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Policy effects on charging behaviour of electric vehicle owners and on purchase intentions of prospective owners: Natural and stated choice experiments

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ABSTRACT

Policy makers are looking for effective ways to promote the adoption of electric vehicles (EVs). Among the options is the roll-out and management of charging infrastructure to meet the EV drivers' refuelling needs. However, policies in this area do not only have a long-term effect on the adoption of EVs among prospective owners, they also have short-term impacts on the usage of public charging infrastructure among current EV owners and vice versa. Presently, studies focusing on both effects simultaneously are lacking, missing out on possible cross-pollination between these areas. This study uniquely combines stated and revealed preference data to estimate the effect of particular policy measures aimed at EV adoption, on the one hand, and charging behaviour, on the other. Using a large dataset (1.7 million charging sessions) related to charging behaviour using public charging infrastructure in the Netherlands we quantify the effects of (i) daytime-parking (to manage parking pressure) and (ii) free parking (to promote purchase of EVs) policies on charging behaviour. To estimate the effects of these particular policies on EV purchase intentions, a stated choice experiment was conducted among potential EV-buyers. Results show that cross-pollinations between EV charging and adaptation policies exist and should be taken into account when designing policies for EV adoption.

1. Introduction

Electric vehicles (EVs) show great promise to help reduce emissions of greenhouse gases (Rangaraju et al., 2015) and local pollutants such as NO_x, SO_x and PM (Razeghi et al., 2016). Despite these potential environmental benefits, the market share of electric vehicle is still relatively small although it should be noted that sales are rapidly growing (International Energy Agency, 2016). Three major barriers have been identified that prevent large scale adoption of EVs: Range anxiety (Carley et al., 2013; Franke and Krems, 2013b), high acquisition costs (Egbue and Long, 2015; Hagman et al., 2016) and a lack of (public) charging infrastructure (Egbue and Long, 2015; Krupa et al., 2014). The first two barriers can be overcome by technological developments of batteries that drive down costs. In the last years the price per kWh storage has fallen rapidly (Nykvist and Nilsson, 2015) and automakers are announcing affordable long range cars (200+ miles) for the period 2018–2022, signalling that EVs are becoming available for a wider range of consumers.

As EVs rely on a new refuelling network, the development of (public) charging infrastructure, or Electric Vehicle Supply

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Equipment (EVSE) infrastructure, is expected to follow the growth of EV sales. However, the deployment of public charging infrastructure faces a chicken-or-egg dilemma. With a low number of EVs on the market today, the business model of charging infrastructure is not viable (Madina et al., 2016; Schroeder and Traber, 2012) and investments in this kind of charging infrastructure is trailing. The development of a public charging infrastructure is however vital for early adopters of EVs especially for those that rely on on-street parking. This problem is particulary prevalent for those that live in multi-unit dwellings or in dense urban areas. Axsen and Kurani (2012) estimate that in the United State only 50% of new vehicle buyers have direct access to minimal level 1 charging, although this varies from region to region. As home charging accounts for approximately 80% of all charging sessions (Idaho National Laboratory, 2015a), facilitating a public charging infrastructure in these areas should be a focus point in accelerating the EV adoption process (Hardman et al., 2017b).

As the market seems to fail, (local) governments step into facilitate a public charge network; charging infrastructure development has been at the centre of attention for municipal policy makers to promote the adoption of EVs. They consider efficient planning of charging infrastructure to be important to meet drivers' refuelling needs (Frade et al., 2011), and to satisfy interests of other stakeholders involved (Wirges, 2016). An increase in parking pressure, a problematic business case and potential grid overload are among the conflicts among stakeholders policy makers encounter when considering EVSE-policies (Bakker et al., 2014). On the other hand, municipalities are considering other ways to promote EVs including measures such as free parking, access to HOV/Bus lanes and monetary incentives (Bjerkan et al., 2016).

