What's the Matter with US Residential Electricity Prices?

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Marginal Cost Pricing: the elusive utility standard

- Utility prices deviate from Social MC because of
  - Natural monopoly setting, average cost pricing
  - Externalities are not a cost to the utility
  - Much less time variation in prices than in SMC
- Leads to DWL in consumption choices
- Mismatch of P vs SMC in electricity also becoming a growing allocative efficiency issue
  - energy efficiency; DG solar policy; carbon pricing, etc.

This paper

- Attempt to quantify the difference between marginal prices and social marginal cost across the US electric sector.
  - Accounting for wholesale prices, distribution losses, and environmental externalities
- Measure relative consequences of the lack of time variation vs. average cost pricing.
  - Currently a measure for calendar year 2015
  - Covering only "basic" residential rates
- Some Punchlines
  - Externality costs are high
    - In many places offsets the inefficiency of average cost prices
    - Large regional variation
  - Distribution marginal costs (losses) are large and usually ignored
  - In most *places* time variation is main source of DWL
  - However, most of the DWL comes in a small number of places where the average costs are too high (e.g. California)

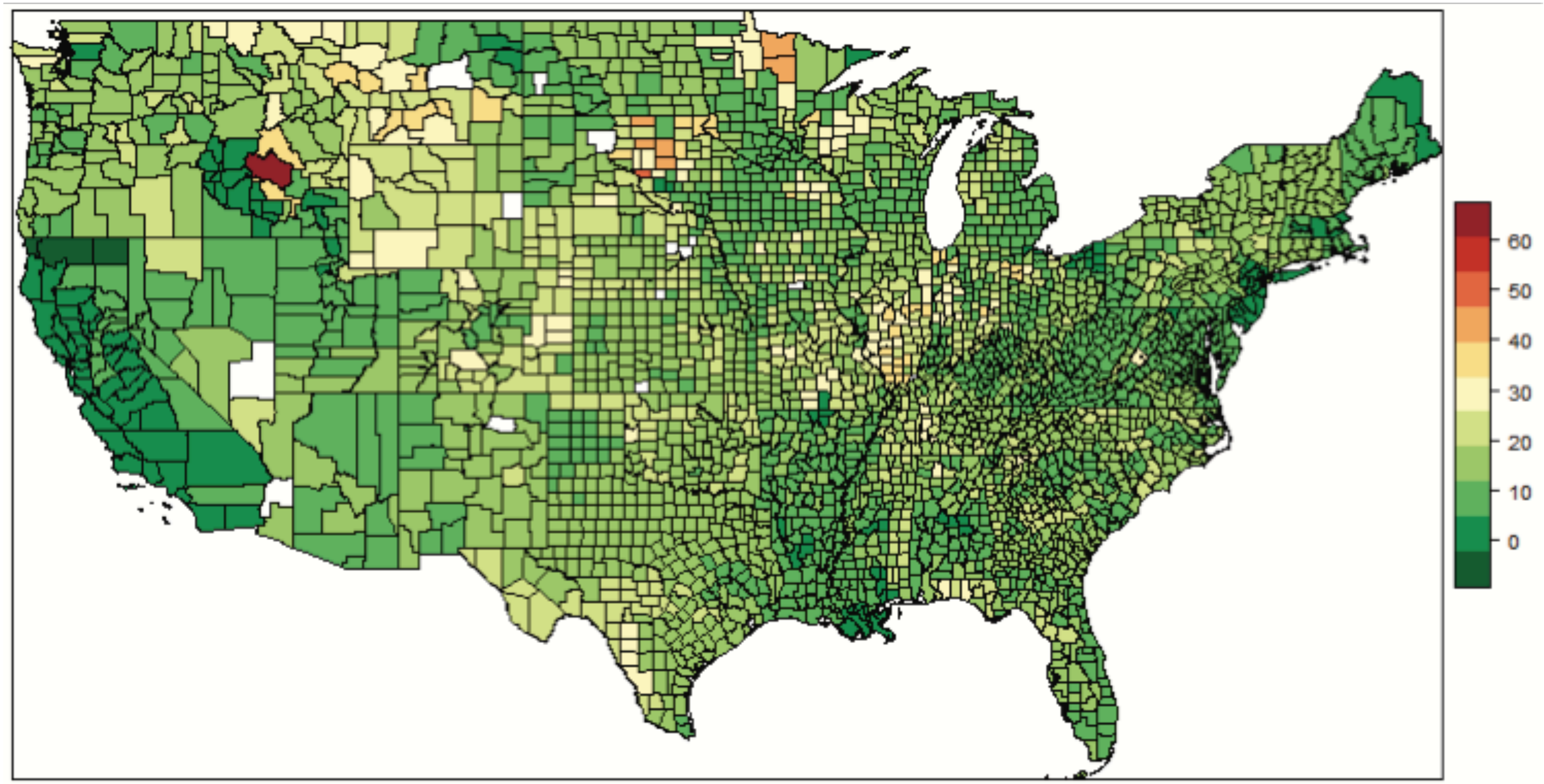
Estimating Retail Rate Structure

- Two-part pricing is common in US utility pricing.
  - Sales and revenue data do not decompose
- Davis & Muehlegger (2010) look at Natural Gas
  - Use monthly variation in quantities, revenues and costs to estimate slope and intercept of revenue and quantity relationship.
  - Find large deviations from marginal cost pricing
    - They had long time series with nice variation in retail prices
    - Much less variation on power side
- Our approach
  - Utilize data on rate structure (monthly fixed charges) from every major utility in the US

