RESOURCES for the FUTURE

How Do Residential Greenhouse Gas Technologies Affect Electricity Prices and Consumer Welfare?

Josh Linn, University of Maryland and Resources for the Future

(with Zeyang Dong, Jing Liang, and Lucy Qiu)

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Context

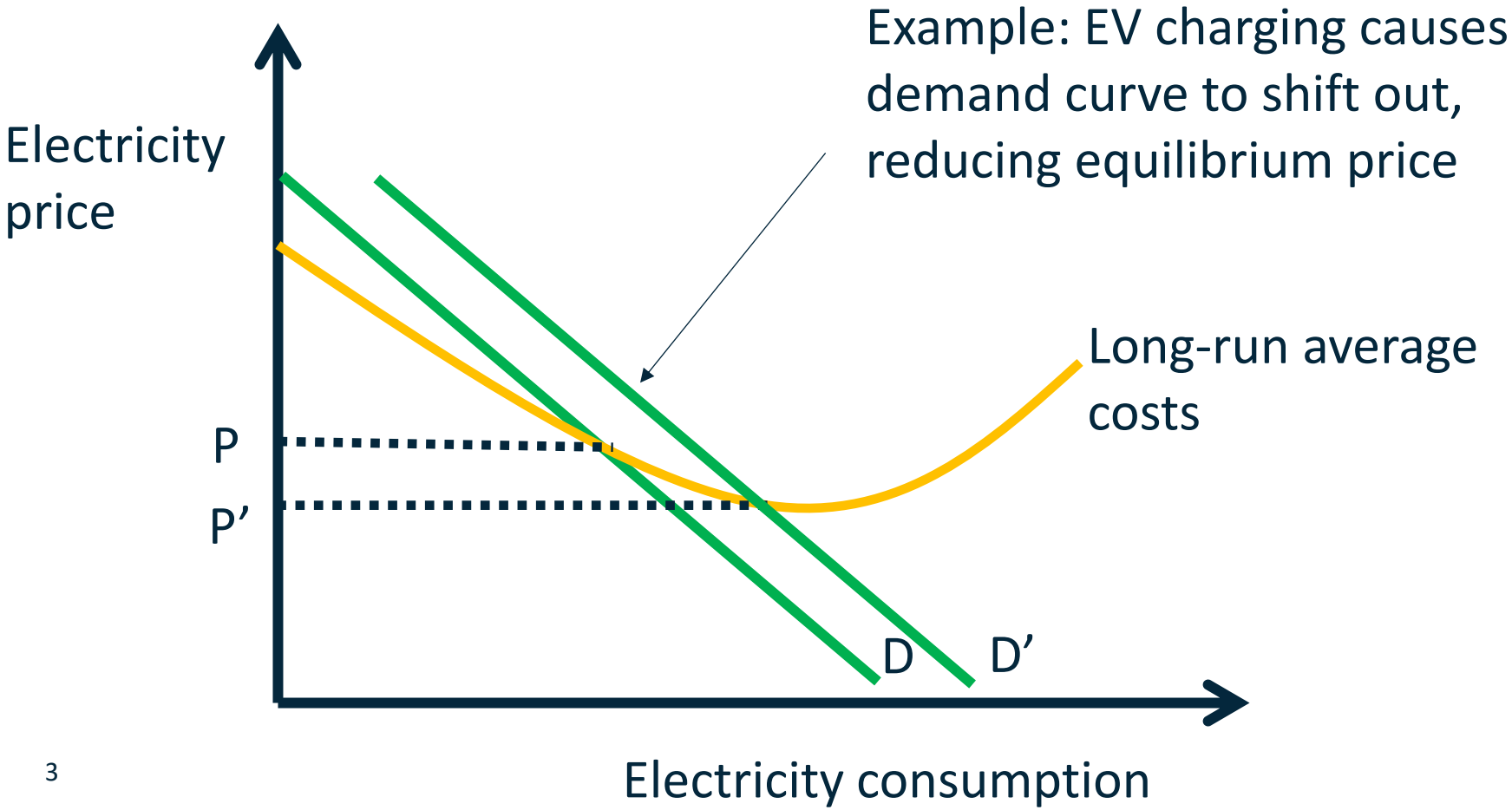
Adopting many residential GHG mitigation technologies affects aggregate household electricity demand

- Positively: heat pumps or electric vehicles
- Negatively: energy efficiency or rooftop solar, building codes, or appliance standards

Most analysis of policies that promote such technologies considers welfare effects of participants

- Compare participants with a valid control group (selection bias, etc.)
- Evaluate private and social welfare changes

These policies will also affect equilibrium retail prices (as we learn in undergraduate micro)



How do technologies affect non-adopting households?

