Household vehicle portfolios and EV demand

Fiona Burlig
UChicago
NBER

Jim Bushnell
UC Davis
NBER

David Rapson
UC Davis
Dallas Fed

Economics of Transportation in the 21st Century
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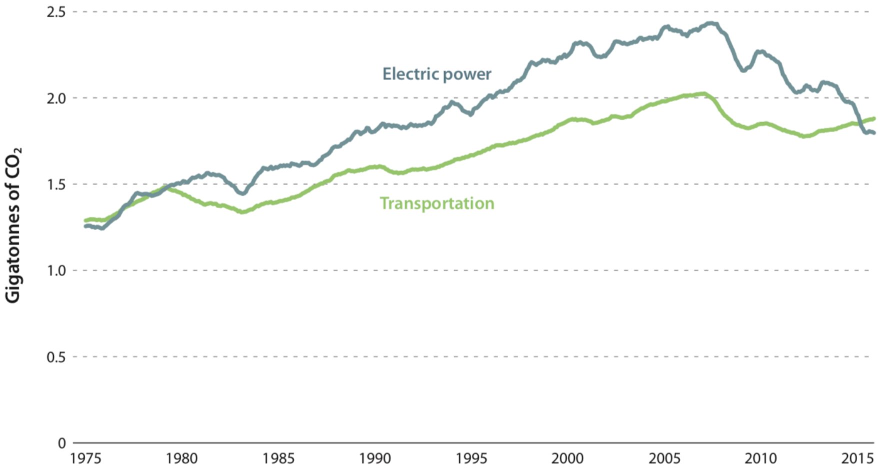
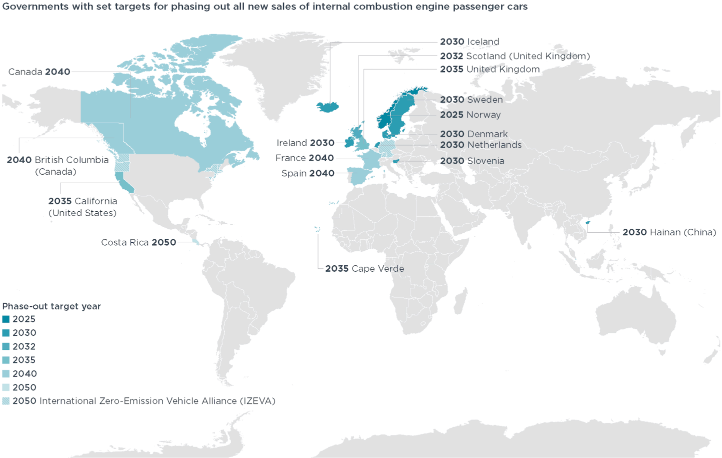
Transportation emissions are large and growing



We're going "all in" on EVs



California: 100% of new cars to be electric by 2035

We provide new empirical evidence on EV electricity use

Today:

How much electricity do EVs actually use (at home)?

What does this tell us about eVMT?

What explains our results?

We know remarkably little about charging behavior

Summary of Crediting Methodology

Per Section 95491(a)(3)(D) of the LCFS rule, the electricity used for non-metered residential charging is determined by the number of non-metered Plug-in Electric Vehicles (PEVs) in the utility's service territory, and the daily average non-metered PEV electricity use per vehicle, using the following equation:

$$PEV\ Electricity\ Use^{Non\ metered} = Number\ of\ Vehicles^{Non\ metered} \times Daily\ Average\ PEV\ Electricity\ Use \times Number\ of\ days^{in\ compliance\ period}$$

For the 2017 crediting period, the daily average per-vehicle non-metered PEV electricity use is assumed to equal the use for separately-metered vehicles in the same utility service territory. The utilities each calculate the daily average electricity use per metered vehicle and the number of separately-metered PEVs for the four quarters of the prior year and submit this information to ARB by January 31st.