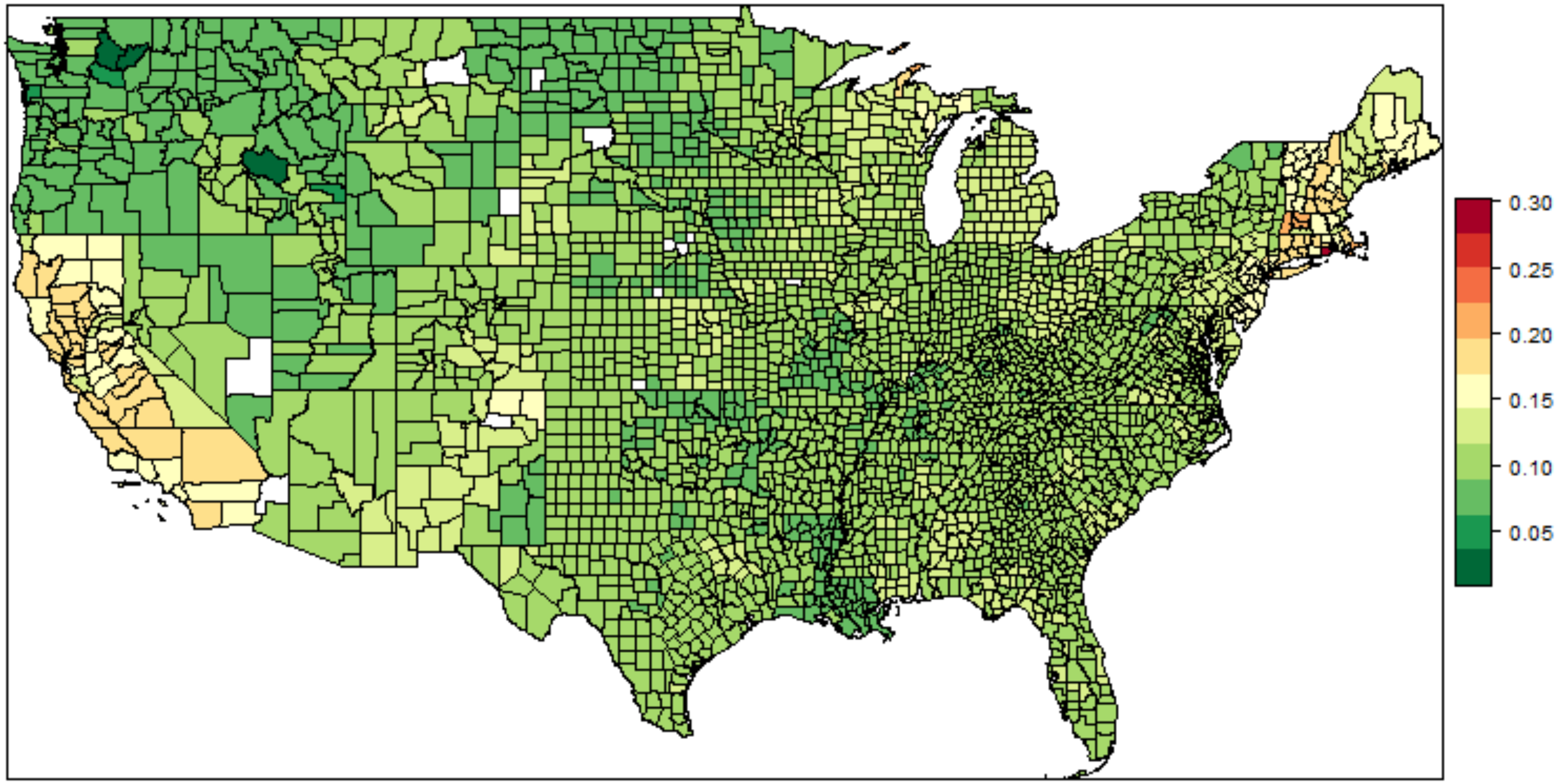
Data Sources: Retail Pricing

- EIA 861
  - Annual revenues, sales, and customers
  - Some issues in retail choice states
    - Most competitive states bundled sales by incumbent - the“provider of last resort”
- US Utility Rate Database
  - Comprehensive but idio-syncratic collection of tarriffs across US
  - Detailed look at rate structure
  - Isolate “standard” residential tariff through string searches
  - Extract monthly fixed charge component of standard rate in each utility region.
- Remove fixed charges, and divide remainder by kWh to get average variable price
  - Does not capture increasing-block or decreasing-block pricing
  - Ito (2014) doesn’t really alleviate this concern
  - But outside CA steps in block pricing are small
  - Revenue and kWh is residential customers on all tariffs

Monthly Fixed Charges on Residential Rates



Residential Retail Variable Price



Data Sources: Social Marginal Cost

- Generation (private costs)
  - Primarily use reported market ("spot") prices in regions covered by organized markets.
  - EIA 714 "system lambda" for regions with no market data
- Environmental
  - Data from Holland, Mansur, Muller and Yates
  - "gold standard" for detailed enviro cost data from electricity
    - E.g. only source of such data
- Distribution
  - Power delivery incurs "losses" that grow more severe at lower voltage levels
  - Wholesale prices include marginal cost of transmission (high voltage) losses, but not of distribution losses