It depends on whether we're on the upward or downward-sloping portion of the average cost curve

- Consider a time period in which fixed/sunk costs have been paid
- Technologies that increase electricity demand cause average price to increase if the variable cost curve is sufficiently steep (higher average variable costs outweigh lower fixed costs)

Outline of the paper

- Estimate effects of electricity demand on average prices using EIA utility-level data and instrumenting for demand
- For comparison, simulate demand changes using electricity sector model
- Simulate welfare changes using household survey data and hypothetical policy changes

How does residential consumption affect average retail prices?

Estimation strategy

- Assume technology adoption affects average prices via aggregate demand
- How do demand-drive consumption changes affect average prices?

Estimation equation

$$\ln(\mathrm{P}_{ist}) = \beta_0 + \beta_1 \ln(\widehat{RS}_{it}) + \beta_2 \ln(\mathrm{PF}_{st}) + \delta_t + \alpha_{is} + \varepsilon_{ist}$$

- Dependent variable is ratio of revenue ($) to sales (kWh), by utility-state-year
- Use heating and cooling degree days to instrument for residential sales
- Control for average fuel prices

Data and main estimates

Data

- EIA 861, utility-state-year residential revenue and sales, 1990-2022
- Average heating and cooling degree days, fuel price, and industrial employment by state and year

Results

- Elasticity of average price to consumption about -0.4
- Other results: control for industrial demand, heterogeneity by interconnection or utility type, competition

Alternative approach: generator simulation

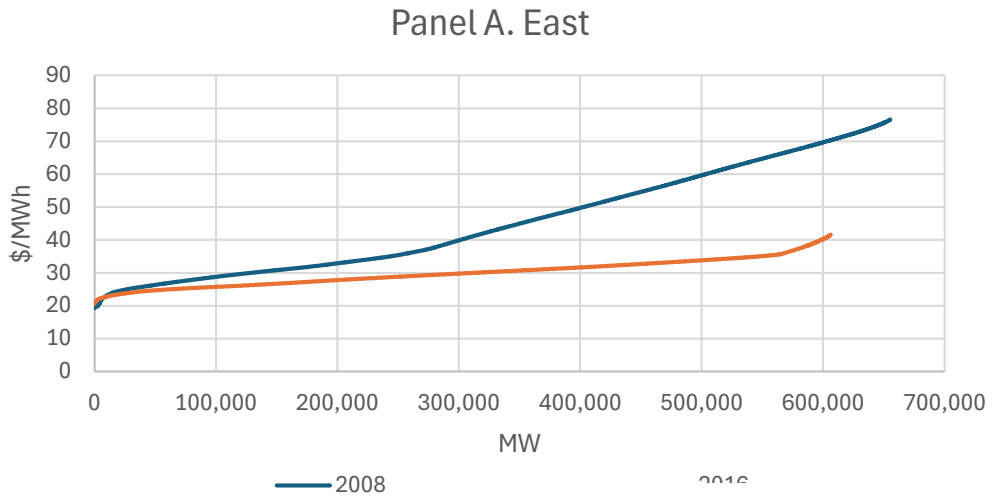
Simulation model

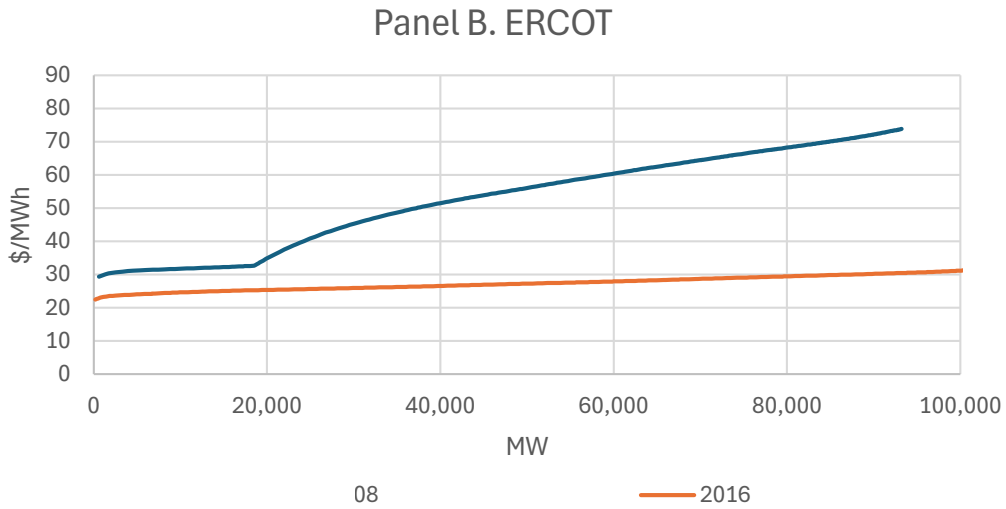
- Extension of Linn and McCormack (2019)
- Simulate hourly generator operation given interconnection-level aggregate demand
- Include reduced-form approach to incorporate startup and ramping costs and transmission constraints

