Cars of the future, today?

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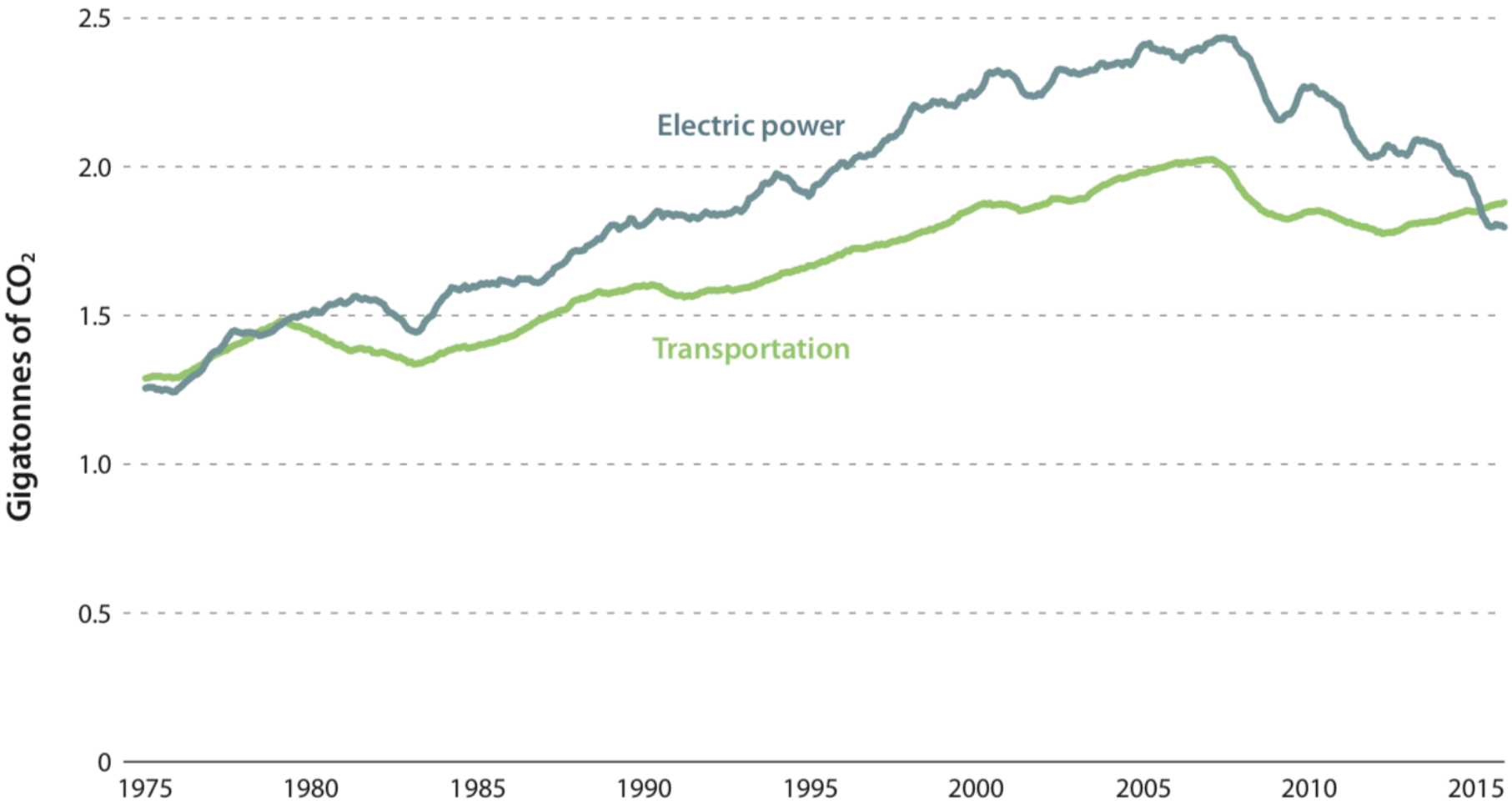
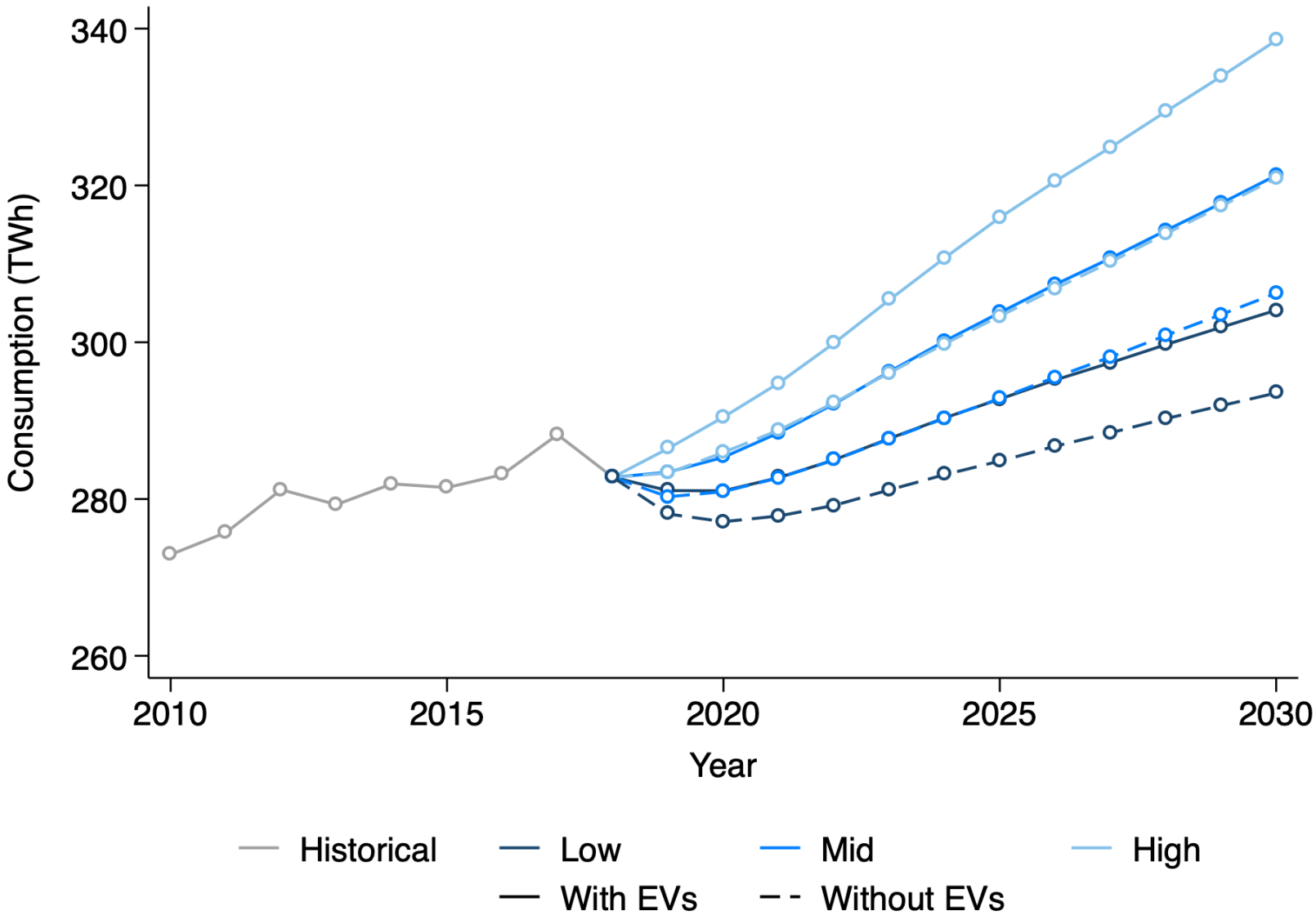
NBER Energy Use in Transportation
June 11, 2020

Transportation emissions are large and growing



Vehicle electrification could transform energy use



We provide new empirical evidence on EV electricity use

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

This question is:

- *Important for policy:* climate; grid planning; local pollution
- *Difficult to answer:* Existing data are very limited
- *Scratching the surface:* Potential for new energy economics questions

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.

Regulators use $\approx$ 500 highly-selected meters to approximate state-wide EV use (cash at stake!)

