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The importance of socio-demographic characteristics, geographic setting, and attitudes for adoption of electric vehicles in Sweden

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ABSTRACT

Although the number of different types of EVs is increasing, they still constitute only a small share of the total vehicle market. There are a number of barriers to car owners' adoption of an EV: travel needs, charging infrastructure, the individual car owner's socio-economic characteristics, attitudinal factors, and environmental concern. In this study, the characteristics and geographic location of all private car owners in Sweden (N = 4,447,118) are charted. Through analysis of survey data (N = 1192), the importance of socio-demographic attributes, geographic conditions, car interest, personal and social norms, and environmental concern is estimated. Mapping EV ownership shows that, so far, EV adoption has mainly occurred in metropolitan areas and also to some extent in hotspots outside the metropolitan areas, and that these hotspots are tourist regions that may be exposed to EVs via, for example, Norwegian tourists in the Swedish case. Logistic regression analyses show that age and education level have positive impacts on EV ownership. Residential area also has an influence to some extent, pointing to a slight neighborhood effect in EV adoption. However, the most important factor influencing EV ownership is the individual's personal norms. In addition to showcasing EV adoption patterns in Sweden, the contribution of this study is to point to the importance of the attitudinal factor of personal norm even when geographical conditions and socio-demographic characteristics are controlled for. Implications of the findings are discussed.

1. Background

As humans' activities contribute to climate change, there is a need to better understand what factors influence individuals' willingness to change environmentally damaging behaviors, such as driving fossil fuel vehicles, into less harmful ones. Today, electric vehicles (EVs) are developing into a stronger alternative to cars that run on conventional fuel, and EVs can be defined as an eco-innovation; that is, a new product that eliminates or reduces environmental harms (see for example Jansson et al., 2010). The consumer adoption of an innovation, such as an EV, is the result of attaining initial knowledge of the innovation, forming an attitude toward it, making a decision to adopt or reject it, implementing the new idea, and confirming this decision (Rogers, 1995). The probability that people will accept, and ultimately acquire, an EV is also argued to be related to the extent to which they have to modify their behavior. EVs include: BEVs (battery electric vehicles), which are plug-in EVs whose energy comes entirely from a battery; PHEVs (plug-in hybrid electric vehicles), which have plug-in capability and whose propulsion can come from either a battery or conventional fuel; and HEVs (hybrid electric vehicles), whose propulsion comes from conventional fuel, but which also have an electric drive system and a battery charged from the internal combustion engine as well as, often, regenerative braking. The range limit of BEVs is more likely to affect driving behavior, while the possibility to switch to the combustion engine in PHEVs and HEVs minimizes the need for behavioral changes (Vergis and Chen, 2015).

The diffusion of different types of EVs is still in its early stages, albeit with variations between countries, regions and driver segments (Vergis and Chen, 2015). In Norway, BEVs and PHEVs amounted to 13.8 percent of the total fleet in 2015, while this figure in the Netherlands was 3.4 percent and in Sweden 1.5 percent, and in the US state of California 5.2 percent (Trafikanalys, 2016b). Various incentives have been used to encourage the adoption of EVs, ranging from exemption from VAT or annual circulation taxes to access to bus lanes and free

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parking. One argument for applying incentives has been to make EV acquisition financially feasible for a wider group of people, as income has often been shown to affect it (Green et al., 2011). In addition to high income, EV adoption has also been connected to people with high education (which is largely correlated with income), the middle-aged, and homeowners (e.g. Hanke et al., 2014; Plötz et al., 2014; Sierzchula et al., 2014). Although several studies show that EV adoption varies with socio-demographic characteristics, other studies have shown that these have a limited effect on EV ownership when psychological factors such as norms and environmental attitudes are included (e.g. Axsén et al., 2016; Nayum et al., 2013, 2016; Nordlund et al., 2016).

Further, developed infrastructure, through available charging facilities outside the home, is also advocated for overcoming acquisition barriers connected to range and distance (e.g. Egbue and Long, 2012; Graham-Rowe et al., 2012; Silvia and Krause, 2016). Geographical context and characteristics have therefore been argued to be of importance for adoption, although with diverging conclusions. On the one hand, spatial concentrations of EVs can serve as barriers, as the electrical grid may be too weak (e.g. Lopes et al., 2009 cited in Saarenpää et al., 2013); or, conversely, a higher supply of charging infrastructure in urban areas can work in favor of EV adoption (e.g. Egbue and Long, 2012; Skippon and Garwood, 2011). So, although EV owners in general mostly recharge their vehicles at home overnight or at work during the day (Broadbent et al., 2017; Bunce et al., 2014), a lack of charging infrastructure can serve as a psychological barrier for non-adopters in that they believe they will want to recharge at public access points more than they will in reality (Lieven, 2015; Figenbaum and Kolbenstvedt, 2016; Morrissey et al., 2016). Further, population composition with respect to age, education level and family size can favor a higher share of EVs in suburban and rural areas compared to metropolitan areas (Plötz et al., 2014). Further, Plötz et al. (ibid) argue that EVs are the most cost-effective for high-mileage drivers, as they are relatively expensive up front but the costs decrease per kilometer driven due to the low "fueling" costs, and this driver segment is more often found outside metropolitan areas.