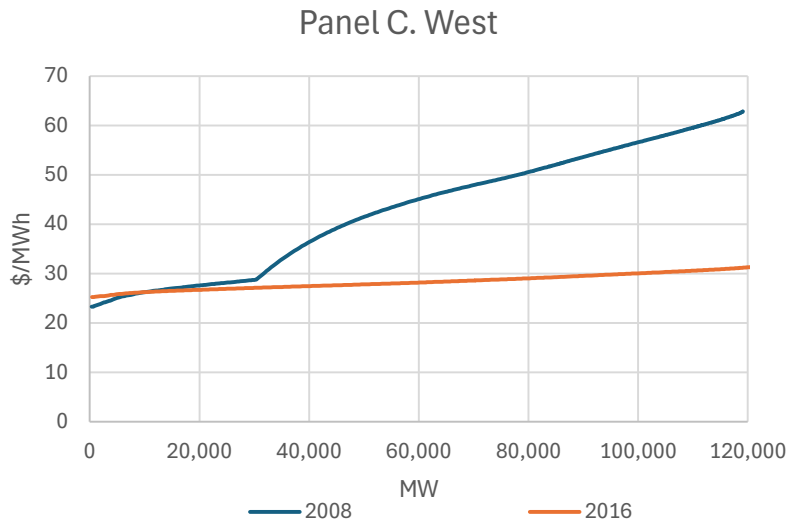
Comparison with econometrics

- Can directly model demand changes caused by technology adoption
- Requires assumptions on market structure and costs

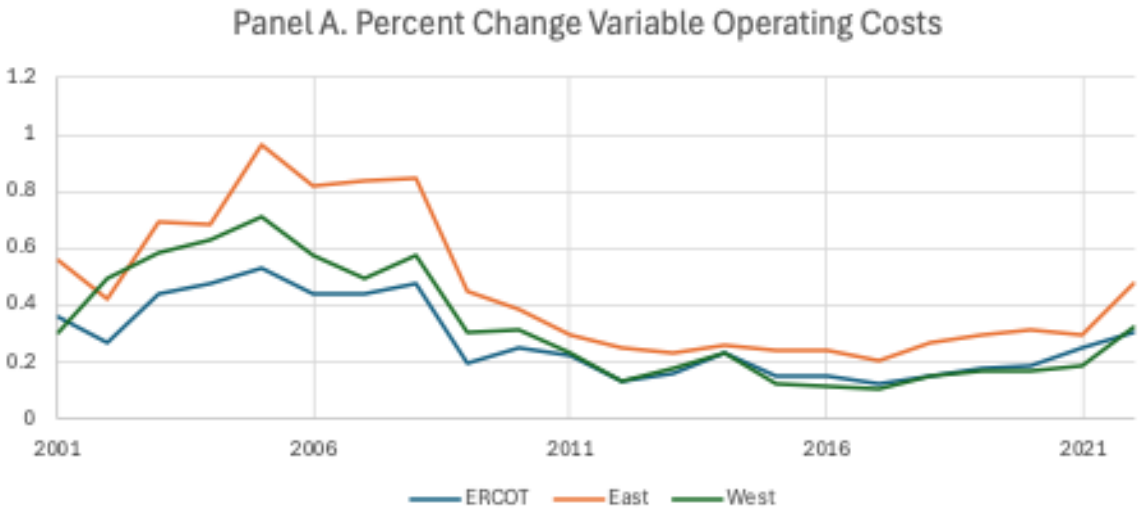
Lower natural gas price have flattened average variable cost curves

