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Can Models Predict Electric Vehicle Users?

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Short Abstract Summary

Several attempts have been made in the literature to characterise the first users of electric vehicles. The approaches span from model-based assessments over techno-economical identification to survey. Here we compare EV user characterisations for Germany from several sources, including a model-based and a comprehensive EV user survey. Our results show already empirical sources can differ substantially but that model-based findings have to be analysed with care but can yield useful insights.

1 Introduction

The diffusion of electric vehicles (EVs) is an important cornerstone in decarbonizing the mobility sector in Germany and elsewhere. Yet, the roll-out of EVs faces multiple challenges. One quite overarching challenge is to design future EVs according to future customer's expectations and needs. This is done more effectively if specific target groups are identified. Furthermore, government incentives will be more effective and efficient if they address the needs of these groups. Thus, reliable estimates of the characteristics of future customers are of great interest to policy makers and vehicle manufacturers alike. The characterization of future target groups for EVs is therefore one prerequisite for realizing a low carbon mobility sector.

The early adopters of EVs have received a considerable amount of attention in the literature (cf. Frenzel et al. 2015 and 2016, Plötz et al. 2014, Peters and Dütschke 2014, Jarass et al. 2014, Egbue and Long 2012, Hidrue et al. 2011, Ozaki and Sevastyanova 2011, Gnann et al. (2015), Jakobsson et al. (2016) and Rezvani et al. (2015) for a review). For Germany, the early adopters of EVs have been characterized as middle aged men, with technical and environmental interest and higher socio-economic status, living in rural or suburban areas (Peters und Dütschke 2014, Plötz et al. 2014). For the US, Curtin et al. (2009 P. 43f) found that potential buyers of EV tend to be wealthy, are enthusiastic about the idea of being able to avoid gas stations, value the environmental benefits offered by EVs and want to demonstrate their personal convictions by their decision to purchase an environmentally-friendly car. No clear results were found with regard to the gender of early adopters or where they live (rural or urban). Hidrue et al. (2011) found that early adopters of EVs in the US are young or middle-aged and have a bachelor degree or higher. Unlike Curtin et al. (2009), Hidrue et al. did not find any evidence that household income influences the likelihood of EV adoption.

In contrast to these findings for the Early Adopter, later adopter groups have hitherto received little to no attention in the literature (Rezvani et al. 2015). However, the next adopter group is important for mass market adoption. So far, only few studies have quantitatively analysed the potential early or late Majority of EV buyers, i.e. little re-search went beyond early adopter and innovators (Rezvani et al. 2015). Based on qualitative data from expert interviews Dütschke, Schneider and Peters (in press) propose four Majority groups. (1) Technology enthusiasts which are expected to predominantly include men who use the EV as an additional car and for which joy of driving and the image of an EV are important. (2) Environmentally aware individuals who regard driving a conventional vehicle in conflict with their personal values (3) Urban

individualists with a high need for mobility and a high emphasis on comfort and flexibility (4) Well-off consumers motivated to choose an EV as an optimal combination of something new and innovative that is also useful in everyday life. These groups and their characteristics largely correspond to the findings of Truffer et al. (2000), who analysed the characteristics of early EV users in the 90s. Axsen et al. surveyed 1754 'new vehicle buyers' in English-speaking Canada. In or-der to analyse the next EV-user group they first applied a design space approach (Kurani et al., 1994; Turrentine and Kurani, 1998) to filter the potentially EV-interested customers. They found that 36% of their analysed group would potentially buy a PHEV or battery electric vehicle (BEV) and coined the members of this group "potential early mainstream EV market" (Axsen et al. 2015, p. 197). The group was clustered into six groups using the k-means clustering algorithm: A "Strong Pro-environmental" cluster (17%) "where respondents have higher than average engagement in environmental oriented lifestyles, higher environmental concern, and are highly liminal (open to change)", a "Tech-enviro" cluster (12%) which distinguishes itself with "high levels of engagement in both the technology- and environment-oriented life-styles", a "Concerned" cluster (19%) which can be characterized only "to have a high level of environmental concern", a "Techie" cluster (17%) "that only have a high level of technology-oriented lifestyle", an "open" cluster (18%) "that have a relatively high degree of lifestyle openness" and an "Uninvolved" cluster (18%) that was characterized by having "lower than average on all four variables" that were named so far. These four clusters were a posteriori merged into two groups: The "Pro-environmental" group one the one hand contained the "Strong Pro-environmental", the "Tech-enviro" and the "Concerned" clusters. The "Non-environmental" group on the other side contained the "Techie", "Open" and "Uninvolved" clusters. In a second study, Kurani et al. (2015) conducted workshops in California where owners of EVs and owners of conventional vehicles met. From this meeting they derive that potential later EV customer groups will be more price sensitive than earlier customer groups (Kurani et al. 2015, S. 12).