2. Aim and research questions

In this study, socio-economic attributes of car owners and geographic characteristics of place of residence, as well as the owners' norms and environmental concern, are investigated for different groups of car owners in Sweden, with the aim of investigating which, and how, different factors correlate with the actual adoption of an EV. The specific questions addressed are: (i) What are the socio-economic characteristics of EV owners, and in what respects do they differ from non-EV owners? (ii) Where are the geographic EV "hotspots" in Sweden? and (iii) What is the relative importance of socio-economic and geographic attributes compared to norms and environmental concern for the adoption of an EV?

The study is based on geo-referenced register data on all individual car owners in Sweden and a questionnaire survey of a sample of adopters and non-adopters of different types of EVs.

3. Previous studies

3.1. Socio-demographic attributes

Eco-innovations are ideas, products and processes that, when used, are less harmful than relevant alternatives, or contribute to specified sustainability targets (OECD, 2007; Rennings, 2000). Alternative fuel vehicles such as flexi fuel vehicles (FFV) and EVs are eco-innovations as they reduce carbon dioxide emissions, but are also innovations because they lead to new marketing, technological, and business models (Aggeri et al., 2009; Jansson, 2011). Some people are more prone to testing and accepting innovations, and these early adopters are key actors in the adoption of innovations. Studies on the adoption of electronic products have shown that gender, age, income and education level (e.g. Dickerson and Gentry, 1983; Im et al., 2003), as well as employment (Martinez et al., 1988), are important drivers for adoption. However, the conclusions on the relationship between socio-demographic attributes and adoption are ambiguous, and related to the innovation studied and the context. The often weak effects of socio-demographic attributes can decrease or even disappear when other explanatory variables are entered in modelling adoption (Jansson et al., 2017a).

Turning to EVs, education level, income (although income is often correlated with education level), age and green lifestyle (measured as major changes in lifestyle and shopping habits in the past five years) have been shown to be positively correlated with the intention of acquiring an EV (e.g. Hanke et al., 2014; Hidrue et al., 2011). In a study on forecasted EV adoption rate in Ontario between 2012 and 2050, Ahmadi et al. (2015) showed that men's adoption rate would be higher than women's, as men drive more and are therefore more willing to invest in a vehicle. Additionally, in a study on respondents in driving schools in Nanjing, Zhang et al. (2011) found that the number of family members, along with the opinion of peers, maintenance costs and the degree of safety, affects price sensitivity. A German study on who the likely EV buyer is (in this study, EV is synonymous with BEV, PHEV and range-extended EVs) identified middle-aged men with technical professions, living in a rural or suburban area (Plötz et al. 2014). The authors' explanation for this is that this group is more likely to benefit economically from an EV due to their high annual mileage, and that they have the money to buy an EV. The number of vehicles in the household can also positively affect EV adoption. In a multi-car household an EV, and particularly a BEV, requires less adaptation as it can serve as the "second" car, designated for shorter trips and supplementing the conventional long-range car (Axsén et al., 2016; Figenbaum and Kolbenstvedt, 2013; Jakobsson et al., 2016).

It is worth keeping in mind, though, that from a consumer's point of view, a BEV may be regarded as more technologically advanced and associated with uncertainty, compared to an HEV or a PHEV (Vergis and Chen, 2015). Studies on EVs do not always distinguish between the different types, while different consumer segments' views and attitudes may differ according to type of EV and energy form. Using existing literature and vehicle registration data from the US, Vergis and Chen (2015) found that the owner's education level and awareness of EVs, as well as geographic attributes (population density), correlated with the BEV market share but not the PHEV market share, which emphasizes the need to distinguish between hybrid and non-hybrid EVs.

3.2. Geographic characteristics

Studies on the adoption and diffusion of a new technology, such as the Internet, point out that geography matters. While driving an HEV does not require major changes in driving behavior, since the vehicle is not dependent on charging poles, acquiring a PHEV can be regarded as the adoption of a product that requires certain changes in behavior. Though limited range or access to charging poles, etc., can be circumvented by switching to conventional fuel, the full potential of a PHEV is dependent on the availability of charging infrastructure and driving distances. BEVs, on the other hand, require changes in driving behavior; therefore, technical attributes such as range, charging time, speed, and reliability are of great concern in regard to adoption. When travelling in areas where the daily travel distance is generally high, range differences between charging and refueling vehicles become important. Regional differences in electricity and gasoline prices can also be significant in predicting BEV and PHEV/HEV adoption, respectively, as can climate differences (Vergis and Chen, 2015). Besides energy costs, weather and out-of-home charging infrastructure, Vergis and Chen also found that education and an awareness of the existence of EVs were correlated with BEV adoption, while the adoption of PHEVs was correlated with incentives, market characteristics in terms of number of models available, and a more temperate climate. Hence,