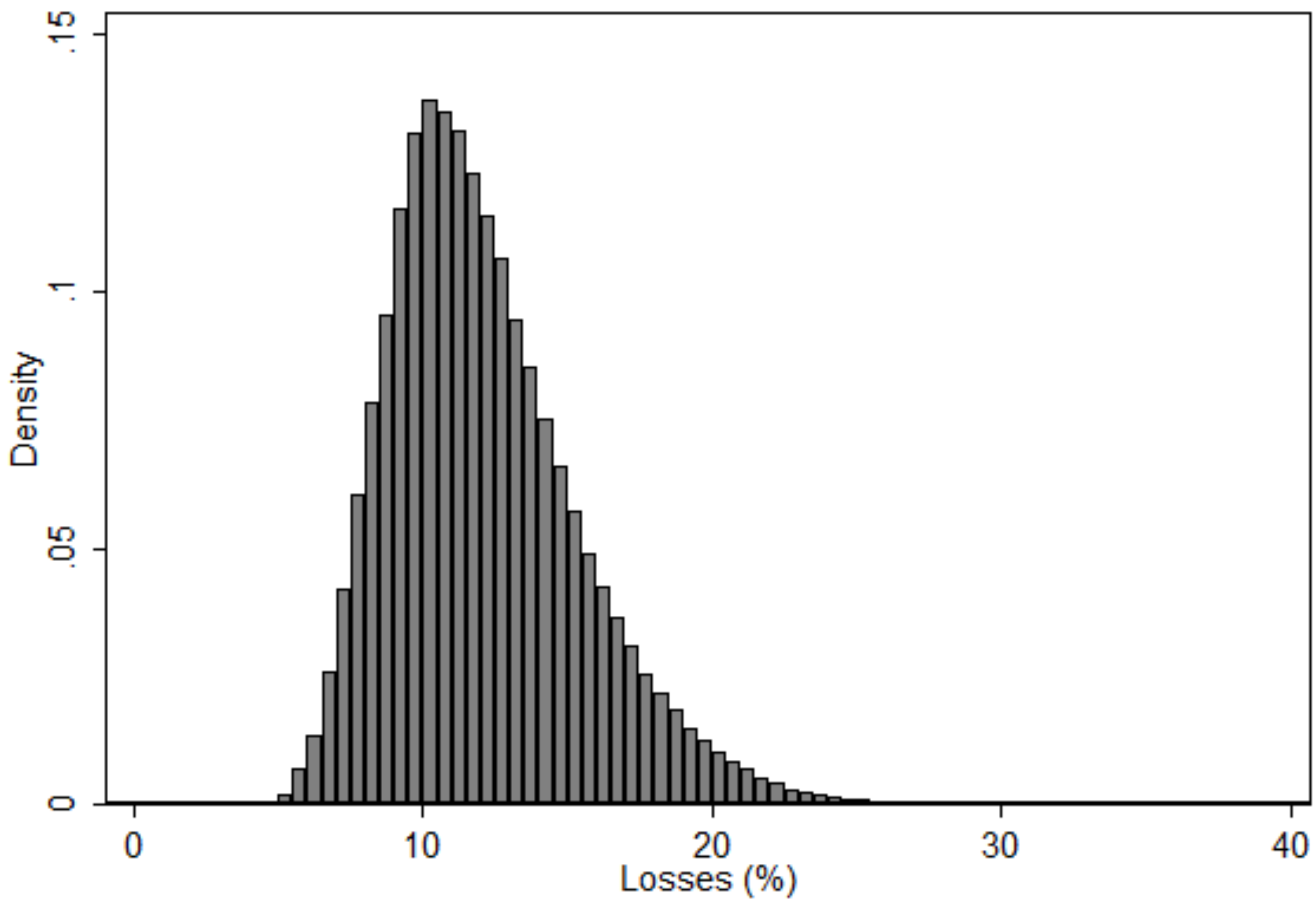
Distribution Losses

- Share of power lost increases
  - At lower voltage – residential distribution
  - Along longer distribution lines – res distribution
  - When there is more flow on the line
    - We assume a quadratic relationship $L=\alpha Q_t^2$, so marginal losses $2\alpha Q_t$ are approximately twice as large as average losses
- Data are available from by utility from EIA-861
  - But aggregated across all customers and all hours of the year
  - Not available for all utilities, about 90% of load
- We estimate average losses on residential distribution

Estimating Distribution Losses

- Average losses strongly correlated with residential share of load, load/km^2, load/circuit, circuit optimization
- Currently we control for residential share and density (customers/km^2) plus state and utility type
- Use this to estimate the average losses attributable to residential load
- Then invert $\alpha=\Sigma L_t/\Sigma Q_t^2$ to get α, and estimate marginal losses in hour t are $\gamma_t=dL_t/dQ_t=2\alpha Q_t$
- Scale up PMC and EMC by $1/(1-\gamma_t)$ in every hour

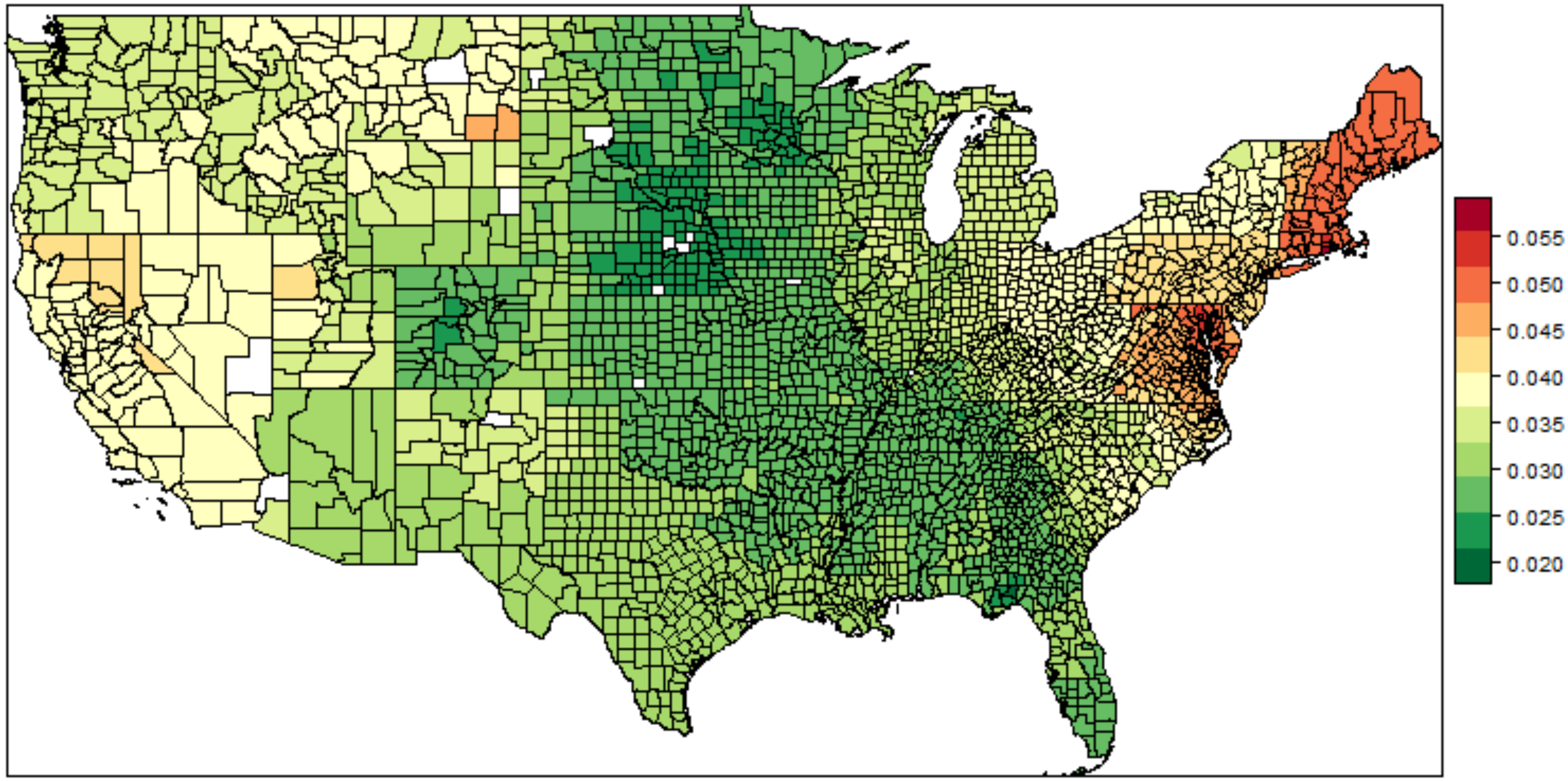
Histogram of estimated hourly marginal residential losses



Note: Outliers >40% dropped (this was less than 0.0001% of residential kwh sales)

Average Private Marginal Cost Accounting for Distribution Losses

(load weighted)