- CA regulators use $\approx$ 500 highly-selected meters (cash at stake!)
- Large dependence on survey data with highly-selected respondents
- OEMs know the numbers better, but rarely share

We overcome previous hurdles with restricted-access data

We combine utility data and DMV data to map cars to consumption

Utility data

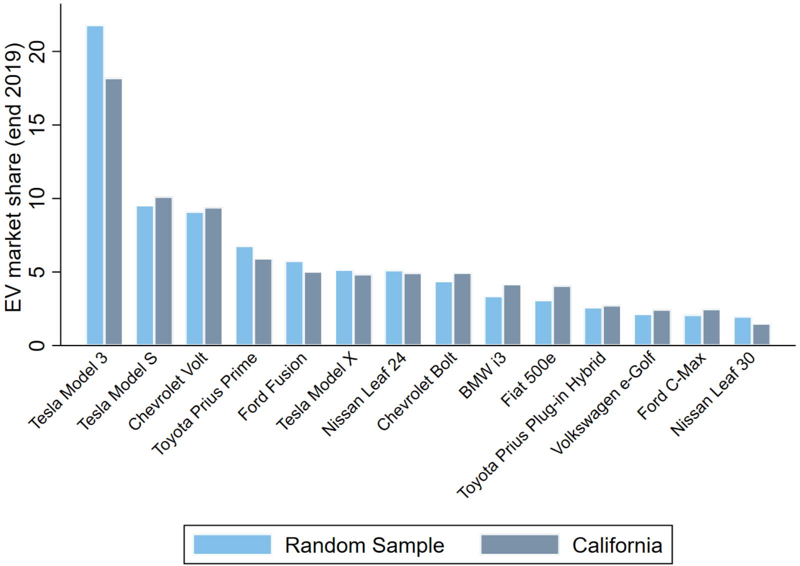
- 10% of IOU service territories
  - Stratified sample targets high-EV areas (8%)
  - Fully random sample (including some from stratified) (2%)
- Data from 2014 – 2019
- Crazy big number of hourly electricity use observations
- Customer details, including address and tariff

DMV data

- Address-level registration info for universe of CA EVs, 2009-2019
- Registration dates allow us to estimate timing of arrival
- Detailed info from VIN stems on car characteristics

→ We match more than 140,000 EVs to households on address
→ We also match all ICE registrations to get HH portfolio of cars

Our sample of EVs is (largely) representative of California's



We employ a panel fixed effects research design

To estimate the causal effect of EV adoption on load, we estimate:

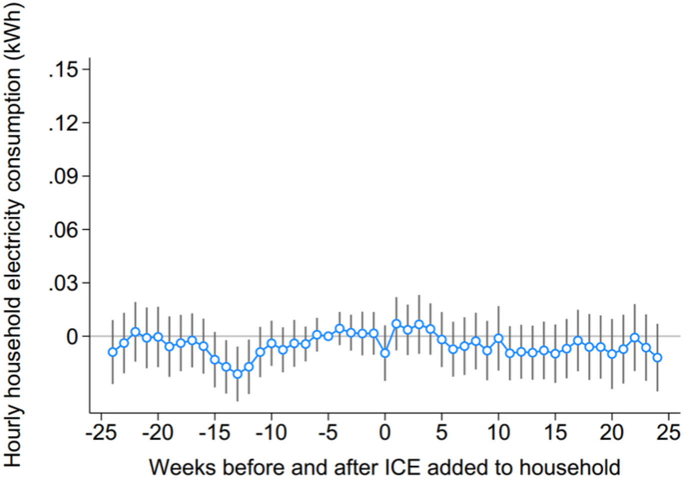
$$Y_{ith} = \beta EV_{it} + \gamma Solar_{it} + \alpha_i + \delta_t + \varepsilon_{ith}$$

where:

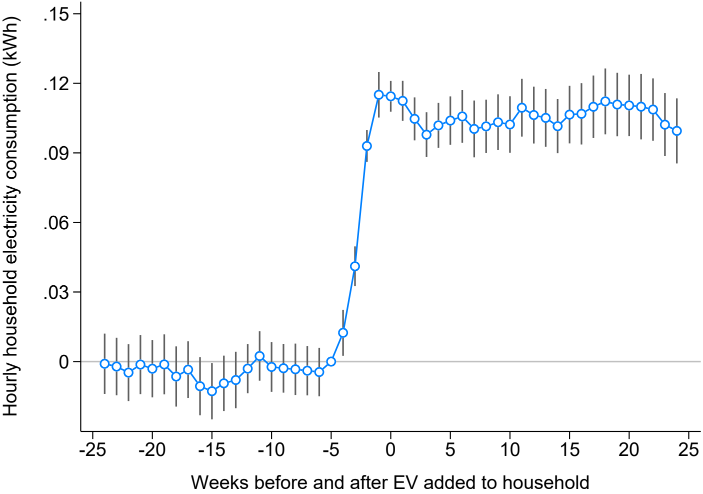
- Y_{ith} is kWh/hr at household i in week t in hour-of-day h
- EV_{it} is the count of EVs
- $Solar_{it}$ is a solar indicator
- α_i are household FE (can be more flexible)
- δ_t are week-of-sample FE (can be more flexible)
- ε_{ith} is an error term, two-way clustered at CBG and week-of-sample

Identifying assumption: Conditional on FE, the timing of EV adoption is as good as random (and no other contemporaneous changes)

Falsification test: ICE vehicles don't impact electricity use



Event study estimates of the impacts of EV adoption



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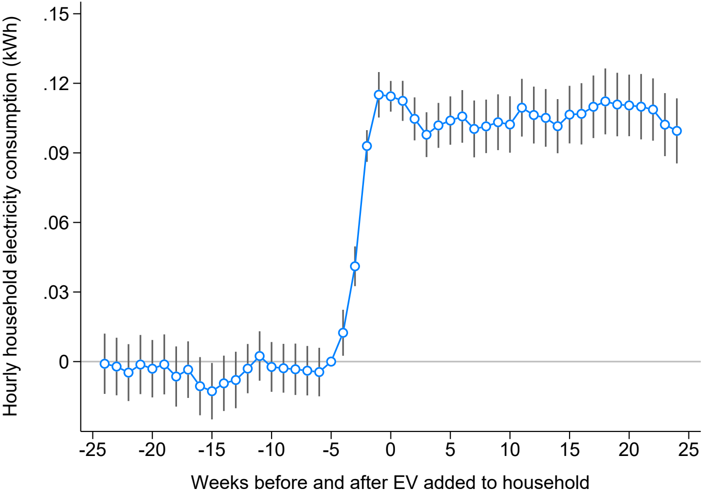
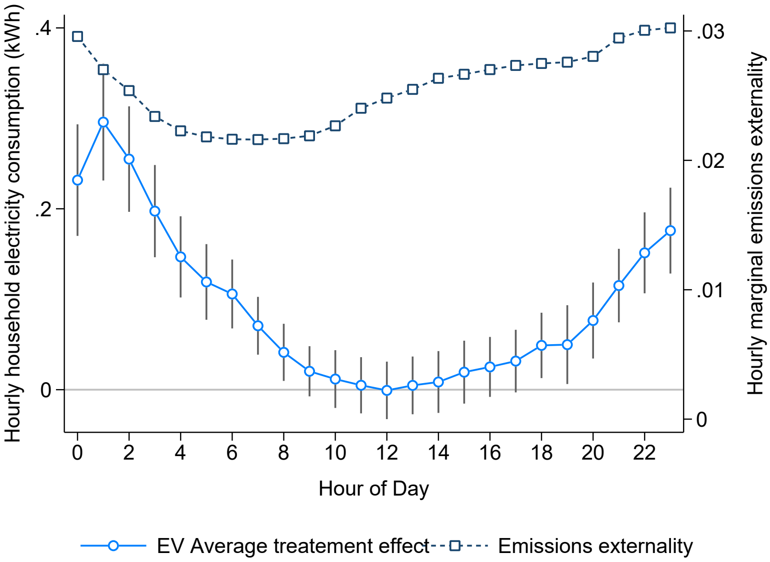
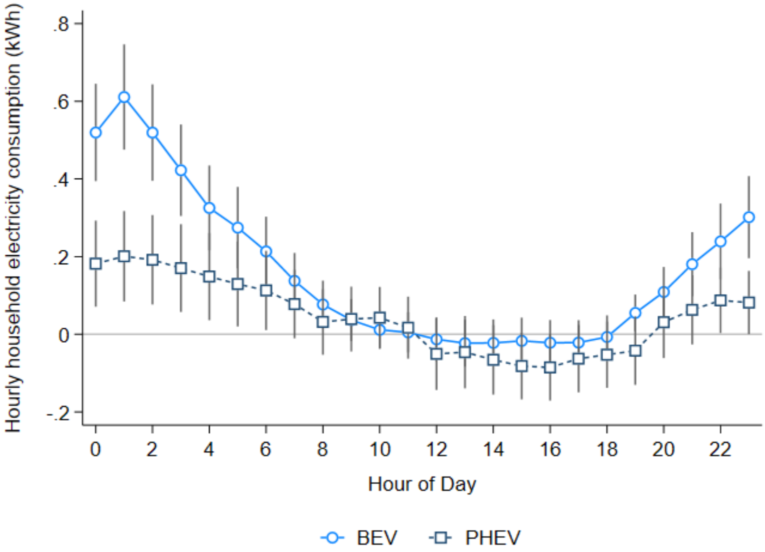


