On the Chicken & Egg Problem in Transportation Electrification

Jason Hawkins

1 Introduction

Vehicle electrification is widely regarded as a critical tool for climate change mitigation in the transportation sector (Musti and Kockelman 2011). While the United States is seeing an increasing share of electric sales, the pace of adoption remains well below the necessary level to mitigate climate change impacts. One barrier to widespread adoption is the lack of charging infrastructure (Sullivan and Taylor 2021).

2 The Electric Vehicle and Charging Station Problem

Electric vehicle ownership is often referenced as exhibiting a "chicken and egg" behavior arising from the supply and demand relationship. Individual demand for electric vehicles is influenced by the available supply of charging points. Consumers are unwilling to purchase vehicles due to range anxiety and a perceived lack of charging stations. Suppliers are not incentivized to provide charging stations unless there is sufficient demand to warrant their cost. There is a clear role for public policy in such situations. The government deems electric vehicles as a solution to a public ill (i.e., climate change) and can incentivize either suppliers by providing installation subsidies or consumers by installing charging stations. While the problem has been recognized in the literature (Melliger, Vliet, and Liimatainen 2018), empirical analysis is minimal.

An important consideration to the analysis is how electric mobility system may differ from one based on fossil fuels. In the conventional private mobility model, the individual owns the vehicle and purchases fuel from centralized and privately owned refueling stations. In contrast, electric vehicles may be charged in the home using previously existing infrastructure. The presence of charging points in the home begs the questions 1) if (or to what extent) out-of-home charging stations are required for travel? and 2) to what extent is range anxiety a perception versus a reality?

According to the Bureau of Transportation Statistics, 98% of trips made in the US are less than 50 miles (Vehicle Technology Office 2022). Given that most battery-electric vehicles (BEVs) have a range greater than 200 miles (Elfalan 2021), it is feasible to make most trips on a single charge. However, long-distance trips (over 50 miles) comprise 30% of total vehicle-miles traveled (VMT) (Aultman-Hall 2018). There is clearly a need for out-of-home charging stations to accommodate these trips. Even if most trips can be accommodated by in-home charging, the vehicle purchase decision will be influenced by consideration of these longer trips that require charging stations (Silvia and Krause 2016). Additionally, Wolbertus et al. (Wolbertus et al. 2018) find that there is still a demand for charging stations in places where public daytime charging is the only option, such as at the workplace.

3 Data Sources

We use a combination of open-source and purchased data in our analysis. The two key input datasets are charging station locations provided by the Alternative Fuel Data Center (AFDC) and electric vehicle registrations provided by Experian Inc. The vehicle registration dataset comprises a 10-year panel at 2-year increments (i.e., 2012, 2014, 2016, 2018, 2020). Total vehicle registrations are recorded by county for the United States.

This initial analysis is based on the charging station data and EV sales by state for the period 2013 to 2020 as the county-level registrations were not made available in time for publication. EV sales and market share data is provided by EVAdoption, and state population data by the U.S. Census Bureau.

```
C:\Users\jhawkins17\AppData\Local\Temp\ipykernel_15120\2346844971.py:2: DtypeWarning: Columns
  df_ch_stn = pd.read_csv("../Data/Transport/alt_fuel_stations_w_county.csv")
```

```
df_ch_stn all 53684
df_ch_stn no private 49852
df_ch_stn (after removing nan open year 49846
```

TO DO: - plot total vehicles and total charging stations per person - create county-specific Granger causality statistics - Input demographic data by county - create generalized propensity scores - create regression inputs - run regressions - write literature review - write results and discussion - get casey's stuff working in the paper - write up methods

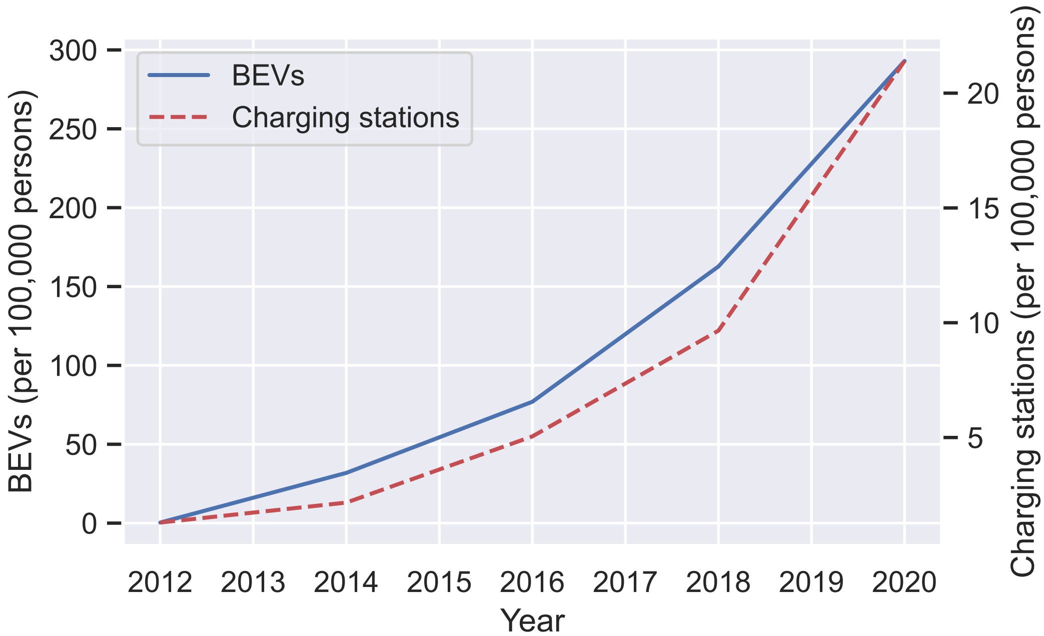

Figure 1: US BEV Registrations and Charging Stations

4 Methods

5 Results

```
{# {python} # ## Number of Charging stations per county # ax = gplt.choropleth(
#   final[final['STATEFP'] == 6], #   hue = "Charging Stations", #   edgecolor='darkgrey',
#   linewidth=.5, #   cmap="viridis", #   legend=True, #   projection=gcrs.AlbersEqualArea()
#   figsize = (16,16), #   zorder = 1 # ) #  # gplt.pointplot( #   station_points[station_po
== 6], #   projection=gcrs.AlbersEqualArea(), #   ax = ax, #   zorder = 2, #
s = .4 # )
```

6 Discussion

7 Conclusions

The results presented herein are preliminary and do not consider a key dataset – vehicle registrations. We will expand our analysis to a more robust inferential study in the coming months.

Our causal question is what effect public charging stations have on electric vehicle registrations at the county-level. The treatment variable is continuous over the study period. We propose three causal identification approaches. The first approach is a difference-in-differences approach that is identified off state-level investments in charging stations by year. The second approach is generalized propensity score matching using federal election results, state-level greenhouse gas (GHG) emissions factors, and demographic characteristics (e.g., racial composition, median income, and population density) as inputs to the propensity score.

The final causal inference approach, Granger causality, differs in that it focuses on the temporal phasing of charging station installations and PEV registration, whereas the other two approaches rely on Rubin's potential outcome assumption (Reich et al. 2021). Granger causality relies on the assumption that past treatment knowledge reduces predictive uncertainty. It is a form of time series causal inference that would fit the current context well.

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