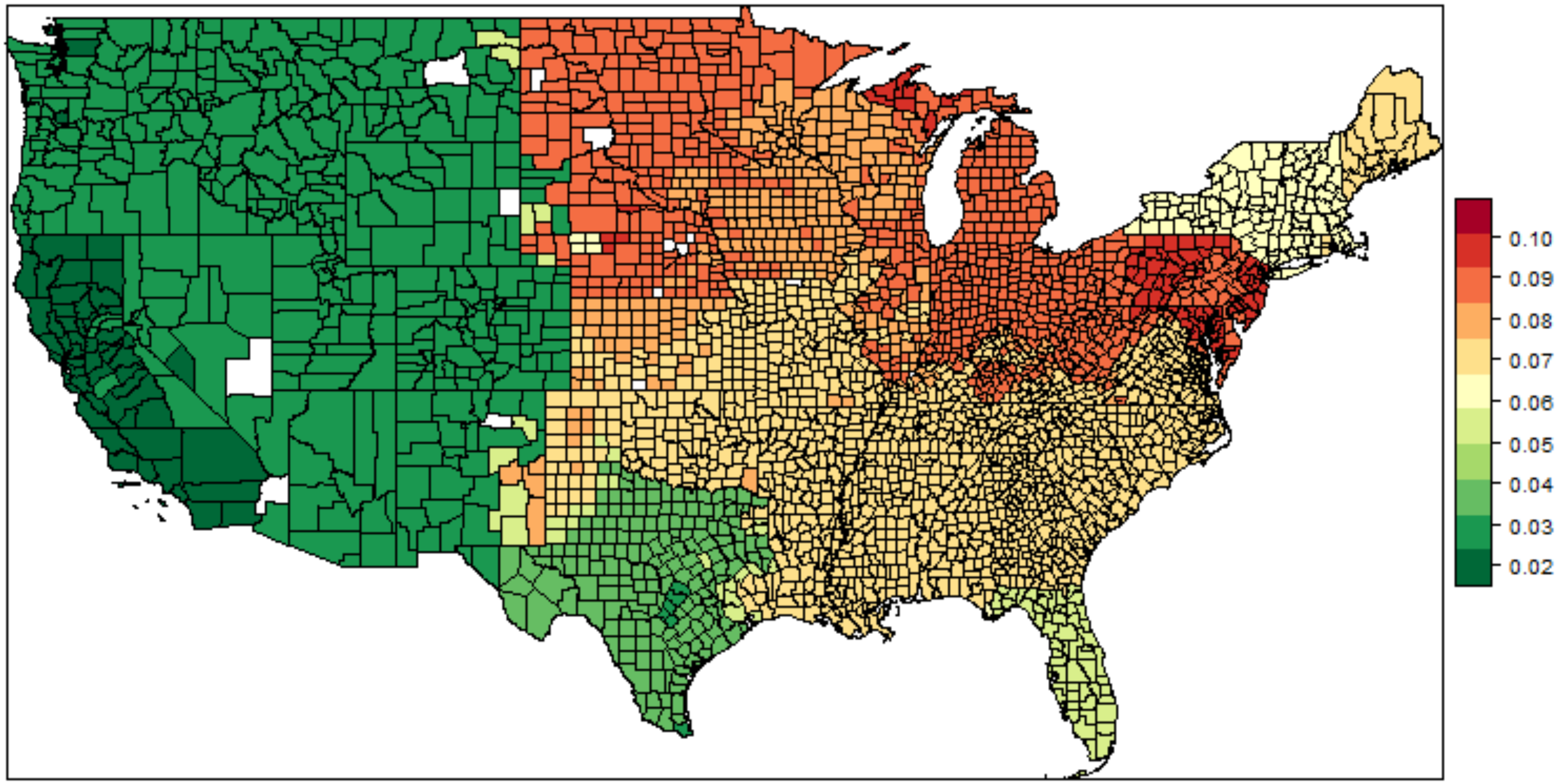
Why is PMC so low?

- Natural gas prices are very low, and gas-fired generation is often the marginal supply
  - Fuel cost of efficient combined-cycle gas turbine between $0.02/kWh and $0.03/kWh
  - PMC of coal often even lower
- Systems are overbuilt so PMC<LRAC
  - Due to miscalculation in planning
  - Due to additions of subsidized renewables
  - Due to compensation through capacity markets and ancillary services