We overcome previous hurdles with restricted-access data

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

Utility data

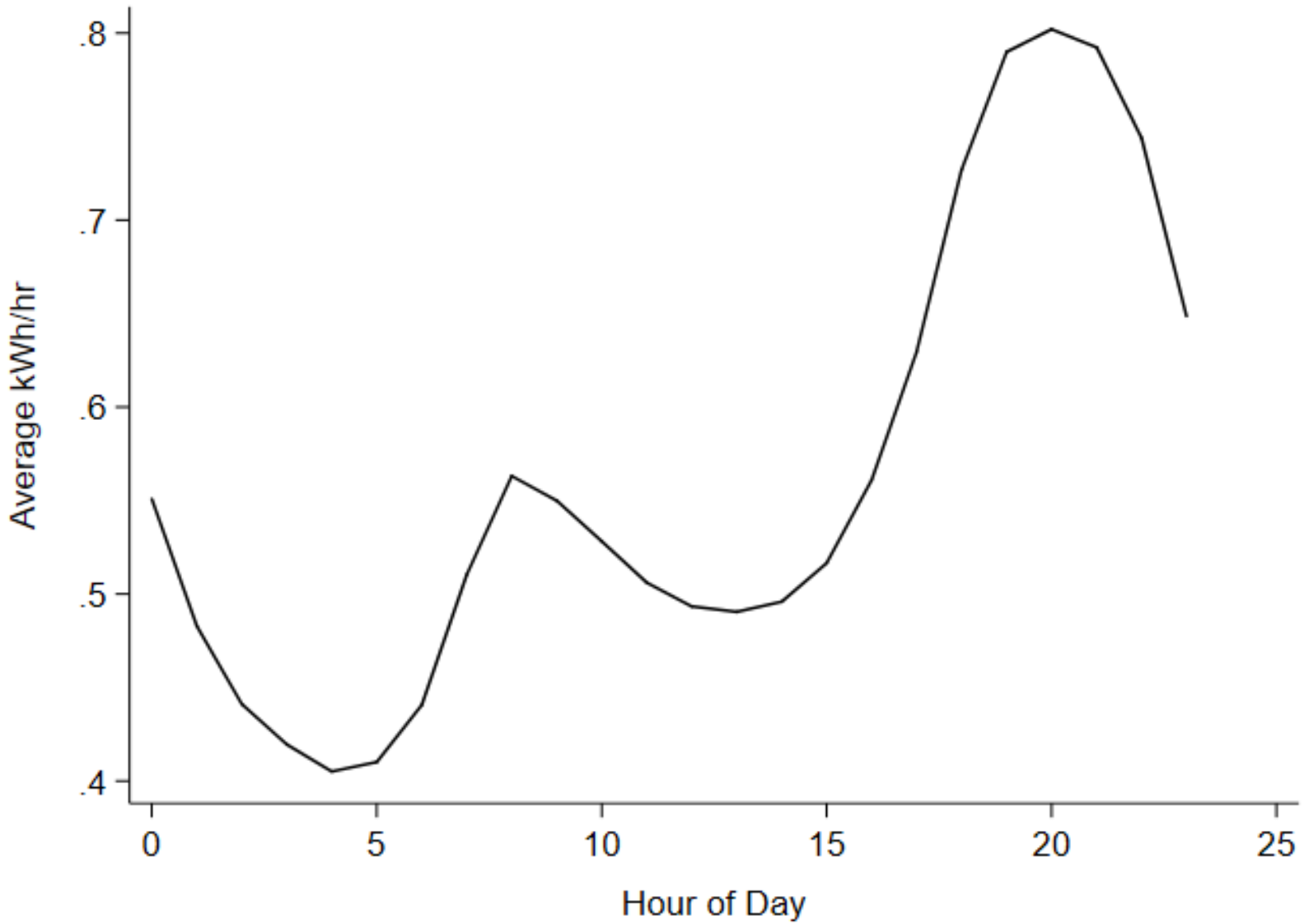
- 10% of each IOU (sample designed to target high-EV areas)
- Data from 2014 – 2018(ish)
- Over 1.7 billion hourly electricity use observations
- Customer details, including address and tariff

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

$\rightarrow$ We match cars to households on address

We overcome previous hurdles with restricted-access data



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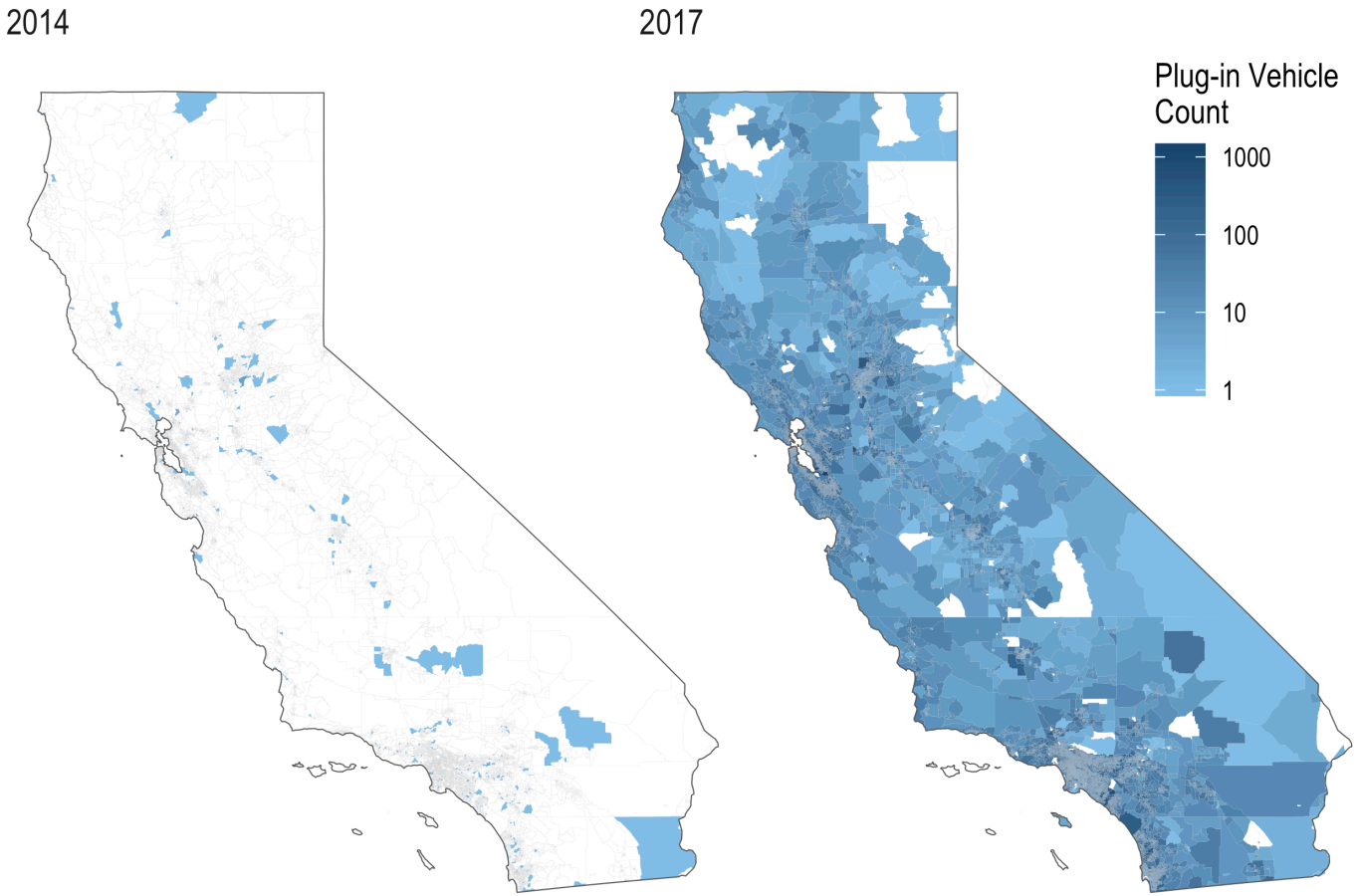

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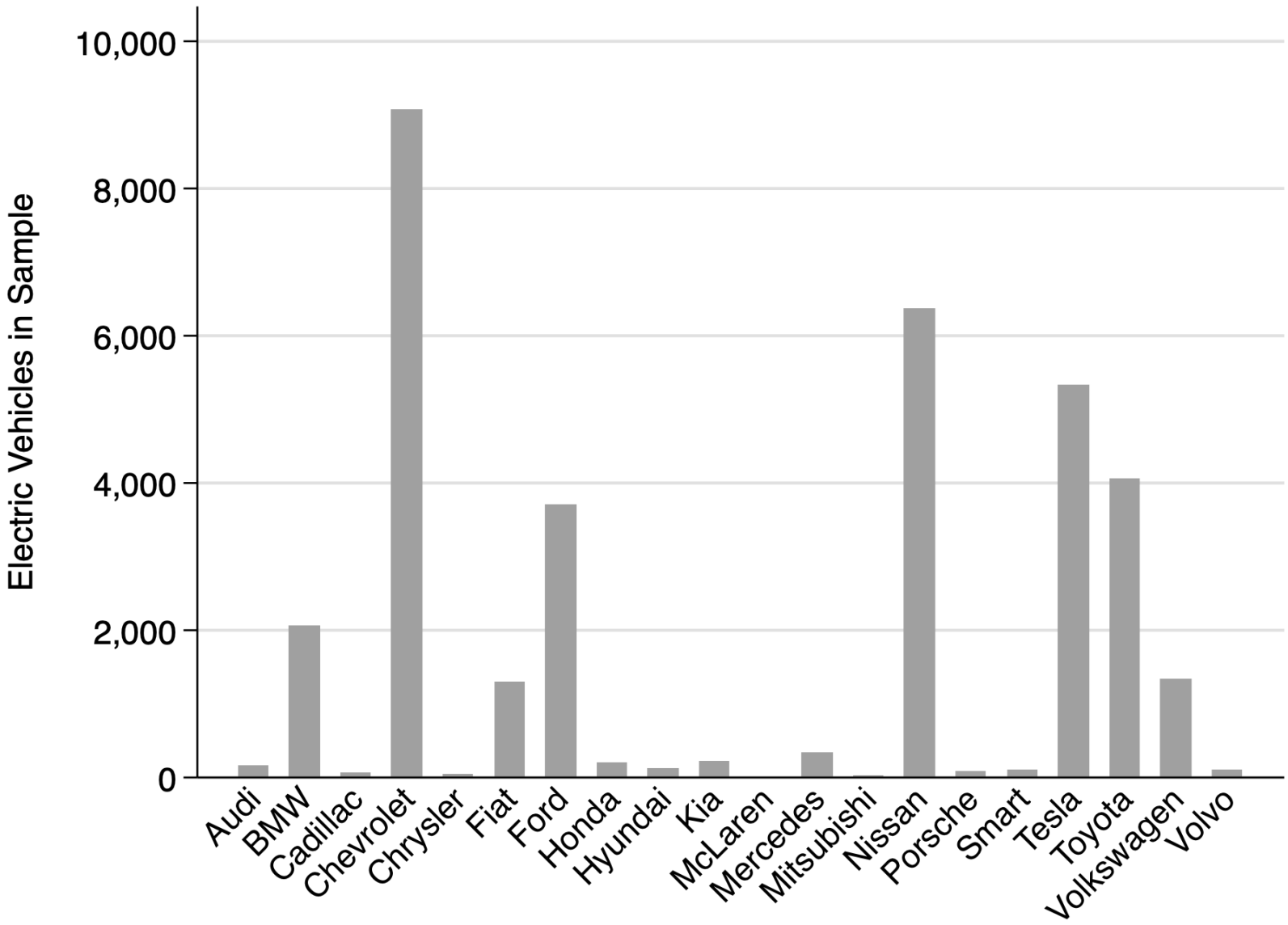