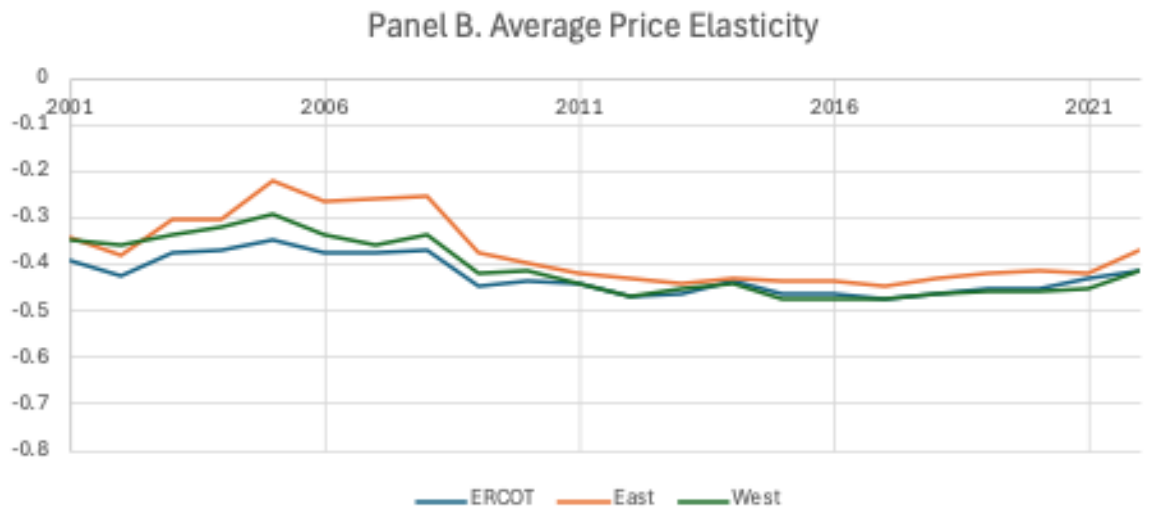






Simulation results for 1-percent demand increase





How does technology adoption affect electricity bills of non-adopters?

Setup

- Household-level data from 2020 Residential Energy Consumption Survey (RECS)
- Estimate change in average retail price caused by installing rooftop solar or buying EVs
- Convert to bill change for each household, depending on whether retailer adjusts fixed charge or variable rate

Key assumptions

- Electricity generation by rooftop solar and EV miles traveled
- Two-part tariff based on utility rate plans