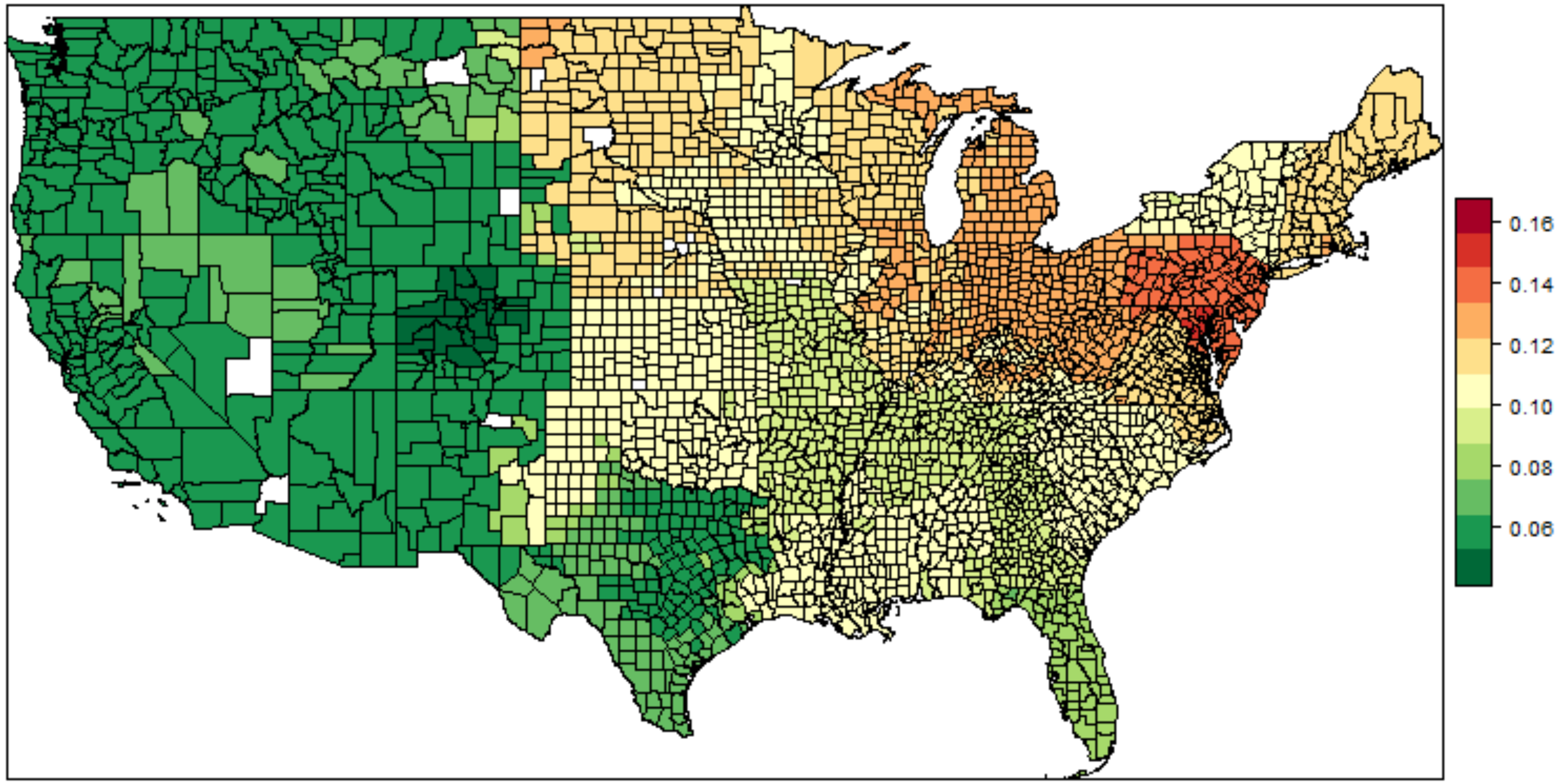
External Marginal Cost

- Holland, Mansur, Muller and Yates, *AER* 2016, create externality cost per MWh by hour of day of consumption by NERC region
  - Based on plant in region providing marginal supply
- Incorporates local pollutants and GHGs
  - GHGs priced at $41/ton, local pollutants costs vary
- Does not account for seasonal, weather, or load variation
  - TBD
- For each utility-hour, we calculate EMC from HMMY based on hour of day and NERC region

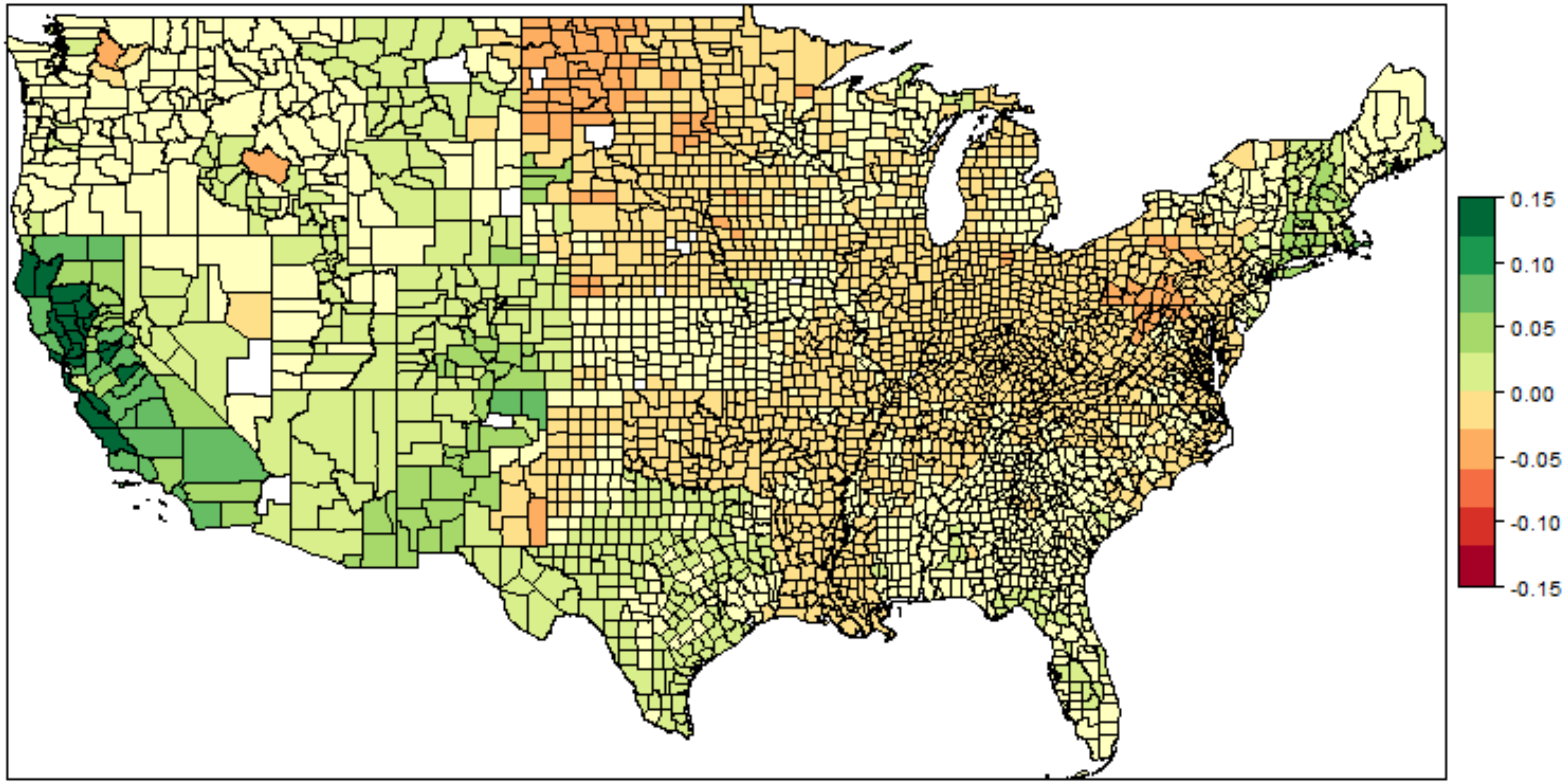
Average External Marginal Cost Accounting for Distribution Losses
(load weighted)



