and more children have a higher chance of car ownership in general, and of having two cars in particular. This argument is partly confirmed by Khan and Habib (2021), who highlighted that the increasing number of children is associated with increasing ICEV ownership levels. In addition, we find that households with more children show a significant inclination to be one-PHEV households and one-BEV households.

Our descriptive analysis suggests the highest income subgroups take the largest share of BEV adoption both in one- and two-car households, compared with other car type. This is in line with the finding of PEV users in Canada (Erutku, 2020), India (Bansal et al., 2018), and BEV users in Ireland (Mukherjee & Ryan, 2020).

Residential environmental attributes

The MNL results indicate that with increasing urban density, the probability of car ownership

decreases. These results are similar to the finding by Anowar et al. (2014), who revealed that residential density reduces the probability of ICEV ownership. Notably, our descriptive analysis shows that the largest share of PHEV users and BEV users are more likely to live in highly urbanized areas. This finding is in contrast with PEV users in the UK (Morton et al., 2018) and BEV users in Germany (Plötz et al., 2014) who are more likely to live in the suburban and rural areas. Second, not only charging accessibility but also associated parking places make PEVs particularly attractive in the urban area with stressful parking pressure in the Netherlands (Wolbertus & van den Hoed, 2020).

2020 effect on household fleet choice

Based on the MNL results with interaction terms, we find that there is a 2020 effect on household fleet choice caused by not only market diffusion but also COVID-19 (**Table 4**). We find that HEVs, PHEVs and BEVs have diffused into other population segments respectively, as suggested by Rogers' curve diffusion model. In general, EVs are more likely to be held by older, lower educated and lower income people, and increasingly outside cities in 2020.

Table 4 Theoretical conclusion of 2020 effect on household fleet choice based on MNL results with interaction terms.

	Age	Education	Household Persons	Income	Spatial variable
One-ICEV households	↓ Younger	↓ Less education-dependent	↓ Older children	↓ Less income-dependent	↓ Weakened negative urbanization effect
One-HEV households			↓ Younger children, ↓ Older children		↓ Weakened negative urbanization effect
One-PHEV households		↓ Less education-dependent	↓ Younger children, ↓ Older children		↓ Weakened negative urbanization effect
One-BEV households	↓ Younger		↓ Adults, ↓ Younger children, ↓ Older children	↓ Less income-dependent	↓ Weakened negative urbanization effect
ICEV+ households	↓ Younger	↓ Less education-dependent		↓ Less income-dependent	↓ Weakened negative urbanization effect
HEV+ households	↓ Younger		↓ Younger children		↓ Weakened negative urbanization effect
PHEV+ households	↓ Younger	↓ Less education-dependent	↓ Younger children		↓ Weakened negative urbanization effect
BEV+ households	↓ Younger		↓ Adults, ↓ Younger children	↓ Less income-dependent	↓ Weakened negative urbanization effect

Note: ↓ means more mass-market consumers.

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