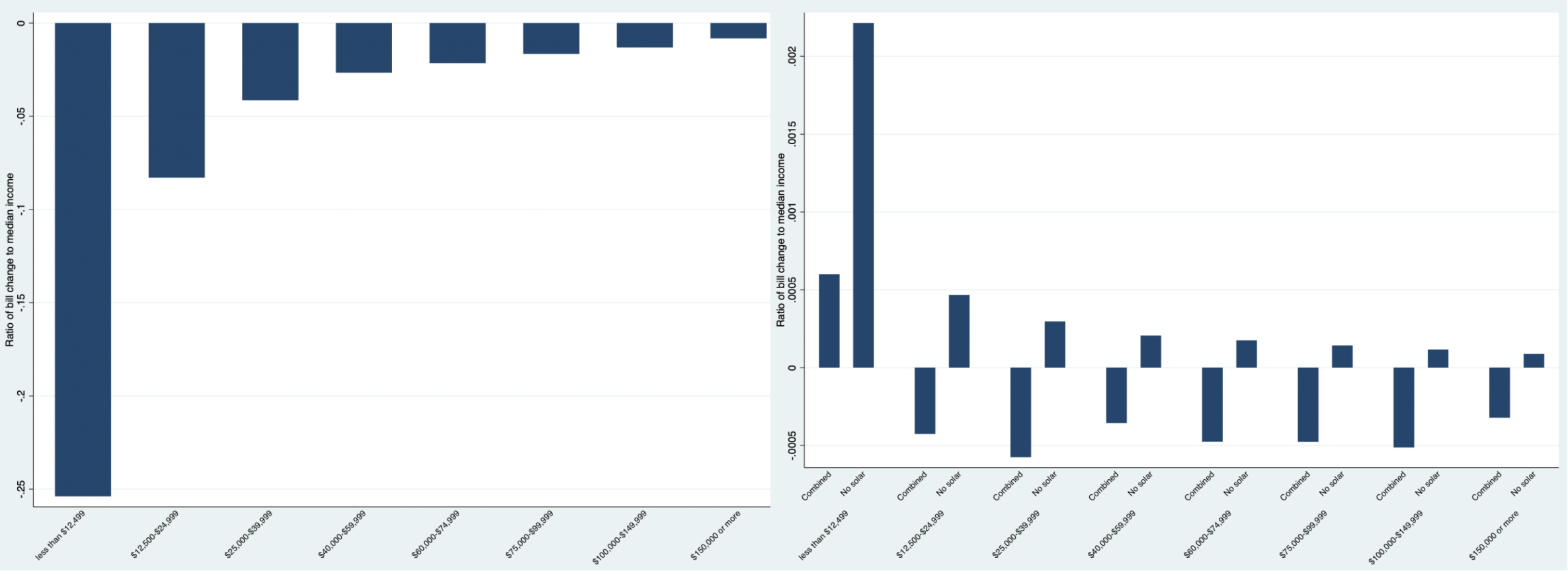
RECS summary statistics

Income Group	Total Customers (Million)	Annual electricity cons (Mwh)	Annual electricity exp ($)	Ratio of electricity exp to median income (%)	Rooftop solar adoption (%)	EV ownership (%)	Energy-consuming area (1000 sq ft)	Estimated fixed charge	Estimated variable rate
less than $12,499	11.71	8.51	1113	13.25	0.63	0.51	1.15	142.53	0.120
$12,500-$24,999	13.16	8.78	1137	5.95	1.07	0.44	1.33	145.81	0.119
$25,000-$39,999	17.91	9.52	1219	3.78	2.09	0.56	1.49	142.67	0.119
$40,000-$59,999	19.59	9.96	1286	2.57	2.10	0.71	1.67	143.58	0.120
$60,000-$74,999	12.84	10.57	1373	2.05	3.00	0.96	1.77	144.87	0.121
$75,000-$99,999	14.86	10.91	1433	1.66	3.71	1.46	1.95	146.13	0.122
$100,000-$149,999	16.53	11.82	1553	1.29	4.78	1.88	2.19	148.49	0.124
$150,000 or more	16.83	13.66	1834	0.87	4.93	4.80	2.74	149.68	0.126