Recent studies have put an emphasis on the empirical identification of early adopter in contrast to many model based characterisation from earlier market phases. Thus, these recent findings allow an assessment and comparison of the model based and empirical findings. The aim of the present paper is to compare model based predictions and empirical assessments of EV early adopter. This comparison would allow future technology diffusions to understand the validity and usefulness of model based early adopter predictions.

2 Data and Methods

2.1 Data

We use several data sets for a comparison of model based and empirical characterisation of EV users.

The first data set is a 2011 survey among German car users (see Peters et al., 2011; Agosti, 2011; Peters and Dütschke, 2013). The participants of the survey of car owners were recruited by various means (internet platforms, online forums, blogs, newspapers, vehicle manufacturers and dealers) in order to get a broad sample including persons who actually drive an EV as well as other consumers with less knowledge of and/or interest in EVs. The sample of this survey consists of 81.4 % men, the mean age is 40.9 years, the modus of monthly household income is EURO 2001-3000 (categorical scale), the average household size is 2.5 persons and on average there are 1.4 cars in the households. 51 % of the respondents hold a university degree (masters or higher) and 42 % work in technical professions.

This first data set is used to analyse two user groups: (1) actual EV users in 2011 and (2) potential early adopter who did not own an EV in 2011 but stated clear interest and the intention to purchase an EV (see Plötz et al. 2013).

The second source of information on EV users is a recent study by Frenzel et al. (2015). We will refer to this user group as "today's user" below as it is the best empirical study available for Germany so far. Frenzel and co-workers (2015) approached all German EV users via mail and a paper-based questionnaire. Their sample includes private and commercial EV users as well as vehicles smaller than passenger cars, e.g. the Renault Twizzy. A detailed description of the sample can be found in Frenzel et al. (2015).

2.2 Methods

We compare the empirical approaches to model based estimates of EV users. The mobiTopp model is an agent-based travel demand model system that is based on the principle of multi-agent-simulation. This means every person of the planning area is represented in the computer as a virtual person, a so-called agent. Each

agent is modelled in the context of his household. In addition, each agent receives a complete activity schedule for a whole week consisting of a sequence of activities with the attributes: day of the week, purpose (activity type), duration and planned starting time of the activity. Based on this schedule the agents carry out their activities during the course of the week. For each activity they perform a destination choice and a mode choice. Afterwards they make the trip to the (new) location and carry out the activity. The simulations run chronologically and simultaneously for all agents. This simultaneous approach allows for the realistic representation of car availability in the household context where several agents share a car: when the car is used by an agent, it is not available for the other agents of the household until the agent using the car returns home.

The EV ownership model is used in order to assign EVs to households and to car users. For the present analysis, we assume that two dimensions mainly affect the EV ownership decision: a EV should fulfil most of people's mobility needs in the same way than a conventional car, i.e. are the people suitable for EV ownership from the car usage perspective. (2) EV owners should belong to socio-demographic groups that appear to be interested in new technologies such as EVs and are affine to own such a car. In order to reflect both dimensions our EV ownership model considers EV usage suitability and an EV usage interest in two separate sub-models. In order to privilege those who combine both conditions, we considered the EV usage suitability and the EV usage interest and combined them for an EV ownership model. The result of this model is a ranking of every agent by its likelihood to own an EV. Early adopters are ranked higher. Depending on the market share of EVs, EVs are assigned according to the ranking from top to bottom. Meaning early adopters are considered first but the more EVs are assigned, the totality of EV users approximates the average car owner. In Weiss et al. (2017), the EV ownership model is described in detail.

