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Preferences and Willingness-to-Pay for BEVs and PHEVs Across Six European Markets

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Abstract
The demand for plug-in electric vehicles (PEVs) — battery and plug-in hybrid electric vehicles — has increased across Europe, but at very different rates. Most existing studies focus on single countries. In this paper, we provide a consistent comparison of preferences for PEVs across six European countries with highly varying adoption levels: the Czech Republic, Denmark, Germany, Ireland, Italy, and Spain.
We estimate mixed logit models with country-specific effects using stated-preference data from a harmonised European survey with 1,000 respondents per country. Unobserved preferences related to PEVs are more negative in Germany, and the Czech Republic than in Denmark and Ireland. While preferences for PEVs are stronger in Italy and Spain. These results indicate that countries face different barriers to PEV adoption. In some cases, improving charging access and economic incentives may be sufficient, while in others, policy measures also should consider acceptance and perceptions alongside infrastructure and pricing.

Background and purpose
Motorised transport is currently undergoing a large transformation towards electrification which will have major consequences for the environmental and economic landscape of our world. Plug-in electric vehicles (PEVs) share of sales in Europe has increased from a marginal 3 % in 2019 to 21 % in 2022. However, the shares differ a lot from about 9 % in Italy and Spain to 39 % in Denmark and 88 % in Norway. Analysing the development across countries can therefore give insights into this huge variation in uptake.

In this study, we seek to analyse preferences for PEVs across several countries in Europe. We use stated preference experiments, since we are still in the early phase of market majority for most of the countries, and to get consistent data across the countries. Our objective is to thoroughly assess factors that are challenging to assess directly within the real market environment, particularly when conducting cross-country comparisons.

Many studies have analysed PEV demand and WTP measures, however, most of these are country-specific and done before PEVs became relevant for the early majority in Europe. Hence, there seems to be room for

research analysing the heterogeneous uptake of PEVs across European countries for the early majority market. This is exactly the gap that this paper tries to fill in the following by addressing the research questions: How are preferences for PEVs different across European countries? How do WTP measures related to PEV demand vary across European countries? and what do these differences tell us about the early majority market for PEVs in Europe?

Method and data

In this section, we discuss the method and the data that we use to estimate the model.

Method

We apply mixed logit models based on random utility maximisation with utilities

$$U_{nj} = V_{nj} + \varepsilon_{nj}$$

These models allow for the model to take panel correlation across repeated observations into account. We do so by including random effects for car segments and fuel types.

Data

The main part of the survey consists of a stated choice experiment. The choice experiment is used to assess factors that affect the demand for PEVs taking into account various fuel types and car segments.

As it could be problematic to present respondents with all 15 combinations, we use a design, where for each fuel type, only two car segments are presented. For each respondent, the two car segments were chosen based on an initial answer as to the two most likely car segments involved in the respondent's next car purchase.

There are two main versions of the choice experiment. The first version is designed for individuals with (potential) access to home charging (the House Design). The second version is for individuals without home charging (the Apartment Design). The difference between these two designs is that only the Apartment Design includes attributes describing charging possibilities near home (one attribute for distance and one for availability) whereas only the House design includes the attribute describing Vehicle-to-grid capability.

The survey consists of four parts:

- Intro questions (needed for customising the SP scenarios),
- Stated choice experiment about vehicle purchase,
- Stated choice experiment about smart charging products
- Background characteristics related to sociodemographics, car usage and attitudes

After a minimum of intro questions needed to customise the choice experiments (framed to make them as relevant and realistic as possible for each individual), the stated choice experiments are presented as early as possible in order to reduce cognitive fatigue of respondents. Respondents were asked to provide information about all cars in the household including information about fuel type, segment, age and ownership. Subsequently, respondents are asked to characterise the expected type of car if buying a new car. In this case, two situations are possible: i) either they can choose to buy a new car without replacing any of the current cars, or ii) alternatively indicate which car they will likely replace. In addition to that, respondents are asked to state the expected timing of their next car purchase. Possible answers are; i) within a year, ii) within 1-5 years and iii) more than 5 years. As mentioned in Section 2.1, each respondent is only presented with two car segments in order to keep the choice experiment manageable. For this reason, respondents are asked to rate the likelihood of choosing a given segment in a future car purchase decision. The two car segments with the highest ratings are used to pivot the choice experiment. In case,

one or more car segments are equally likely to be selected, one is randomly selected. A final question asks respondents about their charging options at home. This information is used to classify respondents according to either the House Design or the Apartment Design.

Results and discussion

Here we give a brief summary of the model estimation and present WTP measures based on the final two models.

Results

The base model is a mixed logit (random effects) model with six random effects. Four for the five car segments (the class of medium cars is used as reference) and two for the three fuel types (the class of ICV cars is used as reference). In addition, we allow the random effects for BEV and PHEV to be correlated. Therefore the base model includes six ASCs, six random effects, and one correlation term. In addition, we include all the continuous attributes as linear but we allow for range to be alternative-specific. The two categorical variables, i.e. charger availability and V2X, are dummy coded. Next, we include two dummies for home charging availability. This gives a base model (Model 0) with 32 parameters. In the next model, we allow the two home charging attributes to be fuel type specific. Finally, we test down this model by removing two insignificant effects with the wrong sign and joining all charging levels for PHEV. This procedure gives the first model that we present as Model 2. Following this, we test how to incorporate systematic heterogeneity into this model specification. Following this, we end with Model 6.

Tabel 1 – An overwiev of model fit to data for the various models

Model	Description	DoF	LL	BIC
0	Base model	32	-34181	68687
1	Model 0 with charging split	36	-34175	68716
2	Model 1 tested down	28	-34177	68638
3	Model 2 with income effects	34	-34047	68440
4	Model 3 tested down	30	-34058	68420
5	Model 4 w. socio-economics added	165	-33487	68648
6	Model 5 tested down	74	-33540	67831

The models show expected results on main attributes, e.g. negative and significant cost parameters. Furthermore, they also show decreasing marginal disutility of cost with increasing income, which is reassuring in a stated choice context.

Based on the models, we calculate WTP for various attributes, see Table 2.

Tabel 2 – Average WTP measures

Attribute	Unit	Model 2	Model 6
Operation cost	Euro / Euro/km	-98578	-89299
Yearly cost	Eure / Euro/year	-18	-18
CO2	Euro / g/km	-22	-23
Acceleration	Euro / s	-250	-255
Boot size		5	5
Range ICV	Euro / km	8	7
Range EV	Euro / km	29	27
Home charge dist	Euro / m	-10	-9
Home charge av BEV	Euro / available 3 to 4 out of 4	5444	5417
Home charge av PHEV	Euro / available 2 to 4 out of 4	2512	2166
Charging speed	Euro / km/10min	61	60
V2X	Euro	2821	2941

Discussion

In the results above, we only show average results across the six countries. However, below these aggregate measures are a lot of heterogeneity across countries. One result is that car owners in Denmark places much higher value on the range of PEVs. We also find that the countries split in three groups when it comes to unobserved preferences for PEVs and that the pattern is similar for both BEVs and PHEVs. The most positive group contain Spain and Italy, while Denmark and Ireland are in the middle. The most negative group consists of Germany and the Czech Republic. There can be many reasons for why we observe this but it highlights a potential in Spain and Italy while it also indicates that Germany and the Czech Republic needs to adjust more than just cost structures and charging infrastructure to reach PEV level seen in Denmark.