Electric Vehicle (EV) Charging Infrastructure and Repercussions of EVs on Household Electricity Load – What Can We Learn From Research Findings?

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See footnotes at end of text.

Governments worldwide perceive electric vehicles (EV) as one possible option to decarbonize transport systems. However, the adoption of this new technology among households is still in its infancy. As such, even though the stock of electric cars worldwide reached 7.2 million in 2019 (IEA, 2020) and displayed a 40 per cent year on year increase, EVs still represent only around 1 per cent of the global car stock.

A number of questions thus arise. First, how does the development of the charging infrastructure affect technology adoption in the market of EVs. Second, what is the effect of EVs on electricity demand and the shape of the electricity load?

Current empirical research can help industry practitioners and policy makers understand the aforementioned interdependencies by providing in depth analyses of the experiences of different countries.

EV Charging Infrastructure

The first question has been addressed in a number of recent studies such as Li, Lang, Xing and Zhou (2017), Springel (2019), Delacretaz, Lanz and van Dijk (2020) or Sommer and Vance (2020). These studies employ data from different countries such as Germany, Norway or the United States and adopt different econometric approaches. However, the majority of these studies shares a common denominator. In particular, due to network effects, a subsidization of the deployment of charging stations is more cost effective and efficient compared to a subsidization of the EV purchase price.

Li et al. (2017) use data for 353 Metropolitan Statistical Areas in the United States between 2011 and 2013 and find indirect network effects due to the interdependence between EVs and charging stations. The interdependence between the two sides of the market (EVs and charging stations) can be characterized as the well-known chicken-and-egg problem since the benefit of adoption/investment on one side of the market increases with the network size of the other side of the market. The authors furthermore show that subsidizing charging stations deployment could have been much more effective in promoting EV adoption than the subsidization of EV buyers through tax credits.

Using Norwegian large-scale vehicle registry data from 2010 until 2015, Springel (2019) finds strong positive feedback effects implying that cumulative EV sales affect charging stations entry and public charging availability impacts consumers’ vehicle choices. Her findings also reveal that a subsidization of charging stations leads to a much higher adoption of EVs compared to a subsidization of EV prices. For instance, whereas every 12 mn USD spent on station subsidies resulted in 835 additional EVs, the same amount spent on price subsidies led to only 387 EVs. However, she also highlights that this relationship inverts with increased spending since station subsidies reach diminishing returns quicker. Hence, she suggests that for a given level of government spending, policymakers should use both types of policies. Using more recent data for the same country, Delacretaz et al.(2020) document a non-linear relationship between EV adoption and the size of the charging infrastructure network. They show that initial infrastructure provisions have long-lasting impacts on the demand for EVs and hence make a case for government support for the early investments in this network infrastructure.

Sommer and Vance (2020) also find a significant effect of charging infrastructure on EV uptake for Germany. Over the course of a year, one additional charging station is associated with 0.312 to 0.744 additional EVs. The authors show that grants for the expansion of the charging infrastructure are more cost efficient than a subsidization of the EV purchase price.

Repercussions of EVs on Household Electricity Load

The second question considering the effects of EVs on electricity load has been less scrutinized in the literature thus far. Muratori (2018) or Burlig, Bushnell, Rapson and Wolfram (2020) are among the few exceptions. Muratori (2018) uses model simulations of residential power demand and plug in vehicle use whereas Burlig et al.(2020) resort to real time residential electricity data and EV car registrations for California. Both papers underline that EV charging could change the shape of the aggregate residential demand and hence affect the electricity infrastructure. Muratori (2018) shows that even with low adoption levels, the penetration of EVs can increase peak demand. Burlig et al.(2020) find low magnitudes of the absolute effect meaning that EVs increase household load by 17-25 kWh per week or by around 20 per cent compared to the load of non EV owners. However, they also emphasize that the load impact is concentrated in the late night and early morning hours and the shape of the load is important for future grid investments. For instance, even an increased expansion of renewable solar energy is less helpful if EV charging occurs at night when the sun does not shine. However, one can expect that this effect can be attenuated with an improvement of battery storage technologies.