Our estimates are approximately half the size of CEC projections

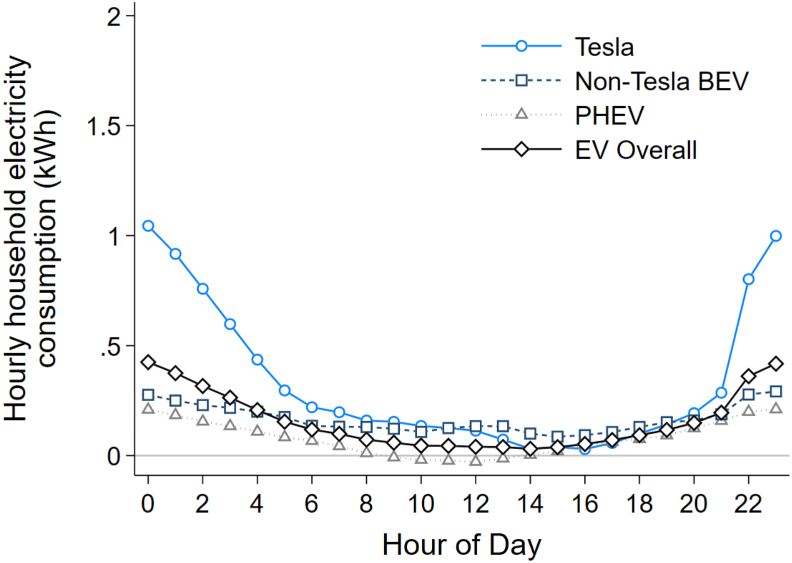
Charging takes place during disproportionately dirty times



As expected, BEVs use more energy than PHEVs



Teslas charge substantially more (note the new Y axis!)



What does this imply for eVMT?

Our kWh of home charging is much lower than previous estimates

To translate to eVMT:

- Calculate home-charged eVMT with model-specific MPGe
- Assume 33% of charging happens away from home
  - More generous than CARB / LCFS (15% away-from-home)
- Assume PHEVs do no home charging $\rightarrow$ put all kWh into BEVs

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We estimate:
Teslas drive 7,500 - 11,500 eVMT per year
Non-Tesla BEVs drive 4,800 - 5,600 eVMT per year
PHEVs drive 2,700 eVMT per year
State average ICE vehicles (9,800 VMT)

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→ For EVs to drive as much as ICEs, need 2x as many unreported kWh as (heavily incentivized) reported kWh!

