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Electric vehicle adoption in Sweden and the impact of local policy instruments

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ABSTRACT

A transition towards a higher share of electric vehicles has the potential to significantly reduce greenhouse gas emissions. The adoption rate of electric vehicles in Sweden is however relatively slow and varies substantially across municipalities. This study empirically examines the impact of local policy instruments designed to promote the adoption of electric vehicles. We use panel data between 2010 and 2016 to estimate the effect of local policy instruments on the share of newly registered battery electric vehicles in Swedish municipalities. We find that an increased number of public charging points increases the adoption rate, especially in urban municipalities. The results further suggest that public procurement of battery electric vehicles has the potential to be an effective policy instrument. Finally, we find that by adjusting policy instruments to the specific characteristics of municipalities and making them visible to the public, their effectiveness can be increased.

1. Introduction

Climate change is one of the greatest challenges of today and the reduction of greenhouse gas (GHG) emissions is therefore essential. Currently in Sweden, the transport sector accounts for about one quarter of the total GHG emissions (Swedish Energy Agency, 2017) and in order to reduce these emissions, Sweden has set a target to achieve a fossil independent vehicle fleet by 2030 (SOU, 2013:84).[1] Depending on the source of electricity, a transition towards Electric Vehicles (EVs) has the potential to reduce GHG emissions and Sweden has therefore implemented several policy instruments to increase the EV adoption. Although the number of EVs is increasing in Sweden, the adoption rate is slow in comparison with other similar countries (Harrysson et al., 2015). Furthermore, there is a significant variation in the adoption rate of EVs across municipalities, despite the fact that financial incentives for EVs are the same. According to the Swedish National Institute of Economic Research (2013), the Swedish adoption rate of EVs is not sufficiently high in order to achieve the target by 2030, and the Swedish Energy Agency (2016) argues that there is a need for more detailed information about the driving forces affecting the adoption of EVs.

The aim of this study is therefore to contribute to the understanding of EV adoption by empirically examining its determinants. We focus on Battery EVs (BEVs) and examine the impact of local policy instruments designed to promote the adoption at a municipal level. The local policy instruments in Sweden include parking benefits and public charging infrastructure. In addition to these existing policy instruments, we also investigate whether public procurement of BEVs has the potential to increase the BEV adoption.

The choice of focusing on BEVs is motivated by the fact that they are highlighted as one of the most attractive technology alternatives to Internal Combustion Engine Vehicles (ICEVs) in order to achieve fossil independence and a more energy efficient transport sector (Swedish Energy Agency, 2014; IEA, 2016). Compared to other EV types, which are described in Table 1, BEVs have the potential to lower GHG emissions to a higher extent since they do not require any fossil fuel. The emissions instead depend on the power source and since over 90% of the electricity production in Sweden is generated from renewable or nuclear sources (Statistics Sweden, 2017), the GHG emissions from BEVs are low. On a local level, BEVs also bring benefits such as air quality improvements and reduced noise (IEA, 2016). However, barriers such as high costs, limited battery capacity, and dependence on charging infrastructure are limiting the widespread diffusion of the EV technology (Axsen et al., 2010; Egbue and Long, 2012; Leiby and Rubin, 2004). Studies further suggest that imperfect information and limited knowledge about EVs contribute to slow diffusion rates (Brown, 2001; Sierzchula et al., 2014).

Related literature has in several countries found both nationally implemented financial incentives (e.g., Beresteanu and Li, 2011;

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[1] Fossil independent vehicle fleet is defined as vehicles not being dependent on fossil fuels.

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Table 1
Description of vehicle types.

Vehicle type		Description
BEV	Battery Electric Vehicle	A vehicle that runs exclusively on electricity using an electric motor and an on-board battery which is charged by plugging it into a charging point (IEA, 2013).
EV	Electric Vehicle	A general term used to describe any vehicle that uses an electric motor (IEA, 2013).
HEV	Hybrid Electric Vehicle	A vehicle that combines a conventional internal combustion engine with an electric motor. Although these vehicles have an electric motor and battery, they cannot be plugged in and recharged. Instead, their batteries are charged from capturing energy that is normally wasted in conventional vehicles (IEA, 2013).
ICEV	Internal Combustion Engine Vehicle	A vehicle using an internal combustion engine, typically fed with fossil fuels such as petrol or diesel. Currently, internal combustion engines are the dominant power source for vehicles (IEA, 2013).
PHEV	Plug-in Hybrid Electric Vehicle	A vehicle similar to a HEV in having an internal combustion engine in addition to an electric motor, except a PHEV has higher battery capacity and can be recharged by plugging it into a charging point. A PHEV is further capable of using electricity as its primary engine source, while the internal combustion engine typically serves as a back-up when the battery is depleted (IEA, 2013).