We employ a panel fixed effects research design

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

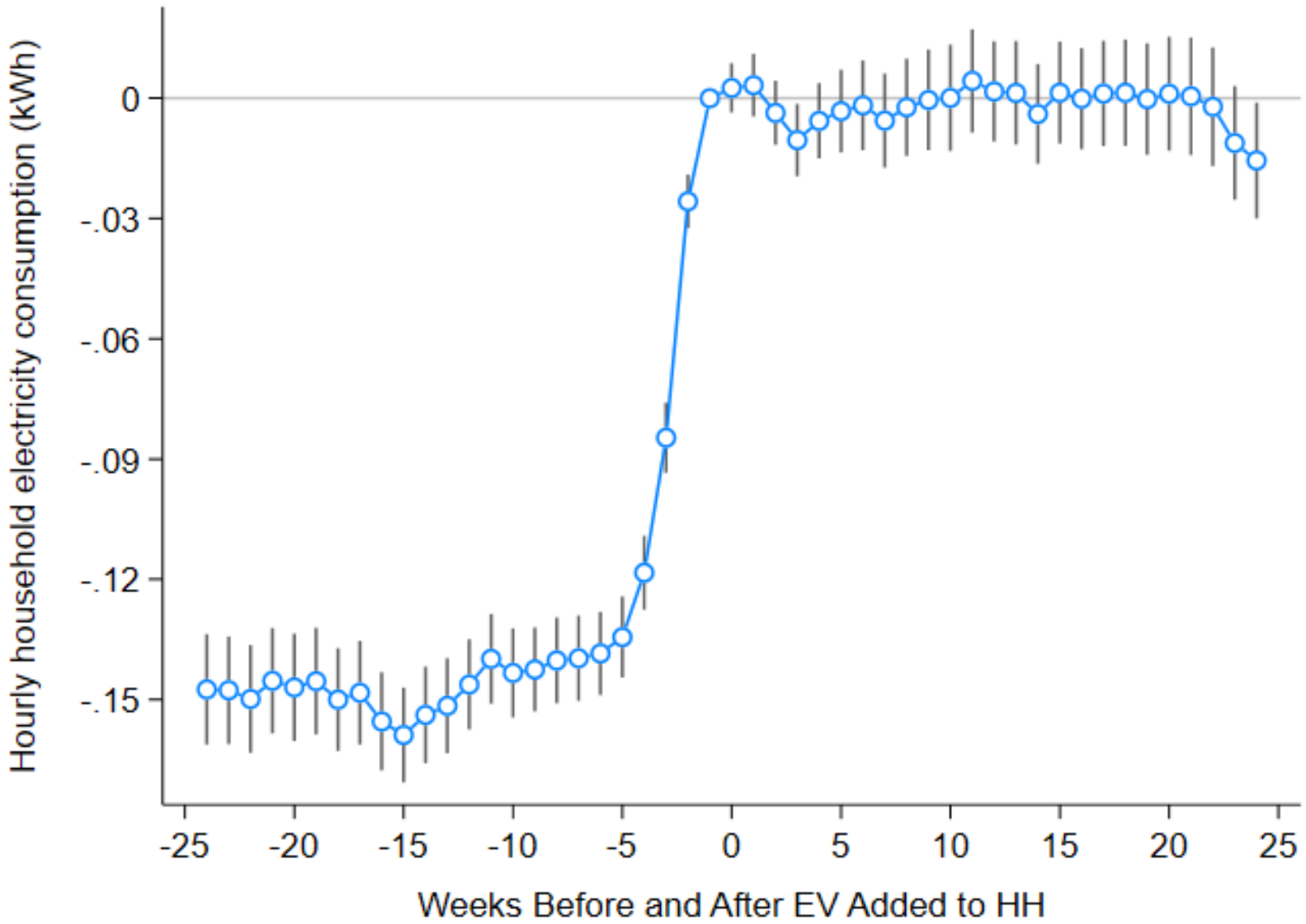
$$Y_{ith} = \beta EV_{it} + \gamma Solar_{it} + \alpha_i + \delta_t + \varepsilon_{ith}$$

where:

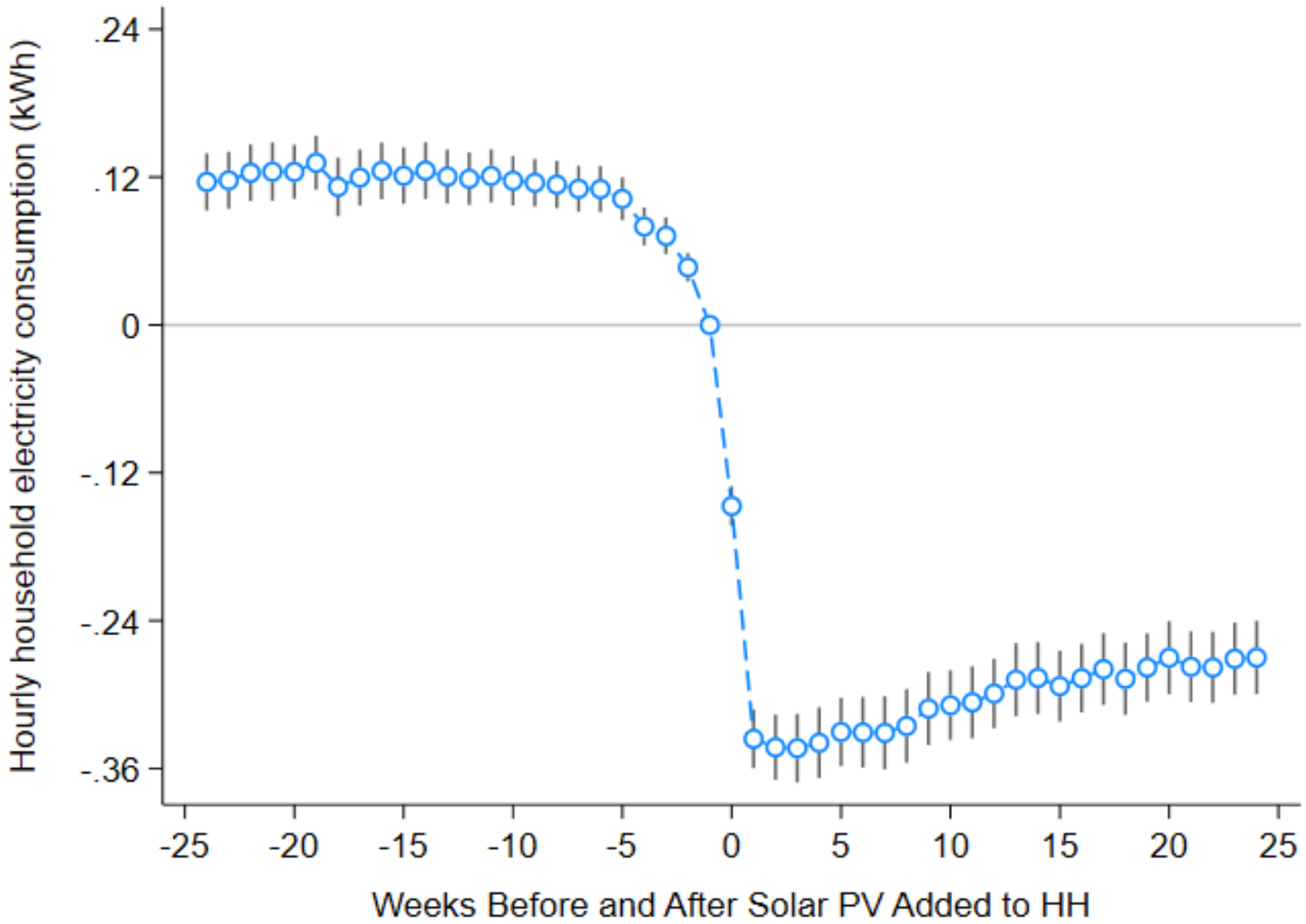
- Y_{ith} is kWh/hr at household i in week t in hour-of-day h
- EV_{it} is the count of EVs
- $Solar_{it}$ is a solar indicator
- α_i are household FE (can be more flexible)
- δ_t are week-of-sample FE (can be more flexible)
- ε_{ith} is an error term, two-way clustered at CBG and week-of-sample

