Access to charging infrastructure and the propensity to buy an electric car

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SHORT SUMMARY

In this paper we utilize rich Swedish car buyer register data including socio-economic information such as home and work location of the car buyer and show that access to charging infrastructure increases the propensity to choose an electric car, both for fully electric cars and chargeable hybrids. For private charging, detached house and receiving a grant for installing charging infrastructure close to the apartment building, both have a strong effect in the model. For public charging, the results indicate that the density of charging stations close to home and work has a small but significant effect.

Keywords: Car type choice, Discrete choice modelling, Electric vehicle adoption, Electrification and decarbonization of transport, Revealed preference, Charging infrastructure

1. INTRODUCTION

Many countries, including Sweden, want to speed up the move towards electric vehicles (EV). In this context, it is important to increase the knowledge about which polices that most cost efficiently could speed up electrification by incentivising car buyers to choose EVs.

Several previous studies investigated who buys an electric car. Recently, Archsmith et. al (2022) utilized car buyer data from the U.S. and showed that buying an EV is correlated with high income, high education, being 35-45 years old and living in more liberal states. Plötz et al. (2014) showed that the group of early EV adopters in Germany was mainly men with families in suburbs or rural areas who value the environment and with a high vehicle kilometres travelled per year. Fevang et al. (2020) investigated Norwegian register data from 2011-2017 and found that EV owners were more likely to be families with children, have high income, high education level and live in central areas. Trafikanalys (2023) used detailed Swedish register data from 2020 and identified high income, high education level, living at the outskirts of an urban area, living in detached house, being male and having Swedish background as explanatory factors for buying an EV. Trafikanalys also compared the results to 2016 and found that the importance of detached house and high income had diminished somewhat. Several studies pointed out that early EV adopters are a special niched group but that EV buyers with time become more similar to car buyers in general and that this development can go pretty fast, around 4-5 years (Bjørge et al., 2022; Fevang et al., 2020; Trafikanalys, 2023). None of the above papers directly examined the influence of accessibility to charging infrastructure on the choice of car type, but the issue of charging is often noted.

Of the studies explicitly considering charging infrastructure, the perhaps most cited study is Springel (2021), already available as a working paper in 2017, which used a two-sided market framework and Norwegian data from 2010 to 2015 to compare the different impacts of subsidies to car purchases and charging infrastructure. Estimates indicated that a dollar spent on charging infrastructure resulted in more than twice as many EV purchases as a dollar spent on vehicle purchase subsidies. Furthermore, this relation was found to revert as spending on charging infrastructure increased. Schulz and Rode (2022) used an event study approach to study Norwegian highly resolved data on location of public charging and the ownership rate of BEVs in 356 municipalities from 2009 to 2019 thus having four more years than Springel. They concluded that charging infrastructure had a stimulating effect on number of EVs, although the direction of causality was not obvious. Illman and Kluge (2020) estimated the effect of increasing availability of public charging infrastructure on the likelihood of buying an EV. The results indicated a positive long-run relationship but on "a rather low scale". Dixon et al. (2020) investigated the inconvenience of EV charging compared to fuelling of an internal combustion engine vehicle (ICEV) in the UK, and found a much larger potential EV charging inconvenience for those who cannot charge at home. Egnér and Trosvik (2018) estimated an aggregate relationship between EV adoption and public charging infrastructure supply at municipal level in Sweden and found that, especially in urban municipalities, EV adoption increased with an increased number of public charging points. Haustein et al. (2021) used three surveys in Denmark and Sweden from 2017, 2018 and 2019 to model purchase intentions. They found that intentions were stable. A significant effect of new fast chargers was found in Denmark but not in Sweden. Patt et al. (2019) used a randomized survey and found that people who own their parking space stated that they were almost twice as likely to purchase an EV as those parking in streets and 50% more likely than those who park in communal parking or in a garage.

The aim of this paper is to investigate the influence of accessibility to charging facilities in Sweden on the choice of a new vehicle and the likelihood of buying an EV, both fully electric vehicle (BEV) and chargeable hybrid (PHEV), controlling for other factors. This is done by re-estimating the Swedish car type choice model updated to the supply of cars in 2019 and the supply of public charging infrastructure in the same year. Thus, the research questions of this paper are:

1) Does accessibility to charging infrastructure influence the choice of car type?
2) If so, in what way and to which extent does accessibility to charging infrastructure influence the choice of buying an electric car?
3) Does the influence of accessibility to charging infrastructure differ between fully electric vehicles and chargeable hybrids?