Example #1: Rooftop solar

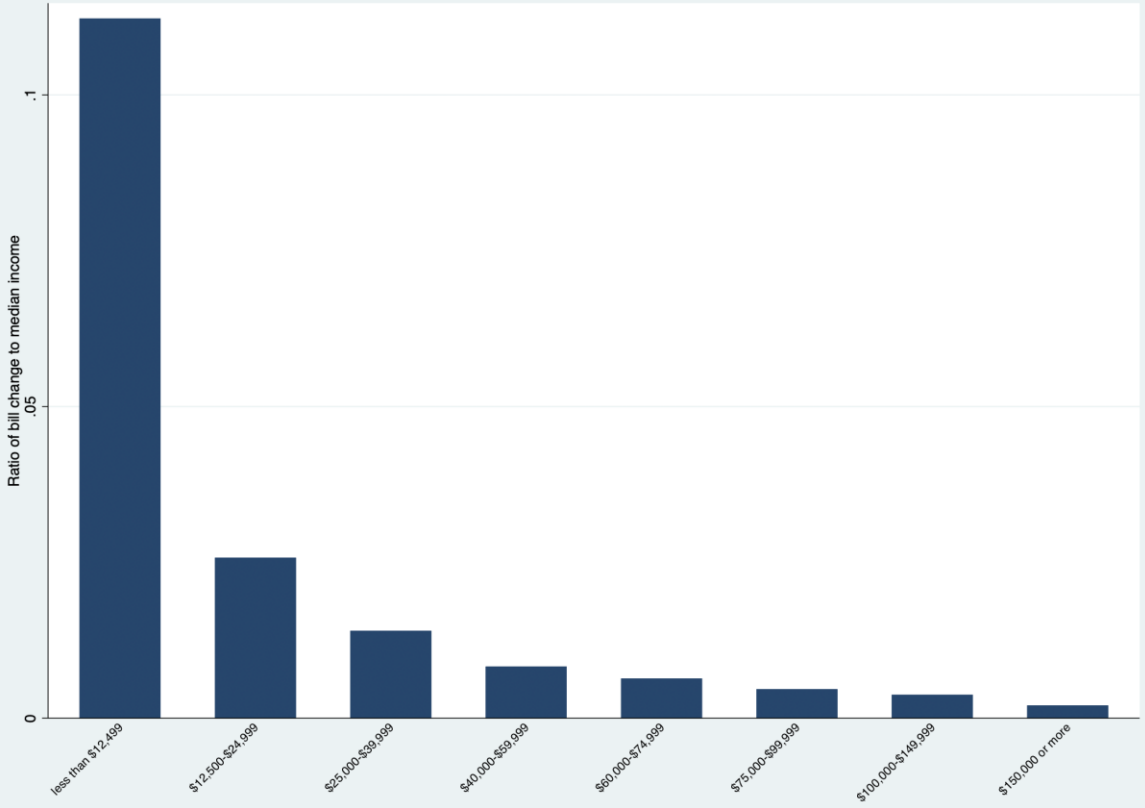
Panel A: Adopters

Panel B: Non-adopters and combined

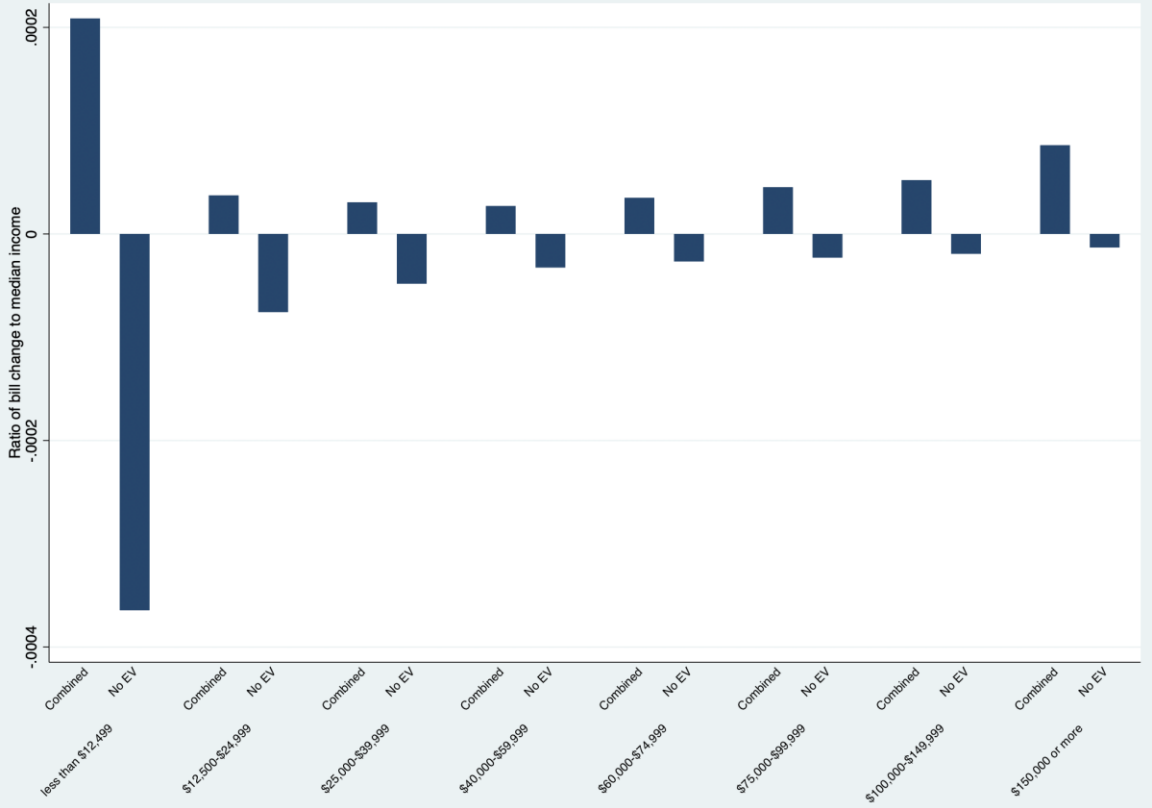


Example #2: Electric vehicles

Panel A: Adopters



Panel B: Non-adopters and combined



Conclusions

Elasticity of average price to demand of about -0.4, whether we estimate from utility data or simulate generation

Accounting for equilibrium price changes increases regressivity of rooftop solar and progressivity of electric vehicle subsidies

Caveats: analysis doesn’t include long-run capital investments