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

Event study estimates of the impacts of EV adoption



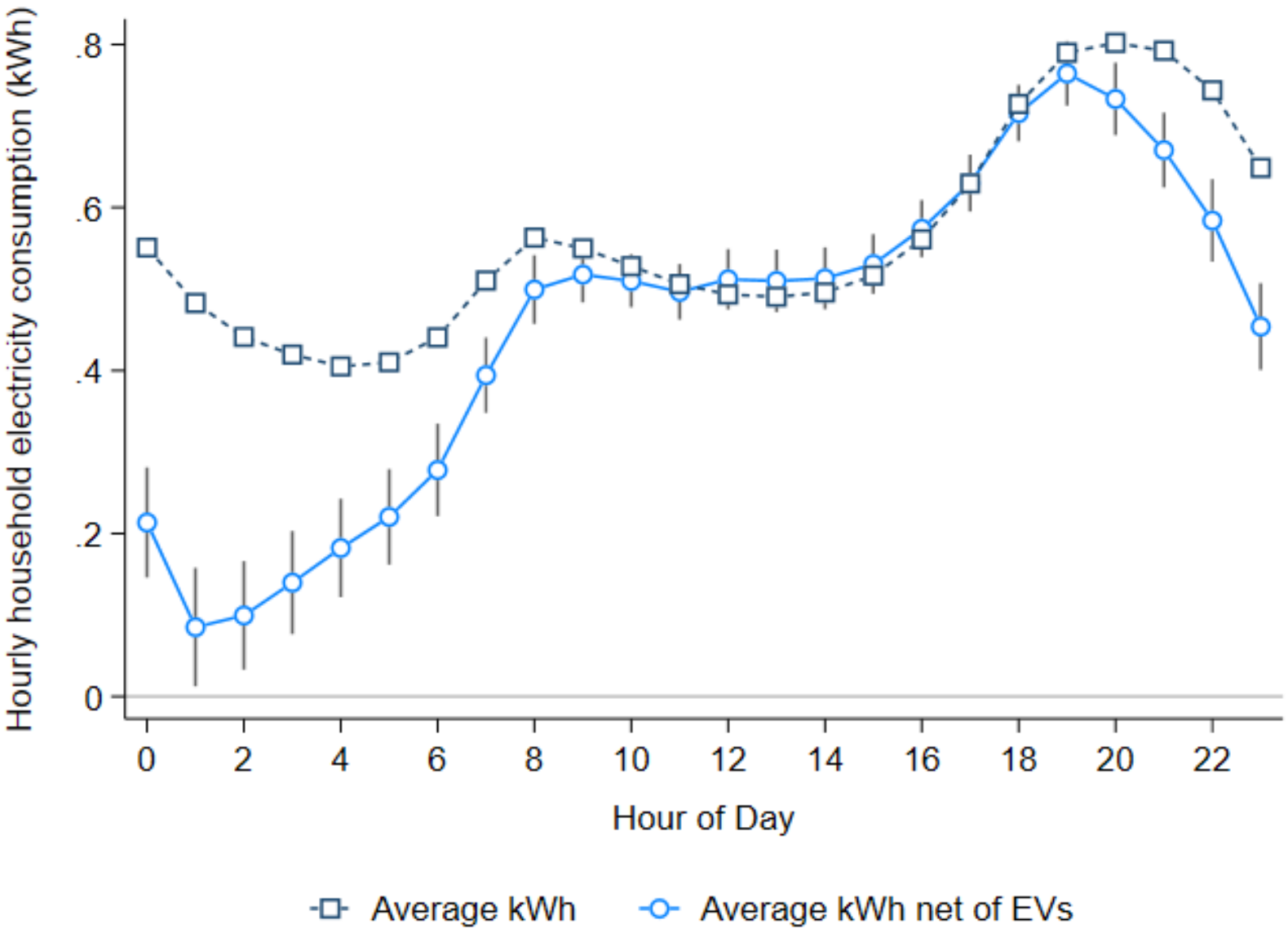
(Bonus! Solar adoption event study estimates)



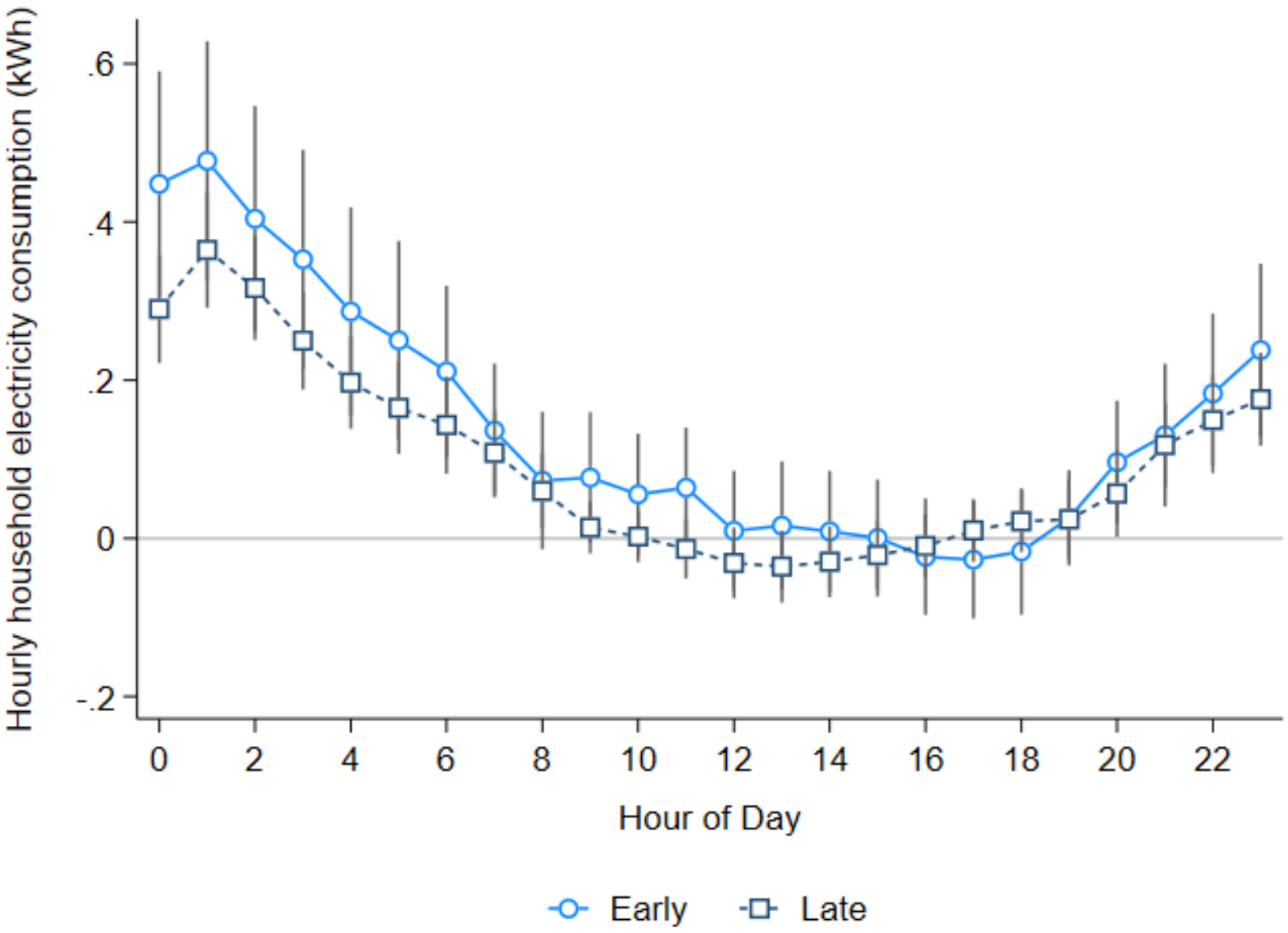
These estimates are robust to varying controls

	kWh/hr	kWh/hr	kWh/hr	kWh/hr	kWh/hr
EV Post	0.12***	0.12***	0.10***	0.15***	0.15***
	(0.02)	(0.02)	(0.02)	(0.01)	(0.03)
Solar Post	-0.48***	-0.43***	-0.53***	-0.36***	-0.41***
	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)
HH FEs	Yes	No	No	No	No
HHxYear FEs	No	Yes	No	Yes	Yes
HHxMofY FEs	No	Yes	Yes	No	Yes
Week-of-Sample FEs	No	No	Yes	Yes	Yes
Observations	70,051,861	70,044,099	70,044,209	70,051,762	70,044,099

