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Are multi-car households better suited for battery electric vehicles? – Driving patterns and economics in Sweden and Germany

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ABSTRACT

Battery electric vehicles (BEVs) could reduce CO_2 emissions from the transport sector but their limited electric driving range diminishes their utility to users. The effect of the limited driving range can be reduced in multi-car households where users could choose between a BEV and a conventional car for long-distance travel. However, to what extent the driving patterns of different cars in a multi-car household's suit the characteristics of a BEV needs further analysis. In this paper we analyse the probability of daily driving above a fixed threshold for conventional cars in current Swedish and German car driving data. We find second cars in multi-car households to require less adaptation and to be better suited for BEV adoption compared to first cars in multi-car households as well as to cars in single-car households. Specifically, the share of second cars that could fulfil all their driving is 20 percentage points higher compared to first cars and cars from single-car households. This result is stable against variation of driving range and of the tolerated number of days requiring adaptation. Furthermore, the range needed to cover all driving needs for about 70% of the vehicles is only 220 km for second cars compared to 390 km for the average car. We can further confirm that second cars have higher market viability from a total cost of ownership perspective. Here, the second cars achieve a 10 percentage points higher market share compared to first cars, and to cars in single-car households for Swedish economic conditions, while for Germany the corresponding figure is 2 percentage points. Our results are important for understanding the market viability of current and near-future BEVs.

1. Introduction

1.1. Background

Electric vehicles (EVs) could reduce global and local emissions from the transport sector (Chan, 2007). Yet, the limited electric driving range of battery electric vehicles (BEVs) is technically and mentally a major hurdle for many consumers and impacts a BEV's utility. The variation in distances travelled by one individual on different days of the year is important for the utility of BEVs (Greene, 1985; Pearre et al., 2011). Furthermore, long recharging times seem to impede BEV adoption as well. On the positive side, EVs can easily be charged at home for most car owners, potentially yielding more comfort since

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extra visits to gas stations become unnecessary (Gnann et al., 2015; Kurani et al., 1996). Another important factor that affects BEV market diffusion are costs for the vehicle. A BEV typically has a higher investment cost and lower operating cost compared to a conventional vehicle. Given these special attributes of the vehicle, it is important to identify how to best utilise its strengths while mitigating its weaknesses. Thus, we need to identify suitable usage scenarios and early adopter groups for the BEV.

One such early adopter or early majority group could be multi-car households. In such households a conventional long-range vehicle could supplement the BEV. This is also observed as important in regions where BEV penetration is high. For example, in Norway, the country with the highest BEV share per capita, 91% of the BEV owners also have another car (Figenbaum and Kolbenstvedt, 2013). Furthermore, multi-car households have higher income (Dargay, 2002; Jong et al., 2004) and are thus more likely to afford the higher purchase price of BEVs. On the other hand, higher income is correlated to higher annual mileage and could imply more trips that exceed the electric driving range of a BEV. These trips would, if travelled by a car, require that the BEV is replaced by either a conventional vehicle in the household, or by renting another vehicle. In both cases the economic viability of the BEV is reduced. Thus, a systematic understanding of the utility of BEVs in multi-car households with respect to the driving need is required to understand if multi-car households are better suited for early BEV adoption compared to single-car households (i.e. households with only one car).

A common line of argumentation for BEVs in multi-car households builds on two assumptions. The first assumption is that households have cars for different purposes; where one car is used for towing, longer trips, and when transporting more people, while another car is used for shorter everyday trips. The second of these car usage scenarios would then be satisfied by a BEV more easily. The second assumption is that households may be able to shift trips between the cars to circumvent the range limitations of the BEV. In this paper we focus on the first assumption and address the following two questions: Are the second cars in a multi-car household better suited as BEVs from a driving pattern point of view? And taking into consideration total cost of ownership, are these BEVs economical compared to conventional vehicles?

1.2. Other studies considering early adopters for EVs

Several studies have analysed the potential first user groups to adopt EVs. It is often stated that EVs are most likely to be used in large cities (Parrish et al., 2011), due to their limited range and small size. However, Biere et al. (2009) as well as Plötz et al. (2014b) analyse car owner groups in Germany from an economic point of view and find that early adopters of EVs are likely to be those with a full-time job living in towns and cities with less than 100,000 inhabitants. For the UK, Anable et al. (2011) focused on demographic and attitudinal variables in the adoption likelihood of EVs and concluded that BEVs are considered as possible second household cars by car buyers, whereas plug-in hybrid electric vehicles (PHEVs) are also taken into account as the main or only vehicle. In the US, an online survey found that early adopters of EVs are young or middle-aged and have a bachelor degree or higher (Hidrue et al., 2011). They did not find any evidence that household income influences the likelihood of EV adoption, although Curtin et al. (2009) found an increase in expressed interest for buying a PHEV in households with higher income. The role of the availability of more than one car in the household seems to be disputed. Kurani et al. (1996) find that it increases the probability of adoption while Hidrue et al. (2011) conclude that it does not affect the willingness to buy an EV. Hidrue et al. (2011) also conclude that economic motives such as fuel cost savings are more decisive for EV adoption than reducing CO_2 emissions. The findings of a survey by Egbue and Long, (2012) indicate that costs and range are rated most important for adoption, while reducing petroleum use was seen as the major advantage. The fact that costs are important is not that surprising given that it is often one of the determining factors for vehicle choice (Bolduc et al., 2008; Horne et al., 2005; Mau et al., 2008; Sprei et al., 2013). A UC Davis study found that range anxiety was less of a problem during a longer trial period (Turrentine et al., 2011). However, it should be noted that these households all had an additional conventional vehicle. So did the trial households studied by Golob and Gould (1998), which found that some trips were shifted between vehicles in the household; however there was still a demand for a longer range.

Some studies have considered the adoption of BEVs in multi-car households prior to this study, specifically, Khan and Kockelman (2012) as well as Tamor and Milačić (2015) use a GPS measured driving data set for the Seattle region in the US to investigate similar questions. Khan and Kockelman (2012) investigate the effect of replacing the car that drives the least in a multi-car household with a BEV of 160 km (100 miles) range and find that 80% of multi-car households would need to adapt their driving less than four days per year, compared to 50% for single-car households. Tamor and Milačić (2015) differ from Khan and Kockelman (2012) in assuming that the BEV will drive the longer daily trip of the two vehicles in a household, as long as this distance is below the vehicle's range. This leads to a higher electric travel distance, as well as lower travel cost for the household. Based on this assumption, they find a BEV with 100 km of range (60 miles) to obtain the same number of days per year requiring adaptation as a BEV with range 190 km (120 miles) when using direct replacement over the whole car fleet. Tamor and Milačić (2015) also compare the incremental cost of a battery with higher range to the fuel cost savings of electrifying more travel. They find that the optimal range of a BEV adopted in a two-car household is 110 km (70 miles) at a battery costs of 350 $/kW h when assuming an acceptance of three days per year of unfulfilled driving. This would then lead to BEV adoption in about 30% of two-car households.

Overall, the findings concerning the early adopters of EVs are still not conclusive and most of the studies focus on the US. Furthermore, most studies suggest that range anxiety is a strong barrier for adoption. In the present study, with its focus on multi-car households, the range limitation may be less of an issue for the second car according to our definition above.