With an expanding market for EVs and EVSEs, interest in studies that measure the effectiveness of policies for EV adoption and of the deployment and management of charging infrastructure is growing (see next section for a review of this literature). However, available studies focus *either* on the (strategic level, long term) policy effects on EV adoption rates *or* on (tactical, short term) policy effects on current EV-owners' usage of public charging infrastructure, missing out on possible cross-pollination between these polices. For example, implementation of highly restrictive policies regarding charging infrastructure may well have a (negative) impact on both charging behaviour of current EV-owners and EV-purchase intentions of current ICE-owners. Understanding these combined short and long run implications of charging infrastructure demand management is crucial for policy makers who want to avoid triggering unintended policy-effects, and more generally, design optimal policies.

This study fills this crucial knowledge gap by uniquely combining natural experiments and stated choice experiments to estimate the effects of charging policies on both charging behaviour of EV-owners and EV adoption intentions of non-owners. More specifically, based on a large dataset on charging behaviour using public charging infrastructure in the Netherlands the effects of daytime-parking (to manage parking pressure) and free parking (to promote EVs) policies on charging behaviour are analysed. To estimate the effects of these policies on EV purchase intentions a stated choice experiment is conducted among car owners that rely on public infrastructure for charging their EVs. Section 2 presents a literature review and identifies the knowledge gaps to be filled with the research in this paper. In Section 3, the methodology of three experiments to investigate the effect of the two policies is outlined. This section includes a detailed description of the policies and how the experiments were set up and data were gathered. The results of these three experiments are presented and discussed in Section 4. The last section provides a conclusion and discusses the policy implication of the results.

2. Literature review

2.1. Charging behaviour

Research on charging behaviour has started with using travel patterns from ICE vehicles and tried to infer charging decisions from these patterns (Liu, 2012; Sathaye and Kelley, 2013). Moving beyond this, exploratory work was done which tried to model the decision to start charging. Franke and Krems (2013a) developed a model in which they incorporated the EV's range, range appraisal by users and specific mobility needs. Franke and Krems (2013a) assumed that if the remaining range dropped below a certain comfortable level and the mobility needs could not be met, the driver would want to charge his car. However, during the evaluation of a trial, they observed high levels of habitual charging behaviour, which seemed to be more opportunity driven in ways comparable to mobile phone battery recharging (Franke and Krems, 2013b). These findings have since then been confirmed in a growing body of literature around the world. Descriptive studies in The United states (Idaho National Laboratory, 2015b), Australia (Jabeen et al., 2013; Speidel et al., 2012), England (Robinson et al., 2013; Wardle, 2015), Canada (Toronto Atmospheric Fund, 2015), Ireland (Morrissey et al., 2016) and the Netherlands (Hoed et al., 2014; Spoelstra and Helmus, 2015) confirm such behavioural patterns. In particular, these studies generally indicate two peaks in starts of charging sessions, one in the morning, reflecting "business charging", and one in the late afternoon, reflecting "home charging". These studies identified differences in charging behaviour by type of users (Helmus and van den Hoed, 2015) and described the influence of free charging and other price sensitivities (Idaho National Laboratory, 2015b; Wardle, 2015).

More recently, a body of work has focussed on assessing the determining factors that influence the decision to charge. Using stated preference techniques Wen et al. (2015) asked drivers about mid-trip charging and found that the State-of-Charge (SoC), dwell time and price are important factors that influence this decision. Jabeen et al. (2013) asked drivers to their most and least favourite option when presented with options for home, workplace and public charging. Time of day, time charging and price were varied across the categories. A strong preference was observed for home charging especially among solar panel owners. Latinopoulos et al. (2017) provided additional insight to charging behaviour, by modelling in and out-of-home-charging. They show that out-home-charging is more common for those that have the opportunity to charge at work or when it is offered for free. Daina (2014) has looked at several factors that could influence the decision to delay charging allowing 'smart charging' technologies that could reduce the impact of EVs on the grid. Daina (2014) showed that EV users are willing to allow flexibility as long as this does not influence the range needed for the next trip.