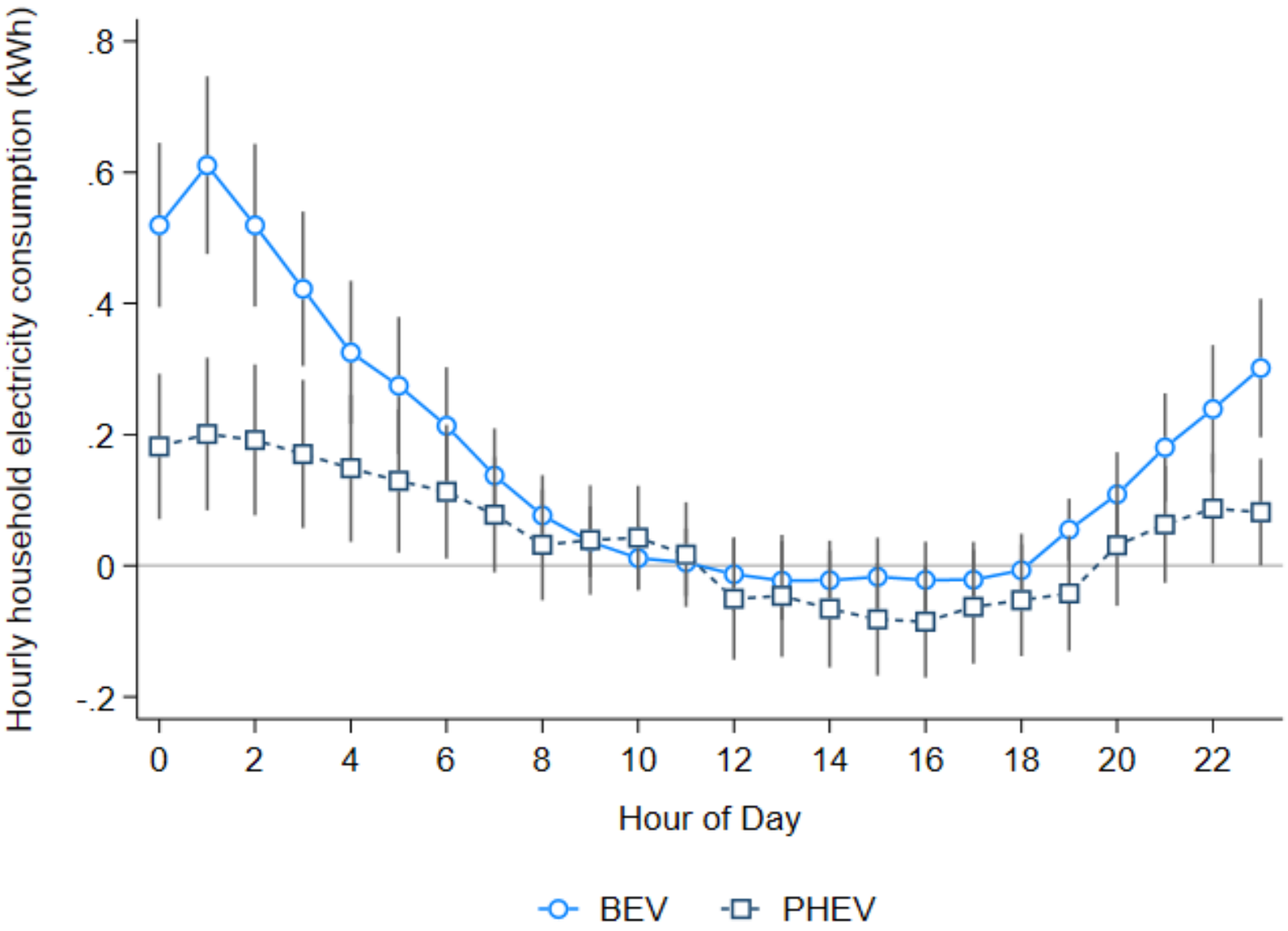
Cars charge disproportionately at night



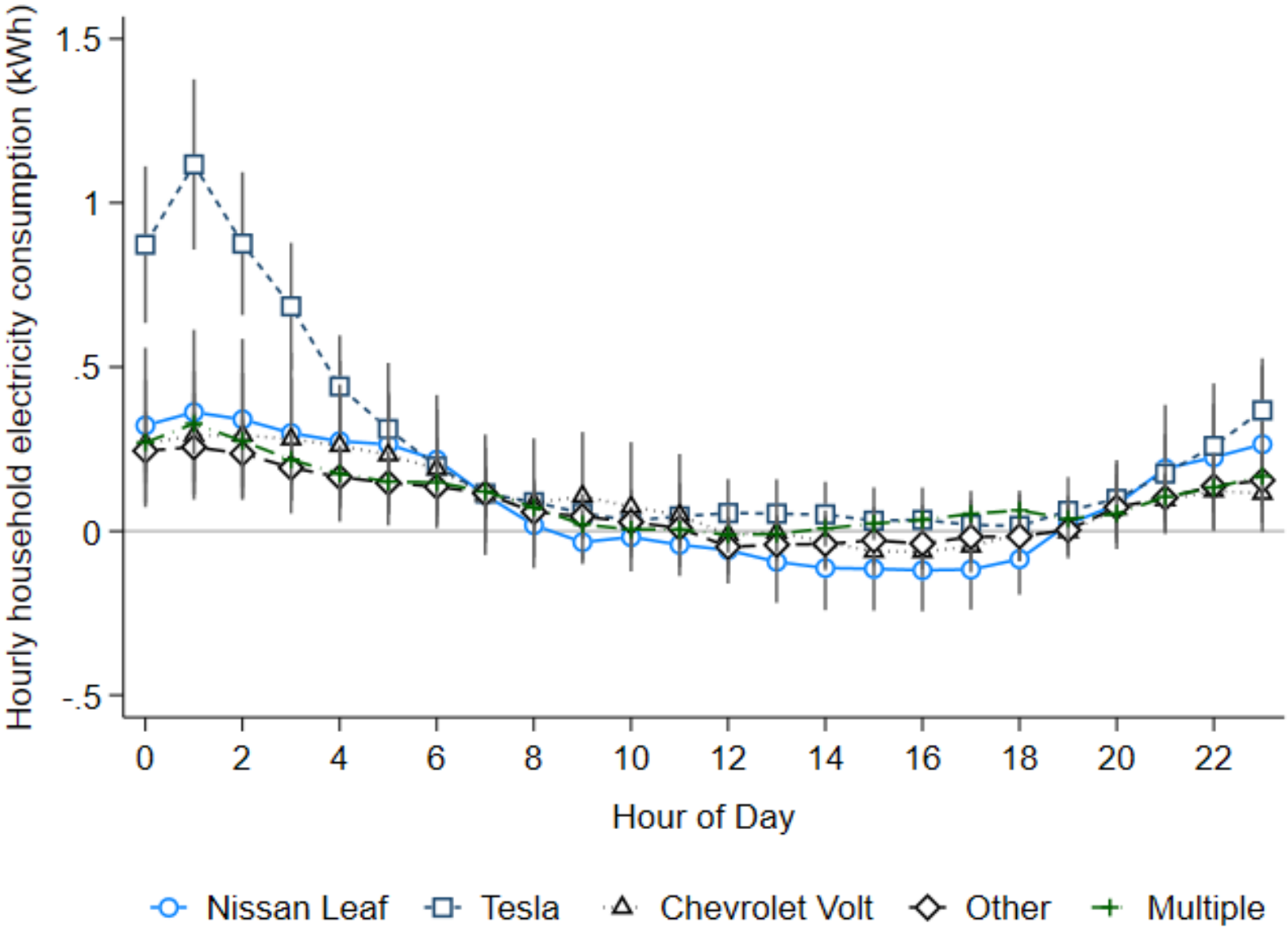
Early and late adopters have similar treatment effects