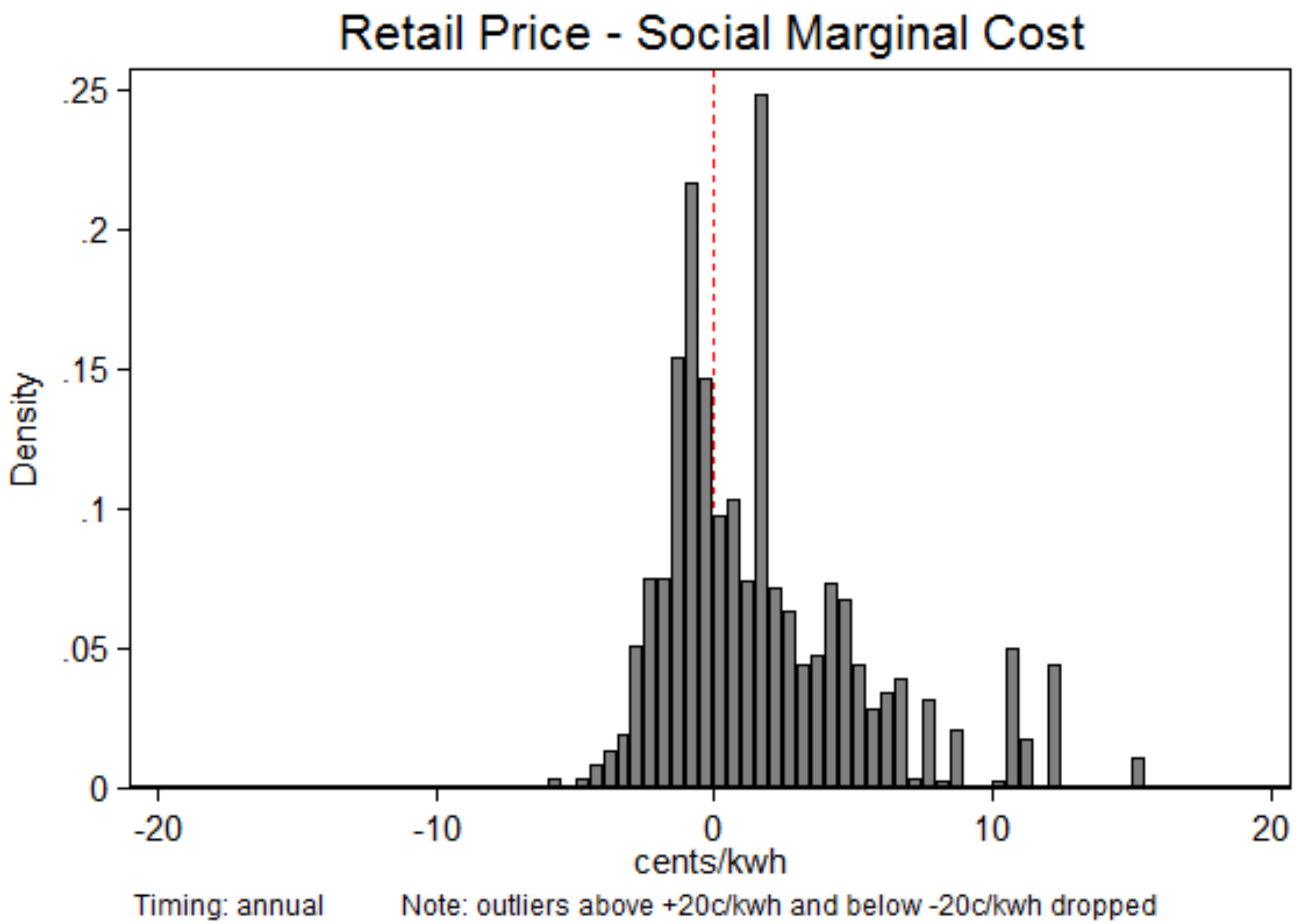
Average Social Marginal Cost Accounting for Distribution Losses
(load weighted)