Before conducting the analysis, we formulate several hypotheses to test.
We hypothesize that important factors for the propensity to buy an electric car are:

- H1 Living in a detached house (as a proxy for easy home charging),
- H2 Living in an apartment where the housing cooperative or landlord has received a grant for installing charging infrastructure (also as a proxy for easy home charging),
- H3 Access to *public* charging infrastructure close to home if you live in an apartment without access to easy home charging,
- H4 Access to *public* charging infrastructure close to work.

Regarding differences between fully electric cars and chargeable hybrids we hypothesize that:

H5 There is no significant difference in the importance of access to charging infrastructure close to home,

H6 Access to local public charging infrastructure close to work is more important for chargeable hybrids compared to fully electric cars given the shorter electric range of chargeable hybrids.

The reminder of this paper describes the data and methods used to test the above hypotheses, and the results and conclusions that can be drawn.

2. METHODOLOGY

In this paper a multinomial logit model (McFadden, 1974) for passenger car type choice of private buyers (as opposed to cars bought by a company) is estimated, building on previous work with the Swedish car type choice model (Engström et al., 2019), but re-estimating the model on data from year 2019 and adding variables related to both private and public charging infrastructure. Year 2019 is chosen due to broken supply chains in the years during and after the Covid-19 pandemic, which led to long delays in delivery of new cars.

Four different sources of data are used in estimation:

1) Choice data in the form of register data on all new cars bought by a private person during 2019 with socio-economic information. The buyer socio-economic information includes home zone (typically a square of 250m x 250m, but in sparser areas a square of 1km x 1km), work zone (2% missing data), household income, type of housing (detached house or apartment), and number of cars in the household. The data on the type of car bought includes information about brand, fuel type, and fuel consumption. Due to long estimation run times, a sample needs to be made from the choice data. All fully electric vehicles and all chargeable hybrids are included in a stratified sample, with random sampling of the other vehicle types up to a sample size of 15000 observations, leading to eight hours estimation time.
2) Supply data consisting of price, operation cost, rust guarantee, size category, and safety classification for each of the 597 car types was formed from all cars sold during 2019. Each car type is categorized by a brand, a fuel type, and a fuel consumption class, i.e. there are several car models averaged into one car type. One of the brand categories is ‘other’, where several uncommon brands are included.
3) Public charging infrastructure data on the location of charging stations in Sweden in 2019 and how many outlets there were at each station.
4) Data on apartment building locations where the housing cooperative or landlord has received a grant for installing charging infrastructure. Locations were matched to car buyer home zones if the apartment building location resides within the home zone square. In the stratified sample of 15000 observations, 396 observations were matched as having received a grant.

As the register data needs to stay on the Statistics Sweden’s server MONA[1], all estimations are performed on the server. The software R/Apollo (Hess & Palma, 2019a, 2019b) is used for model estimation. To account for the stratified sample of electric cars, weights depending on fuel type are included in estimation.

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1 https://www.scb.se/en/services/ordering-data-and-statistics/ordering-microdata/mona--statistics-swedens-platform-for-access-to-microdata/

3. RESULTS AND DISCUSSION

The result of re-estimation of the Swedish car type choice model to year 2019 and including measures of access to charging infrastructure is shown in Table 1. The model includes explanatory variables typically used in car type choice models such as price, operation cost, safety classifications, rust guarantee, and size of the car type. These variables are all significant and have expected sign. *PriceLowinc* is an extra penalty on car price for households with a yearly income of less than 50 kEUR/year. For the size-dummies, the reference size is Small, and for the fuel-type-dummies the reference fuel type is Petrol. Dummies for Brand (e.g. Volvo) are also estimated but are not included in the table due to space limitation. Reference brand is 'Other', a category which includes for example Ferrari and Bentley. *ManyCarsHH* is a dummy which is 1 if the buyer has more than one car in the household and this dummy is only included for BEV alternatives.

The result in Table 1 shows that persons living in a detached house (*Villa*) has a higher probability of buying an electric car. The effect is not significantly different between BEV and PHEV. The same goes for persons living in an apartment where the housing cooperative or landlord has received a grant for installing charging infrastructure (*Grant*). It should however be noted that even if the effect of *Grant* is strong, this variable only applies to a limited number of buyers. Furthermore, the result shows that the probability of buying a BEV increases if there are more than one car in the household. Likely, this is due to BEV cars having a shorter range and are often bought as a second car utilized for regional travel.