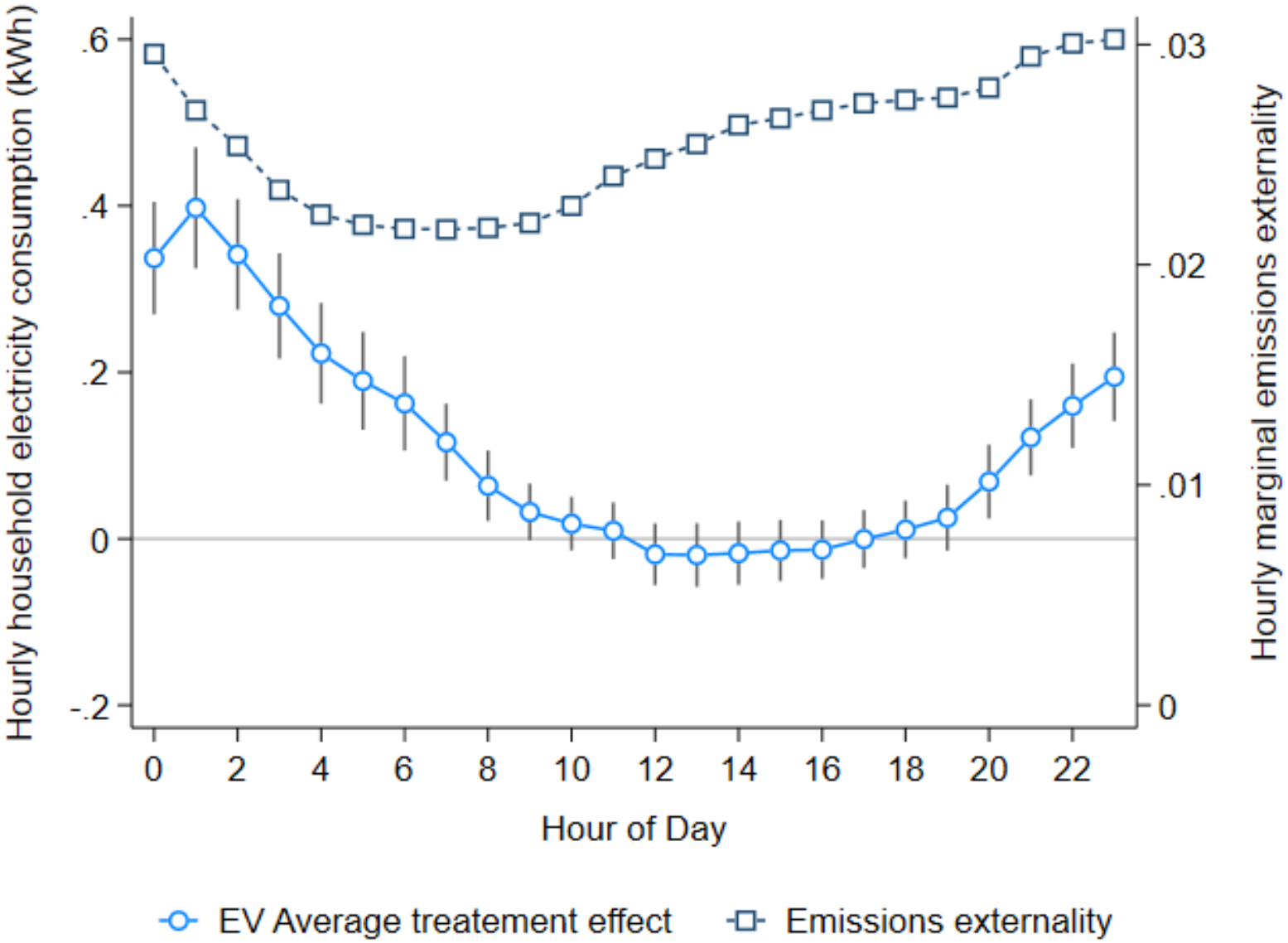
BEVs use more energy than PHEVs



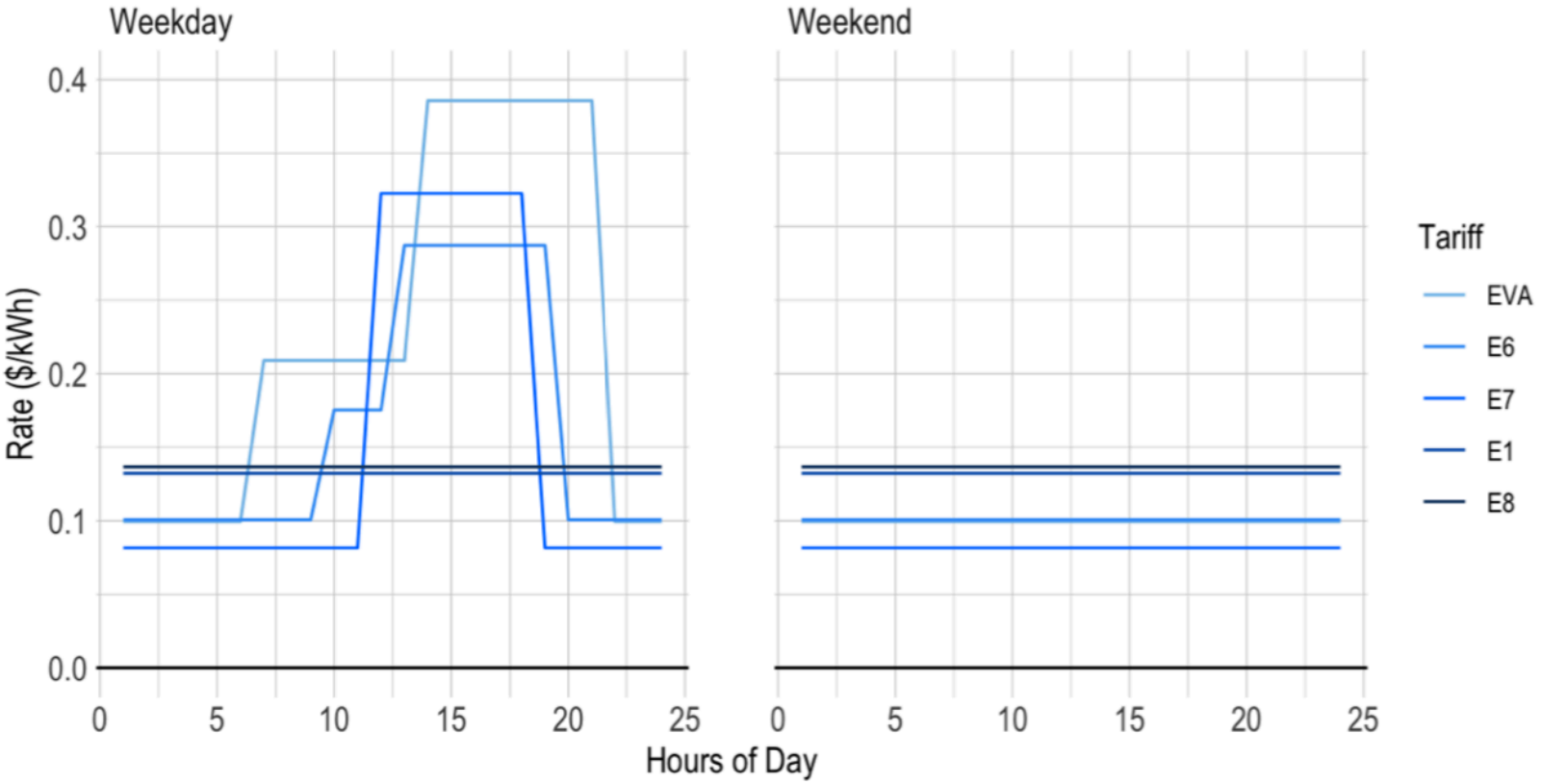
Teslas are power guzzlers (note the new Y axis!)



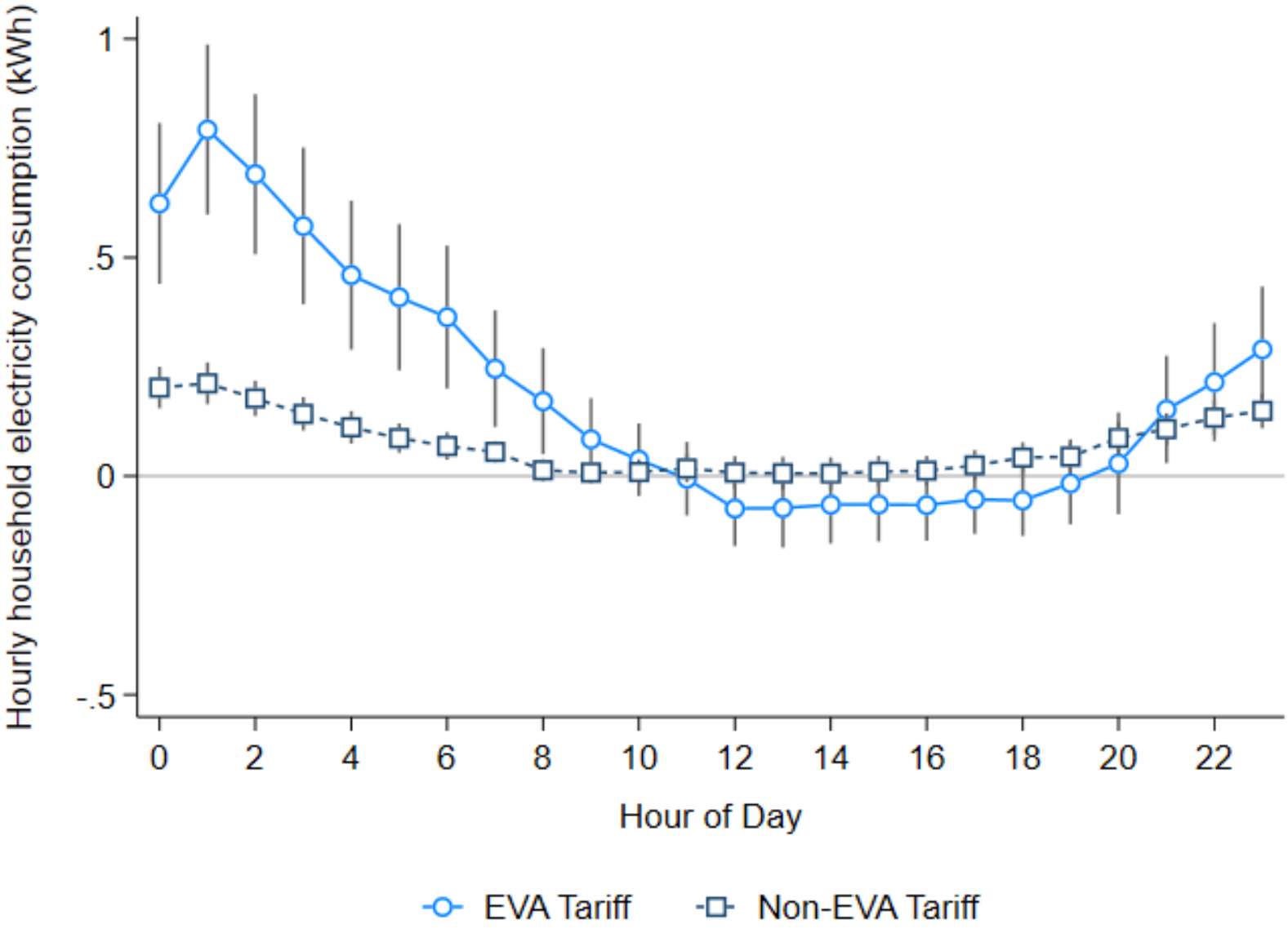
Charging takes place during disproportionately dirty times



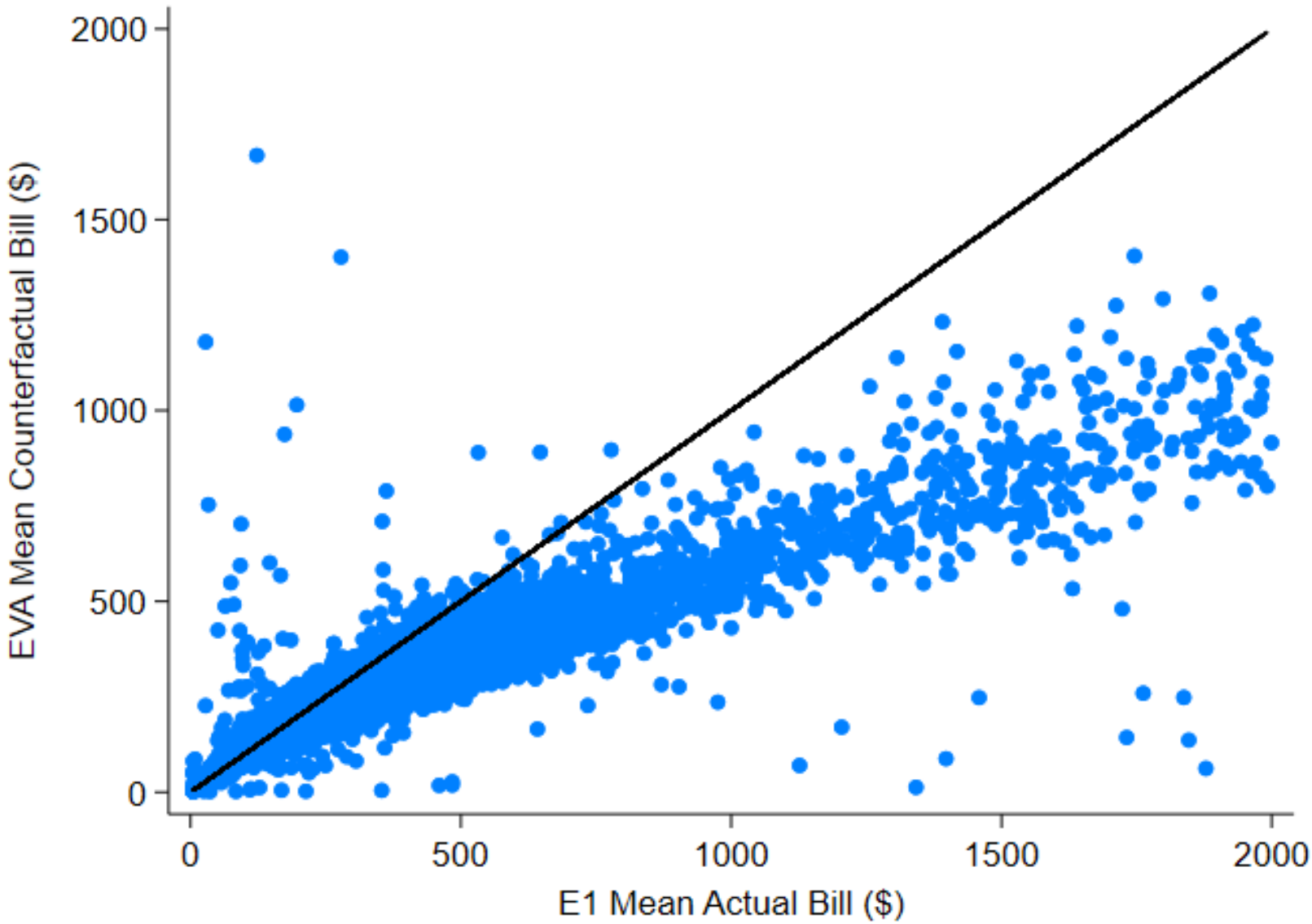
Can prices play a role in shaping charging patterns?