The following graph depicts the evolution of the monthly electricity consumption (right axis) and stock of electric vehicles (left axis) in Switzerland between January 2015 and December 2019. We can see that the more than threefold increase in the stock of EVs from around 16000 in January 2015 to around 57000 at the end of 2019 is not matched by an increase in monthly electricity consumption. This can be explained by the still relatively low uptake of electric cars and the low electricity consumption of each car. Using data for households in the Swiss Canton of Bern, our empirical estimates show that a household's annual electricity consumption is by 14 per cent higher once it owns an EV controlling for a number of household characteristics such as income, family size, size of the flat, heating system etc.[1,2] Assuming a median annual household electricity consumption of 4000 kWh, a 14 per cent increase means 560 kWh increased annual electricity consumption. A back of the envelope calculation implies that the stock of 60000 EVs at the end of 2019 increases annual household

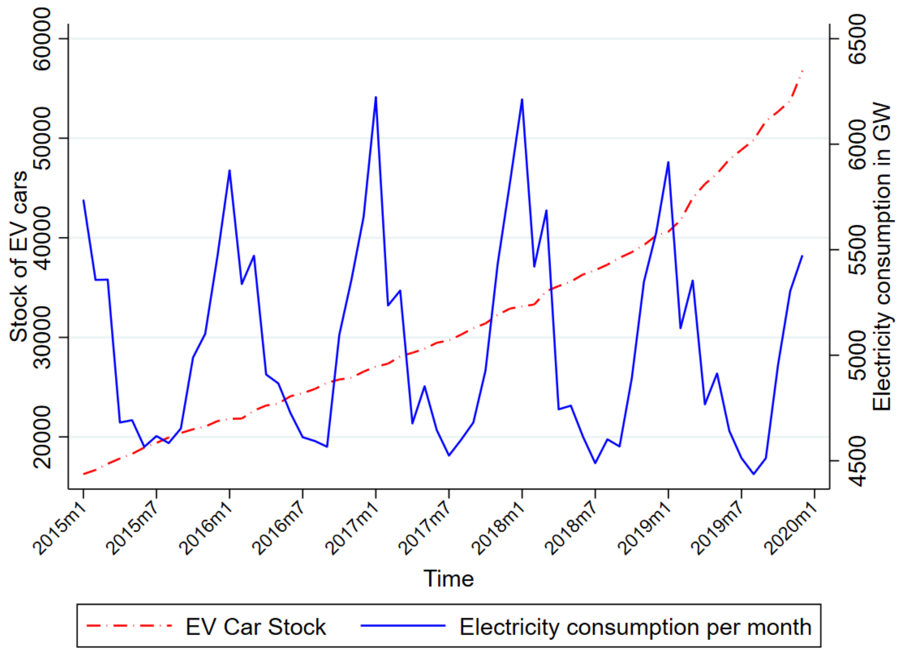

Figure 1: EV Stock and Monthly Electricity Consumption in Switzerland between 2015-2019
Source: Own calculations using information from Swissgrid and MOFIS.

electricity consumption by only 33.6 GW or by 0.05% of Switzerland's overall electricity consumption in 2019.[3]

Hence, this descriptive evidence for Switzerland confirms the results of Burlig et al.(2020) suggesting only a rather limited effect on overall electricity consumption. As long as the adoption of EVs is low and the electricity usage of each car rather limited, we should not expect substantial repercussions on overall electricity demand. Still, the daily load profile is considerably affected. As shown by Burlig et al. (2020), EV owners charge their cars in the late evening and early morning hours when environmentally friendly energy is rather scant.

To sum up, state of the art research in the field documents network externalities between EVs and charging stations. Most papers find that subsidizing charging stations is a cost effective instrument in the deployment of EVs. The preliminary results related to the impact of EVs on electricity demand find at the moment a small effect on overall electricity demand, albeit considerable effects for the shape of electricity load.

Footnotes

[1] We should note that in our data only around 121 out of 51000 households that we can observe over a number of years and for which we observe electricity consumption, car ownership and other socio demographic characteristics, own an EV.

[2] This research is part of a project financed by the Swiss National Foundation entitled "Household Preferences for Electric Vehicles and Renewable Energy and the Effect of These Technologies on Electricity Demand", SNF grant 100018_192554.

[3] In our dataset covering 52000 households in the Canton of Bern we only observe household level electricity consumption so we can only infer something about charging EVs at home. The monthly data used in the graph should however capture charging of EVs all over the country.

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