What explains low EV driving? We present hypotheses

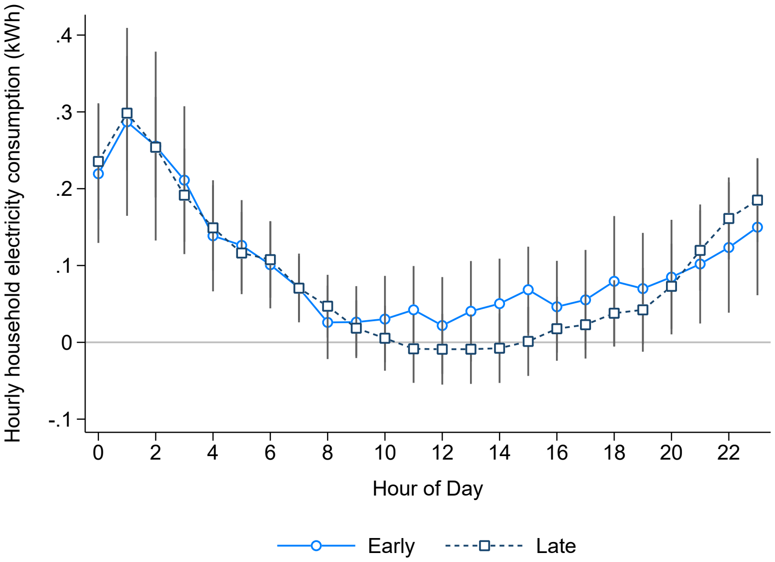
Today:

1. Missing away-from-home charging?
2. Are early adopters different from later adopters?
3. How dependent on geography is this?
4. Does battery capacity explain our effects?
5. Do EV drivers just drive less?
6. Are EVs are complements, rather than substitutes, for ICEs?

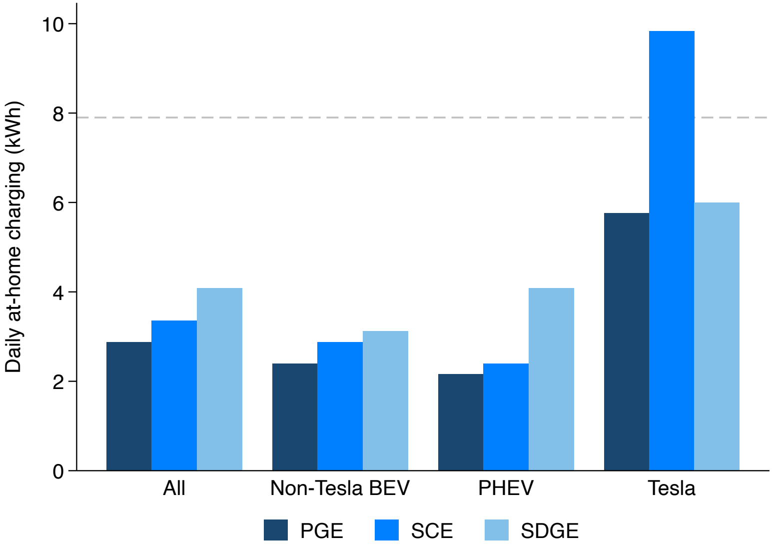
In progress:

- Are California's high electricity prices deterring driving?
- Are there other undesirable attributes of EVs?
  - Poor charging infrastructure; price; comfort; size; no trucks; etc

