GOOD CHARGERS? THE IMPACT OF ELECTRIC VEHICLE DENSITY ON LOCAL GRID COSTS

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Overview

The electrification of transport is viewed as a potent measure to reduce greenhouse gas emissions, and this has been a part of the climate policy strategy in Norway. We observe a rapidly rising share of the Norwegian passenger car fleet becoming electric, with a share of over 30% of new car sales in 2018. However, there exists a literature that, mainly through simulation exercises, find strong reasons to expect electric vehicle (EV) charging to cause substantial future costs to the local grid, unless measures are put in place. Hattam and Greetham (2017) look at how EVs affect load profiles on neighborhood level in low voltage networks. Azadfar, Sreeram, and Harries (2015) look at EV driver charging behavior in terms of time of day, duration, frequency and electricity consumption in light of its implication for electricity network management. Barton et al. (2013) looks at the challenges for grid balancing when EV charging become more prominent, and stress the importance of demand side management with time-shifting of electricity loads from periods of peak demand to off-peak, and from periods of low renewable energy supply to periods of high supply. Other studies also argue for demand side management (see e.g., Haidar, Muttaqi, & Sutanto, 2014; Masoum, Deilami, Moses, Masoum, & Abu-Siada, 2011) as an alternative to costly upgrades of distribution transformer stations.

An increased number of EVs may lead to higher costs to DSOs and subsequently to higher grid costs through the following stylized steps:

1. The EV share increases in a neighborhood
2. Households will charge usually at 3.6-7.2 kW, and the demand for power capacity will increase
3. With a certain size of the EV share and a certain degree om simultaneity of household charging, the existing transformer will not be able to handle the power capacity demand at certain times of day, certain times of year
4. The DSO invests in capacity expansion in the local grid
    - A new higher capacity transformer is installed, and thicker cables are laid
5. This induces new investment costs that otherwise would not have occured, or at least an advancement of investments
6. The new investment increases the capital stock for the DSO.
    - Regulation then says that the DSO can charge higher grid tariffs to cover costs (subtracted any co-funding of upgraded infrastructure)
    - All of the DSO’s customers have to pay the higher tariffs

If indeed the aggregate uncoordinated charging behavior from EV owners does induce higher costs to local grid companies, then Norwegian data would be the first place to investigate. Detailed data of all Norwegian local grid companies (hereafter DSOs – Distribution System Operators) and all registered EV ownership during the last nine years of rapid growth in EV ownership gives a unique opportunity to investigate this relationship. What we find may have implications for how to regulate DSOs, how to price household power usage and how to assess the net social cost of achieving emission reduction targets through promoting EVs.

Based on this motivation, we ask the following two research questions: 1) What are the marginal costs inflicted on DSOs when the number of EVs increases? 2) Through which mechanisms, i.e. which of the DSOs costs, do we find the cost associated with higher EV density?

Section 2 provides the background for why we are concerned with the costs that the rising numbers of EVs may induce on the local grid, based on the literature. Section 3 presents the methods and data. In section 4 we present the results from our empirical analysis. Section 5 discusses the results, and section 6 concludes.

Methods

In this paper we conduct a panel data analysis using a fixed-effects regression model on a balanced panel with annual data for 109 DSOs over the time period 2008-2016. This gives us a balanced panel containing in total 981 observations.

The data set has been compiled through merging together 3 datasets We have matched 1) data from The Norwegian Water Resources and Energy Directorate (NVE) for DSO costs and outputs applied for regulation, with 2) NVE's data for the DSOs legal operational area, with 3) municipalities, which finally can be merged with Statistics Norway's data over registered cars at municipal level.

The main endogenous variable is the DSOs annual *total costs*. The total costs are the sum of *operational costs*, *capital costs*, *depreciation costs*, *CENS - cost of energy not supplied* and *cost of energy network losses*. The independent variables will be the DSO output variables NVE uses for regulation; *subscribers*, *substations* and *kilometers of high voltage line* and the contextual variable we are interested in, namely *number of EVs*. Since this is a fixed-effects model, the time-invariant contextual factors that NVE uses in their regulatory calculation are not included.

Results

Preliminary results: We find that the number of EVs owned in the DSOs operational area is associated with a small, positive effect on capital costs, which is significant at the 10% level. The effect on total costs is smaller and not statistically significant at the 10% level (with standard errors adjusted for clustering the DSOs). On all other cost groups the results were statistically insignificant.

Conclusions

Preliminary conlusions: The results give some support to the literature that expects EVs to cause higher grid investment costs as they force the DSOs to upgrade their infrastructure prematurely. However, the effect is not large enough to advise the regulator of the DSOs, NVE, to incorporate EV density as a cost-driving contextual factor into its regulation. Even though Norway is the country where the EV-share of the car fleet is the highest in the world, EVs still only comprising 7% of the car fleet nationally (up to 12% in some municipalities). It might simply be too early to identify EVs as a cost driver for DSOs, as the numbers still are relatively small. However, now that we have the model up and running, we can quickly update our estimates as new data becomes available.

References

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