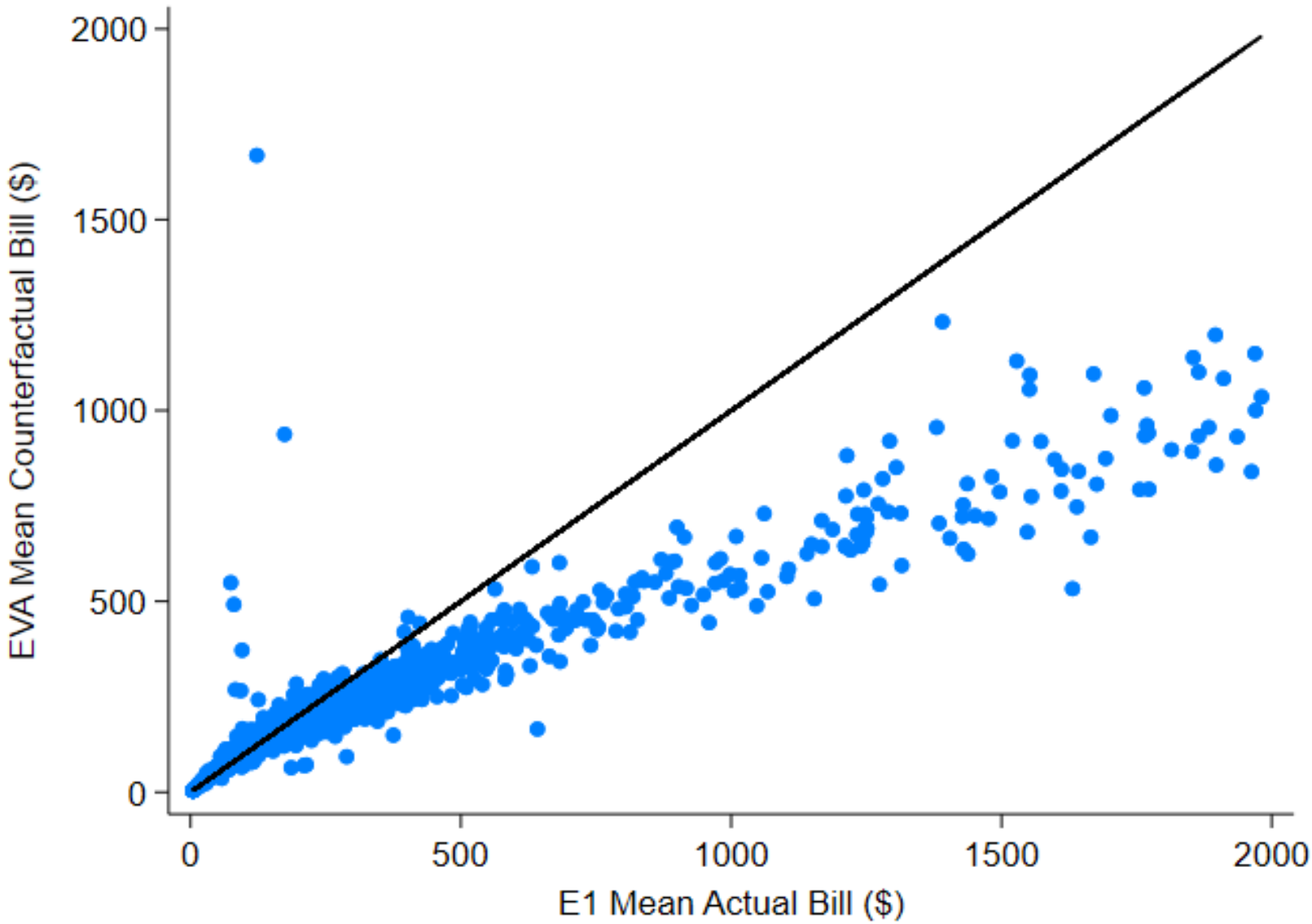
There appears to be selection into the EV tariff



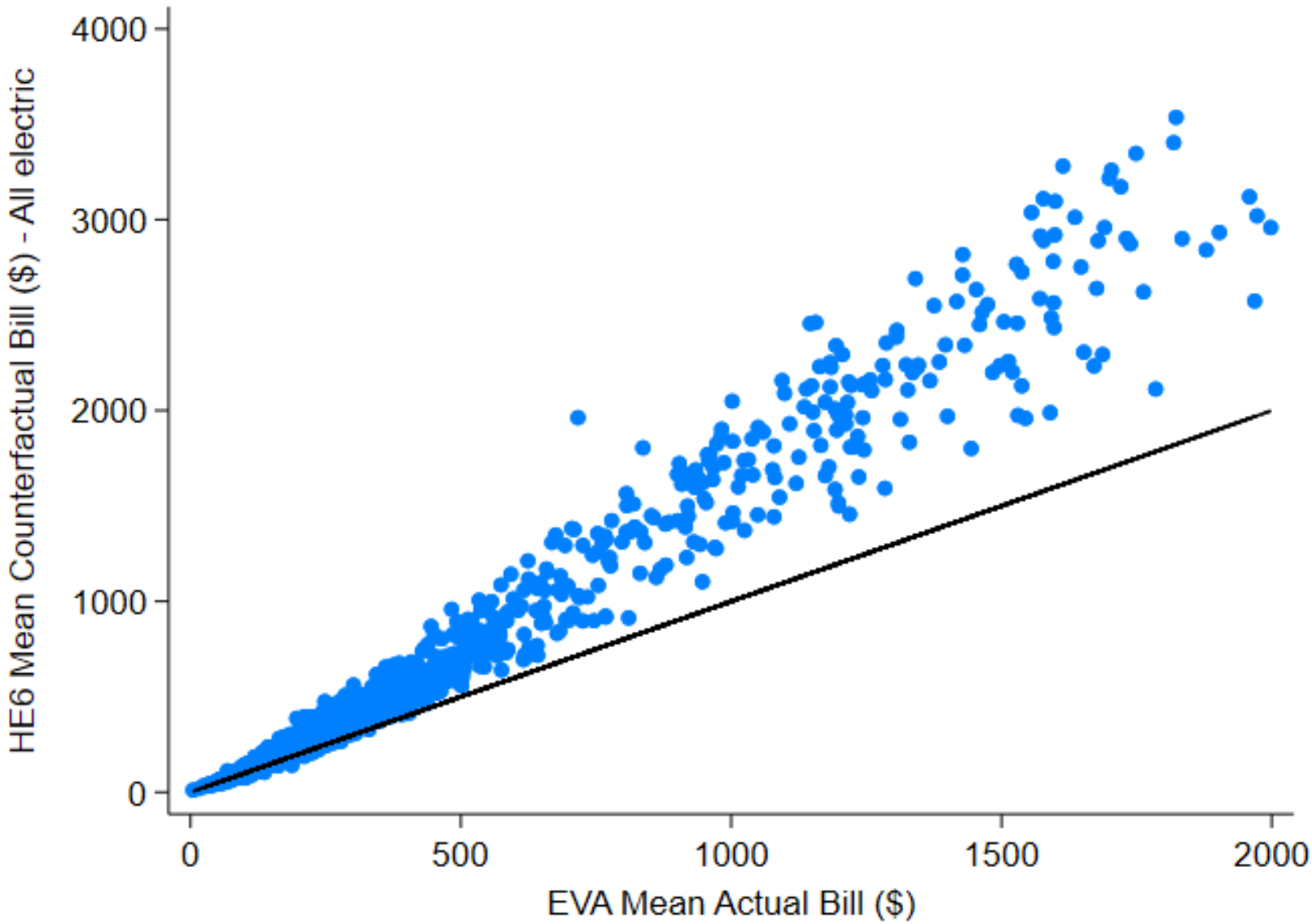
Many households would do better on the EV tariff



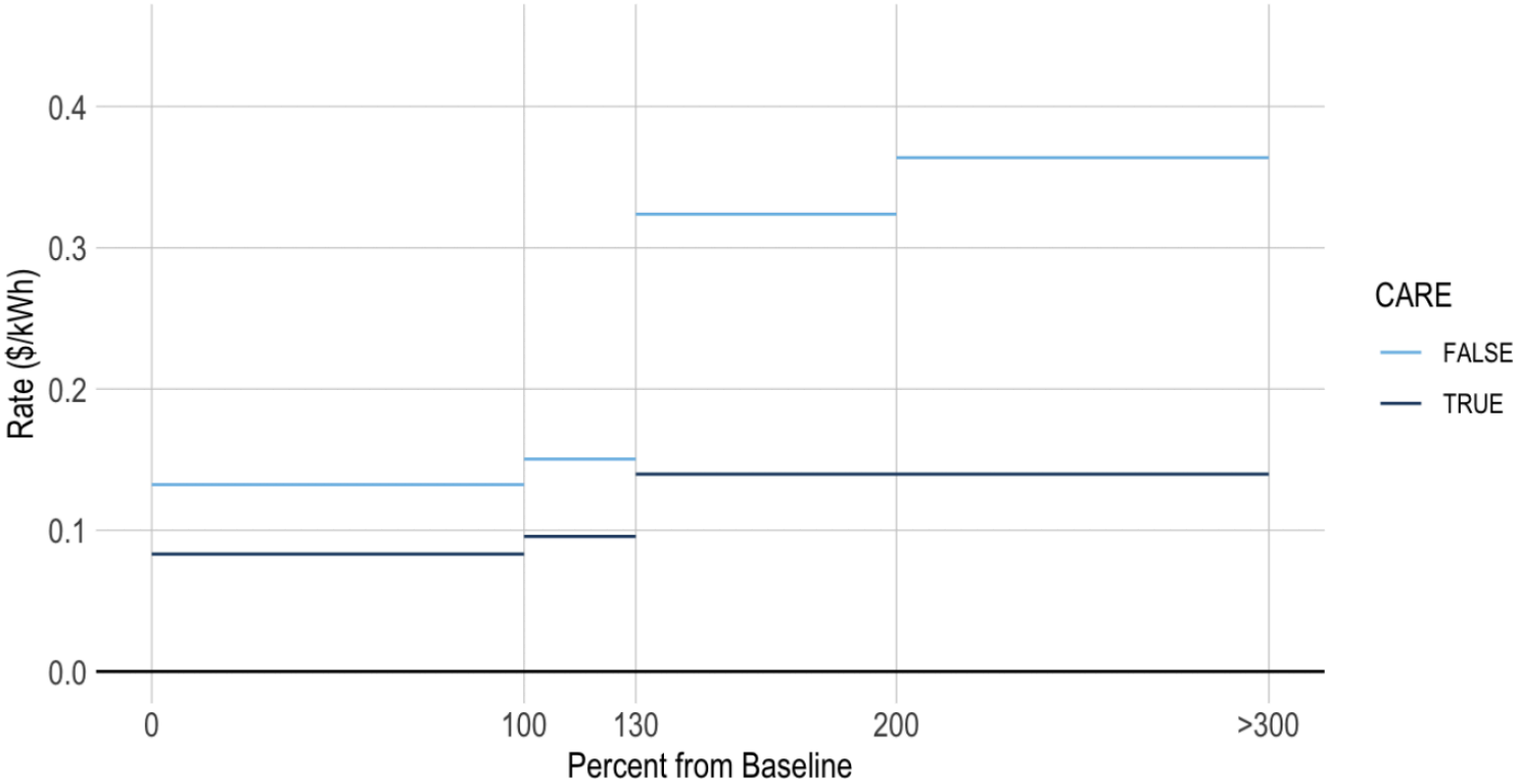
Even many who own EVs!