We use binomial tests for a statistical comparison of differences in socio-demographic and other variables between the model-based and empirical estimates of EV users.

3 Results

3.1 Empirical EV user predictions Germany

The first group of results focuses on the identification of actual and potential EV users from empirical data. Figure 1 shows the household income distributions for today's users, for a sample of EV users from 2011, for potential early adopter in 2011 and as reference for the German population.

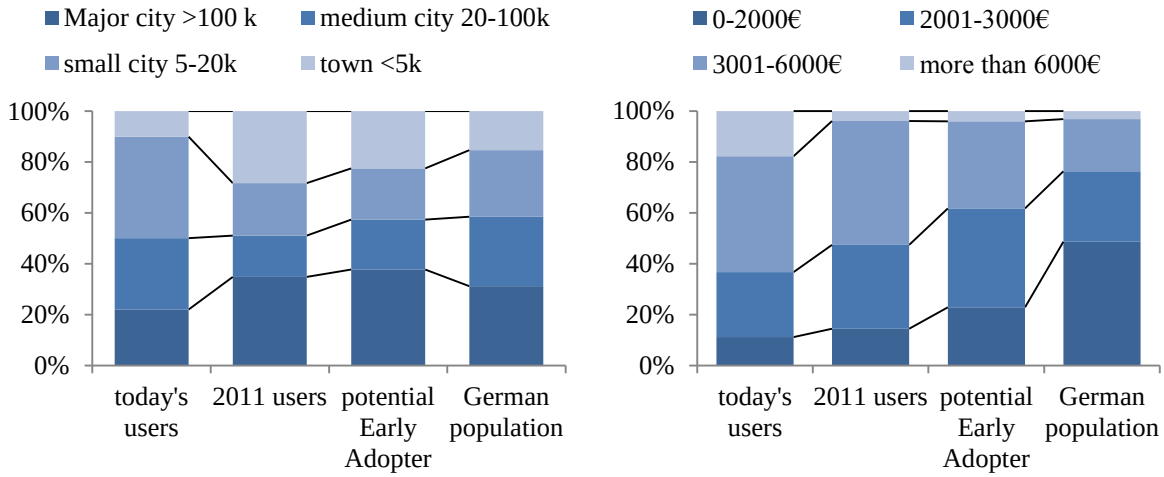

Figure 1: Share of EV users in different city sizes and household net income groups.

The 2011 users and early adopter show an above average share from small cities and towns. The share of users from major cities (more than 100,000 inhabitants) varies between the different sources and could be higher or lower than total share in the German population. Note, however, that a further differentiation in cities with 100,000 – 500,000 and more than 500,000 inhabitants could slightly change the picture.

With respect to net household income, the different estimates agree that first users of EV have a household net income above with average with large shares from very high and high income groups. This finding is

consistent with Rogers' general theory on the diffusion of innovation indicating that innovators and early adopter have high income and high social status.

The shares of EV users from the different city size and income groups are summarised in table 1 and 2. The tables also show the results from binomial tests comparing the shares from different city sizes and income groups between (1) today's users and the 2011 users as well as (2) today's users and the early adopter.

Table 1: Share of EV users in different city sizes.

	today's users	2011 users	potential Early Adopter	German population	Difference today's users vs. 2011 users	Difference today's users vs. early adopter
Major city >100 k	22%	34.8%	37.7%	31.18%	-13%***	-16%**
medium city 20-100k	28%	16.3%	19.7%	27.37%	+12%**	+8%*
small city 5-20k	40%	20.7%	20.1%	26.18%	+19%***	+20%***
town <5k	10%	28.3%	22.5%	15.27%	-18%***	-13%***

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05;

Table 2: Share of EV users in different net household income groups.

	today's users	2011 users	potential Early Adopter	German population	Difference today's users vs. 2011 users	Difference today's users vs. early adopter
0-2000€	10%	14%	23%	49%	-4%***	-13%
2001-3000€	23%	33%	39%	28%	-10%***	-16%*
3001-6000€	41%	49%	34%	21%	-8%*	+7%
more than 6000€	16%	4%	4%	3%	+12%***	+12%**

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05;

Most differences in the group shares are statistically different from zero indicating that the differences are unlikely to stem from random fluctuations of the limited sample sizes only.