Chandra et al., 2010; Gallagher and Muehlegger, 2011; Sierzchula et al., 2014) and locally implemented policy instruments (Mersky et al., 2016) to have a positive impact on EV adoption. However, the effectiveness of the Swedish national financial instruments promoting EVs are found to be weak (Harrysson et al., 2015; Huse and Lucinda, 2014), and the local policy instruments have not previously been empirically examined. This study contributes to the literature in a number of ways. First, by taking advantage of the municipal variation in BEV adoption rates and local policy instruments in Sweden, this study is the first to empirically investigate the impact of local policy instruments on the BEV adoption in Sweden. Second, since municipalities with different characteristics face different barriers to BEV diffusion, this study also examines the impact of local policy instruments across sub-samples of municipalities. Third, this study further contributes to the literature by using a new data set, in which some parts are collected through a questionnaire sent to all Swedish municipalities. Fourth, the potential problem of reversed causality between EV uptake and charging points has in previous related literature not been addressed, which this study therefore is the first to do. Finally, by contributing to the understanding of BEV adoption and its determinants, our findings may also be relevant for policy makers when designing policies for increased BEV adoption.

We present and build on a behavioural utility function for vehicle demand and specify hypotheses based on the theoretical framework and related literature. We use cross-municipality panel data between 2010 and 2016 and use the share of newly registered BEVs as dependent variable. We find that an increased number of public charging points has a significant and positive impact on the BEV adoption, especially in urban municipalities. Expansion of charging infrastructure is therefore indicated to be an effective measure to promote BEVs. The results further suggest that municipalities with a higher number of municipally owned BEVs are associated with significantly higher shares of BEVs owned by private persons and companies, especially in rural municipalities. Therefore, implementing a policy instrument of public procurement of BEVs has the potential to be an effective instrument to increase the BEV adoption. The impact of parking benefits on BEV adoption is also found to be positive, but the results are less robust. Finally, the findings suggest that by adjusting policy instruments to the local conditions of municipalities and making them visible for the public, it can increase their effectiveness.

The remainder of the paper is structured as follows. Section 2 provides a background and a literature review of previous related research and it also includes a section covering barriers to EV technology adoption. Section 3 presents the theoretical framework leading up to the hypotheses to be tested. Section 4 presents the data and the empirical strategy. Section 5 provides the regression results along with a discussion and sensitivity checks. Conclusions and policy implications are presented in Section 6.

2. Background

2.1. Literature review

The effect of financial policy instruments promoting EVs has previously been examined by a number of empirical studies. Diamond (2009) examines the impact of government incentives on Hybrid EV (HEV) adoption by using data of the US states between 2001 and 2006. He finds gasoline price to be a significant driver, whereas government incentives are found to have a weaker effect. Consistent with Diamond (2009), Beresteanu and Li (2011) also find gasoline price to be a driver of HEV adoption. Other studies find evidence that financial incentives lead to significantly higher EV sales (e.g. Chandra et al., 2010; de Haan et al., 2007; Gallagher and Muehlegger, 2011). Sierzchula et al. (2014) add to the literature by examining how socio-economic factors and charging infrastructure, in addition to financial incentives, influence the EV adoption. Using sales data of BEVs and Plug-in HEVs (PHEVs), they perform a cross-country analysis and find that financial incentives and charging infrastructure are significant factors explaining a country's EV market share. In an empirical study even more closely related to ours, Mersky et al. (2016) aim to identify determinants of BEV adoption at a regional and a municipal level in Norway. They find access to charging infrastructure, proximity to major cities, and income to have significant and positive effects on BEV adoption.

The number of empirical studies examining factors affecting EV uptake are limited because the stock of EVs, both globally and in Sweden, only began to increase considerably after 2010 (IEA, 2016). Therefore, several previous studies analysing the demand for EVs use models based on survey data, rather than models consisting of sales data (Axsen et al., 2009; Bolduc et al., 2008; Brownstone et al., 2000; Eppstein et al., 2011; Hidrue et al., 2011; Mau et al., 2008; Mueller and de Haan, 2009). For example, findings by Langbroek et al. (2016), based on a stated choice experiment, also show that policy instruments have a positive influence on EV adoption. They further argue that use-based policy instruments, such as free parking or access to bus lanes, are efficient alternatives to financial incentives.

In a qualitative study by Bakker and Trip (2013), the main finding is that knowledge and experience of driving EVs are important in order to increase the EV adoption. They argue that by having municipalities as lead users of EVs, it can communicate to the public that the municipality supports the technology. Public procurement may thus promote the use of BEVs. We provide evidence of such an effect by empirically investigating a potential policy instrument of public procurement of BEVs is expected to affect the overall municipality BEV share.

This study contributes to the literature by providing a detailed assessment of the role of local instruments and other potential drivers on the BEV adoption rate. The study further adds to the literature by using a data set that not previously has been used to analyse this question. The impact of charging infrastructure as a policy instrument promoting EVs has only to a limited extent been examined in previous empirical