Households already on EVA do worse on TOU



There is variation in electricity pricing we will use



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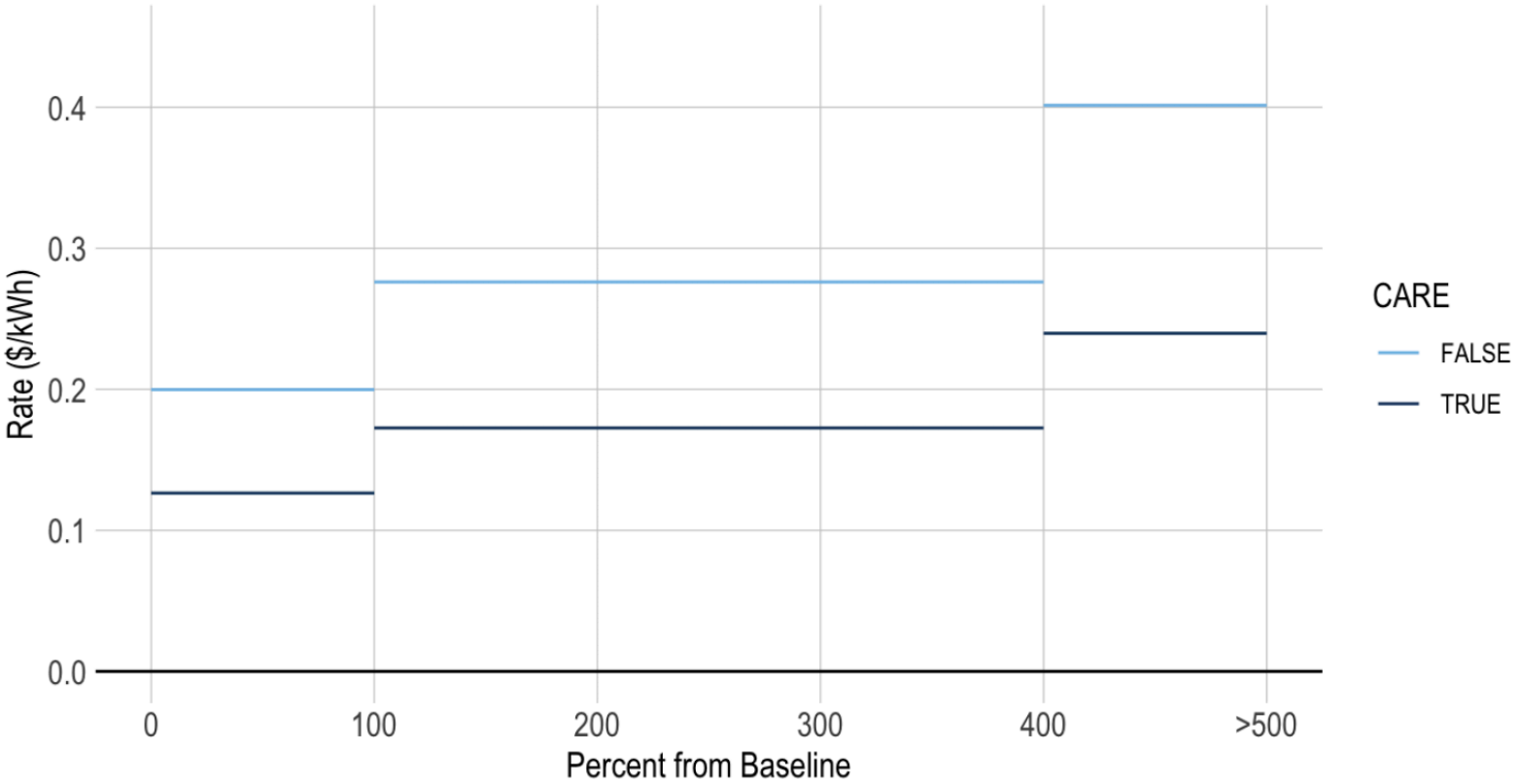

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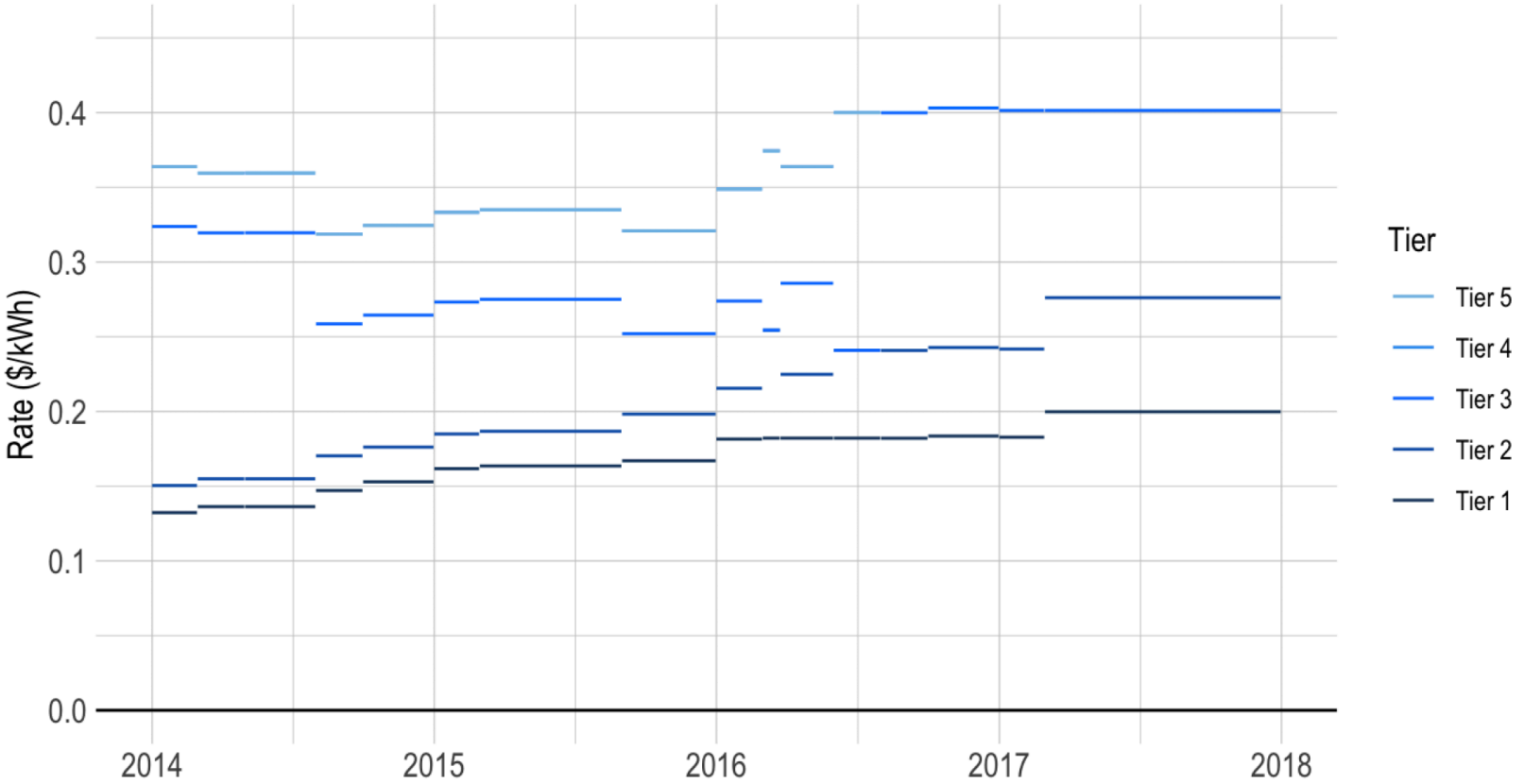

We are scratching the surface: lots more to do!

So far:

- Assembled a novel dataset on EV adoption and electricity use
- Reduced form evidence on EV load (1/2 of state estimates)
- Charging happens at night (high marginal emissions)
- Heterogeneity by car type; not much else

In the works:

- Selection into different tariffs (+ solar)
- Price elasticity of charging (times)
- Others?

Thank you!
Questions? Comments?
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