3.2 Model based EV user prediction

Potential EV users can also be identified by models. Figure 2 compares the mobiTopp model based characterisation with empirical EV user data. The average age of the EV users from mobiTopp is higher than in the empirical data, but mobiTopp also assigns very young EV owners a smaller role than in the German population. With respect to the individual shares of age groups, only the differences in the 41 – 50 and over 60 years of age groups are statistically different from zero between the mobiTopp estimate and the 2011 users and potential early adopter.

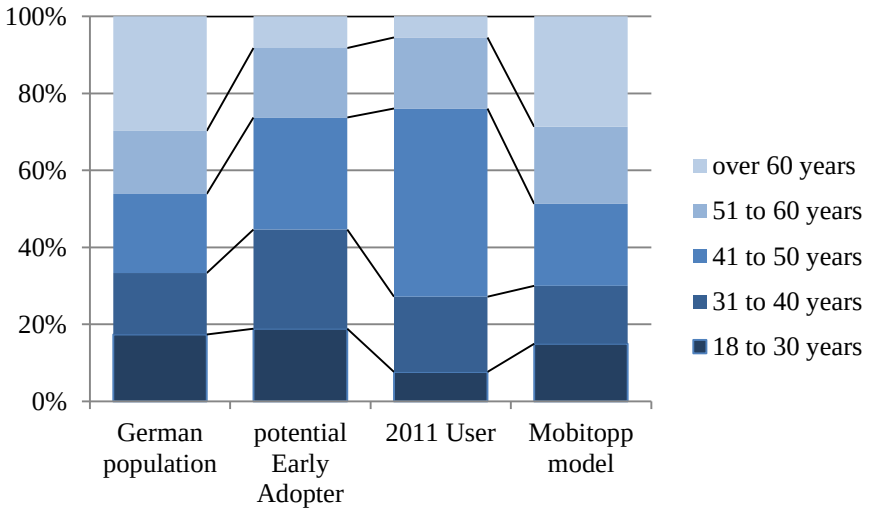

Figure 2: Share of EV users in different age groups according to surveys and the mobiTopp model.

A further important quantity is the share of males among the EV users. According to Frenzel et al. (2015), 89% of today's EV users are male. This should be compared to 2011 EV users with 96% males and 91% males among the potential ear as identified by Plötz et al. (2014). Here, mobiTopp assigns a BEV to 51% males in clear contrast to the aforementioned studies. However, considering an EV market share of 12%, EV owners determined by mobiTopp are not just early adopters anymore, which explains that the EV owners are much closer to the German population.

With respect to the number of people living in an EV owning household, mobiTopp suggests shares in excellent agreement with today's users (cf. Table 3).

Table 2: Share of EV owning households by household size.

	today's users	2011 users	potential Early Adopter	MobiTopp
1 person	11%	18%	24%	13%
2 persons	39%			40%
3 persons	19%	82%	76%	20%
more than 3	31%			27%

Furthermore, the difference between the 2011 users and the potential early adopters is noteworthy.

4 Discussion and Conclusions

Our results come with some uncertainty. First, socio-economic data from actual EV users is still scarce and sample sizes are limited. This makes the use of statistical methods even more important in comparisons of EV user characteristics. Furthermore, it implies that non-representative samples can have noteworthy impact on the findings. Here, we focused on data for private users despite the fact that commercial car buyers play an important role in the early market diffusion of EVs (cf. Gnann et al. 2014). Second, EV market diffusion and ownership models make additional assumptions about the purchase decisions and framework conditions that might be over-simplifications. Thus, there estimates have to taken with an appropriate grain of salt.

Furthermore, the mobiTopp model applied in the second group of comparisons is not a designated vehicle purchase model but rather a multi-agent simulation of mode choice. However, the model as such is accordingly not built for EV user prediction. Accordingly, conclusions on such aspect have to be taken with care since they do not follow the model purpose. Accordingly, the model shows correct tendencies with respect to early EV adopter but not more.

In summary, we compared empirical and model-based estimates of EV user characteristics in Germany. We find similar tendencies in the different approaches yet with noteworthy and statistically significant differences in the details. Overall, general trends can be identified by models and early empirical findings but more data and better EV market diffusion models are left as open issues for further research.

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