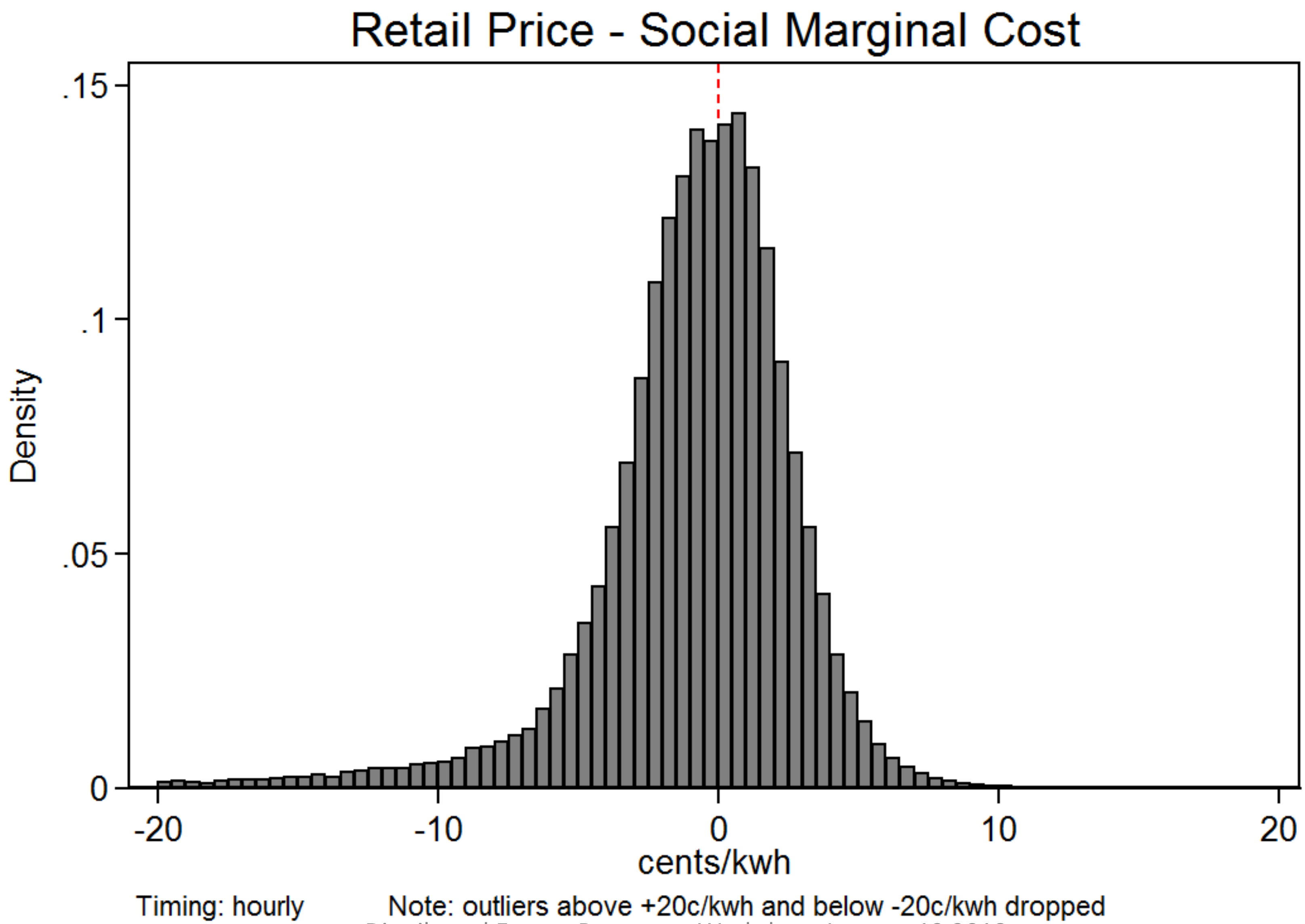
Price-Average SMC



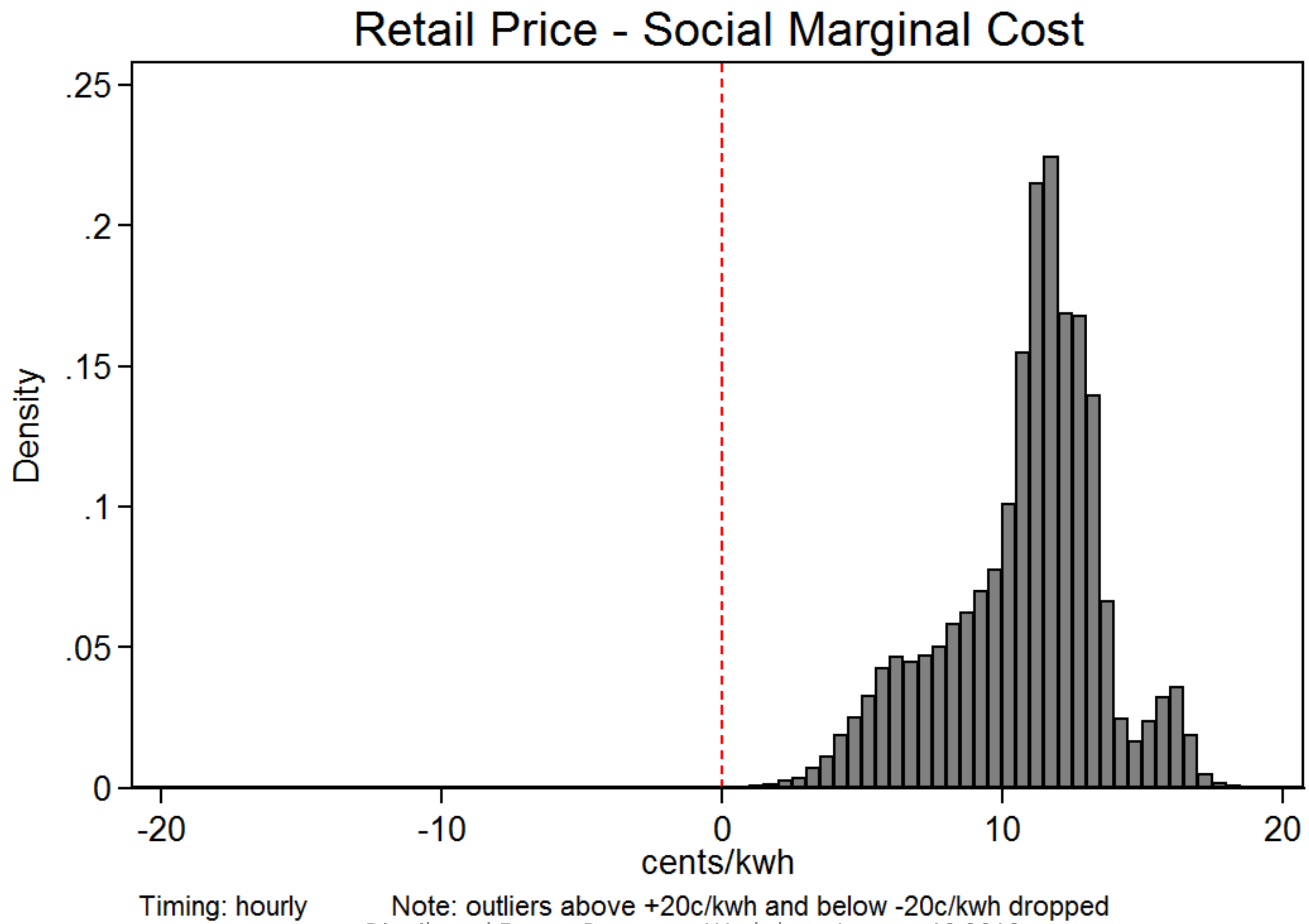
Histogram of P-SMC_{avg} across utilities