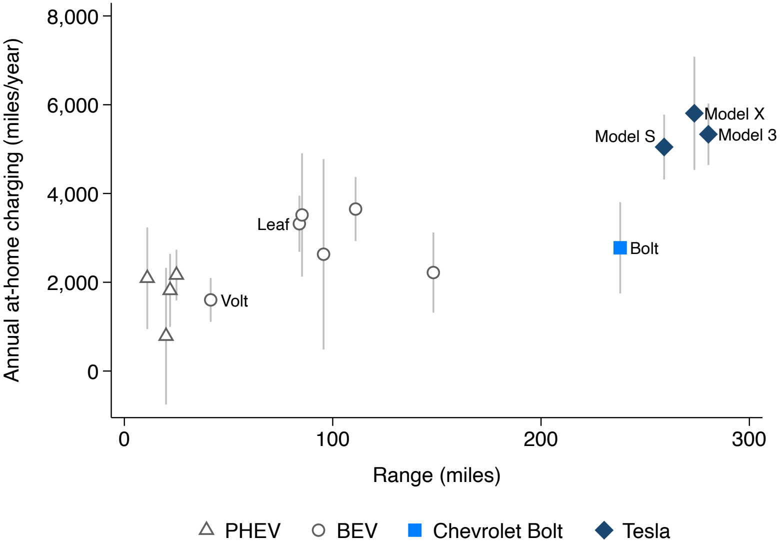
Are things changing quickly? Maybe not



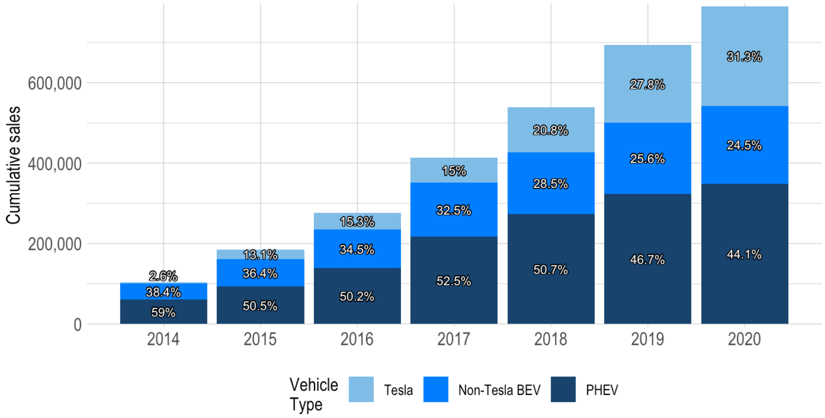
Southern Californian EVs drive more, but not that much



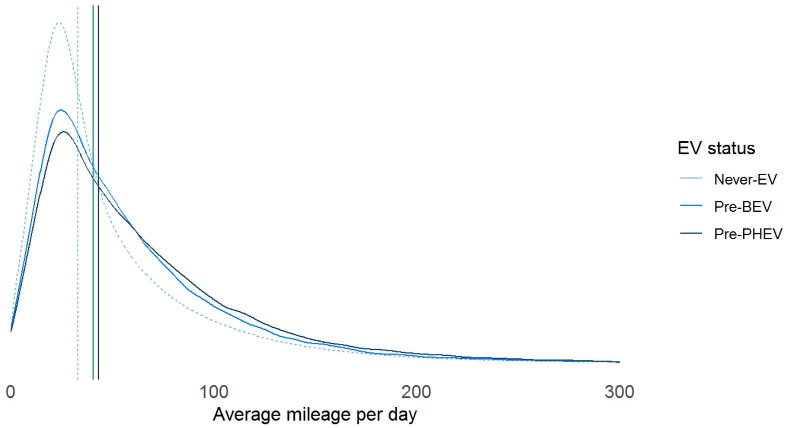
Not fully explained by range; Teslas exceptional



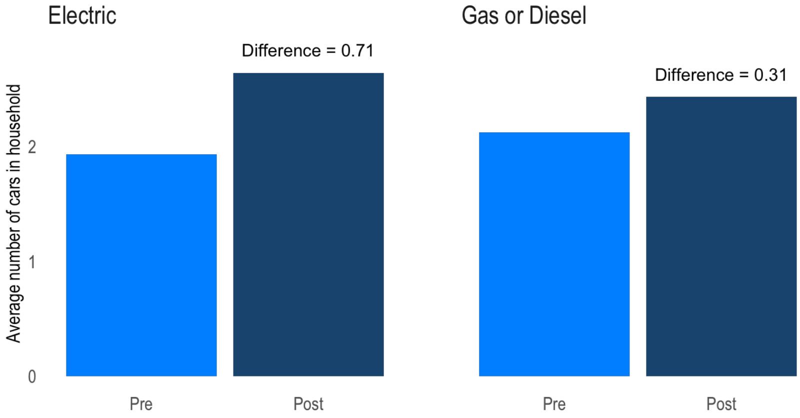
While Tesla market share rises, PHEVs remain very popular



Do EV drivers just drive less? We don't think so



EVs are additional cars, not substitutes



Summary: We estimate low EV driving

We show:

- EVs are additional cars, not substitutes

We provide evidence against:

- Early adopter effects
- Selection into EVs based on low VMT

Further evidence is required on:

- Battery size effects
- The role of electricity prices
- Hundreds of millions of mysterious unreported out-of-home kWh??
- Others?

We're making policy with limited evidence. We need more research!

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Thank you!
Comments? Questions?
burlig@uchicago.edu