The result also shows that, for persons living in an apartment, the number of public charging stations within 1km from home (*PublicChargingHome*) significantly increases their probability of buying an electric car, even though the magnitude of the effect is smaller than that of *Villa* and *Grant*. There is no significant difference in the effect for BEV and PHEV. The number of public charging stations within 1km from work (*PublicChargingWork*) also has a significant effect on the probability of buying an electric car. Just as with public charging close to home, the magnitude of the effect of public charging close to work is rather small compared to the effect of *Villa* and *Grant* and there is no significant difference between effects for BEV and PHEV.

Table 1: Result of car type choice model estimation

Variable name	Variable type	Utility functions	Parameter value	T-value
Price	Numeric	All	-0,0031	-17,1
PriceLowinc	Numeric	All	-0,0056	-22,9
OpCost	Numeric	All	-0,066	-16,9
RustGuarantee	Numeric	All	0,51	15,0
PassengerSafety	Numeric	All	0,0048	2,9
SafetySystems	Numeric	All	0,0073	6,7
SafetyInfoMissing	Dummy	All	-1,17	-6,0
SizeMid	Dummy	All	0,77	27,0
SizeLarge	Dummy	All	1,08	37,3
SizeSport	Dummy	All	-0,58	-5,8
PHEVDiesel	Dummy	All	-4,66	-7,2
PHEVPetrol	Dummy	All	-3,22	-23,8
HybridPetrolEthanol	Dummy	All	-0,51	-3,9
HybridPetrolGas	Dummy	All	-3,93	-19,2
HybridDieselElectric	Dummy	All	-1,26	-14,4
HybridPetrolElectric	Dummy	All	-0,61	-15,3

BEV	Dummy	All	-2,91	-18,8
Diesel	Dummy	All	-1,13	-44,7
ManyCarsHH	Dummy	BEV	0,41	4,2
Villa	Dummy	BEV, PHEV	0,80	7,1
Grant	Dummy	BEV, PHEV	0,86	3,7
PublicChargingHome	Integer	BEV, PHEV	0,037	3,3
PublicChargingWork	Integer	BEV, PHEV	0,023	6,2
WorkInfoMissing	Dummy	BEV, PHEV	0,32	1,3

Accessibility to public charging close to home/work can be measured in different ways. We started out by measuring it using distance from home/work to the closest public charging station. However, these variables were not significant in model estimation. As shown above, changing to number of public charging stations within 1km from home/work turned out to be significant. We also tried number of public charging outlets within 1km from home/work (there are often many outlets at one charging station), which resulted in similar estimation results as using number of public charging stations. These results indicate that density of public charging stations is more important than distance to the closest station.

4. CONCLUSIONS

In this paper we investigate if, in what way, and to what extent access to charging infrastructure influences the propensity to buy an electric car. We estimate a car type choice model on revealed preference car buyer data from Sweden in 2019. We find that access to charging infrastructure does influence the propensity to buy an electric car in several ways. Hypothesis H1 and H2 are both confirmed, i.e., persons living in a detached house or in an apartment in a housing cooperative which has received a grant for installing charging infrastructure, have a large and significant propensity to buy an electric car. Hypothesis H3 and H4 are also confirmed, i.e., persons living in apartment buildings with access to public charging infrastructure close to home have a small but statistically significant propensity to buy an electric car compared to persons living in an apartment without public charging nearby. Access to public charging close to work has similar effects. Hypothesis H5 is also confirmed, i.e., the results show no significant differences between the effect for fully electric vehicles and chargeable hybrids when it comes to access to charging close to home, regardless of whether it is public charging or home charging. However, hypothesis H6 needs to be rejected, i.e., access to public charging infrastructure close to work does *not* seem to be more important for chargeable hybrids compared to fully electric cars.

To summarize, charging infrastructure, both public and private, seem important for private buyers to choose an electric car, both for the choice of fully electric vehicles and chargeable hybrids. Proxies for easy home charging have large and significant effects in the model, whereas density of public charging stations close to home and work both have significant effects in the model but of a smaller magnitude. In future research, one would also want to test different measures of access to public charging infrastructure during long-distance travel on the propensity to buy an electric car.

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