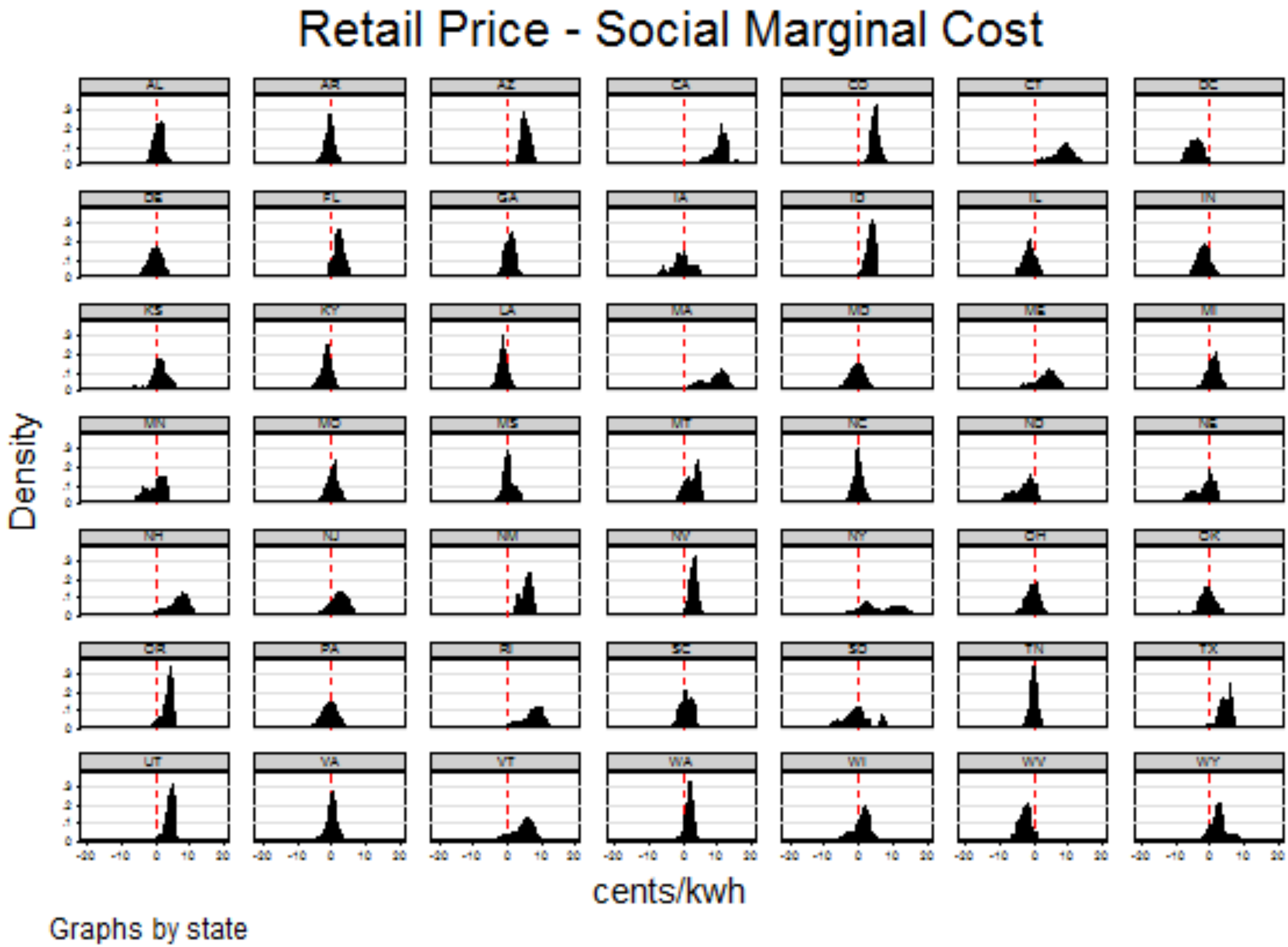


Fixed Retail Price vs. SMC in PA

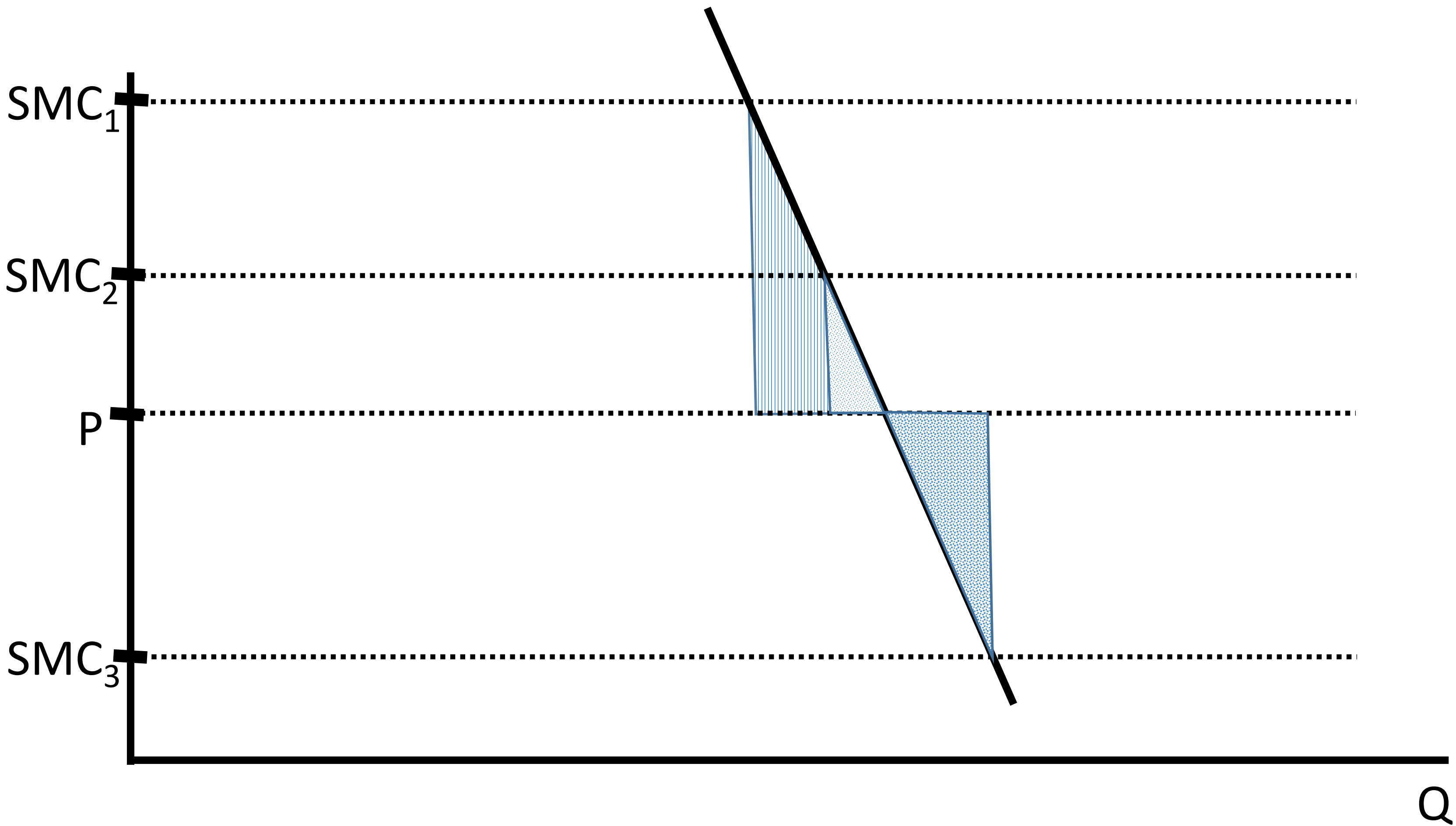


Fixed Retail Price vs. SMC in California




Retail Price - Social Marginal Cost
AL
AR
AZ
CA
CO
CT
DC
DE
FL
GA
IA
ID
IL
IN
KS
KY
LA
MA
MD
ME
MI
MN
MO
MS
MT
NC
ND
NE
NH
NJ
NM
NV
NY
OH
OK
OR
PA
RI
SC
SD
TN
TX
UT
VA
VT
WA
WI
WV
WY
Density
cents/kwh
Graphs by state

Deadweight loss calculations



Decomposing deadweight loss from mispricing

- If demand slope same in all hours, so response is same to change in average price as to hourly price change, then

$$DWL = \sum_h \frac{1}{2s}(\bar{P} - SMC_h)^2 = \frac{1}{2s}[H \cdot (\bar{P} - \overline{SMC})^2 + \sum_h (\overline{SMC} - SMC_h)^2]$$

- But demand changes hour to hour
- We assume that the elasticity of one unit of demand at retail price is the same in all hours and for hourly or average price change so

$$DWL = \frac{1}{2\hat{s}}[\sum_h Q_h \cdot (\bar{P} - \overline{SMC_w})^2 + \sum_h Q_h \cdot (\overline{SMC_w} - SMC_h)^2]$$

  - where

$$\overline{SMC_w} = \frac{\sum_h Q_h \cdot SMC_h}{\sum_h Q_h}$$

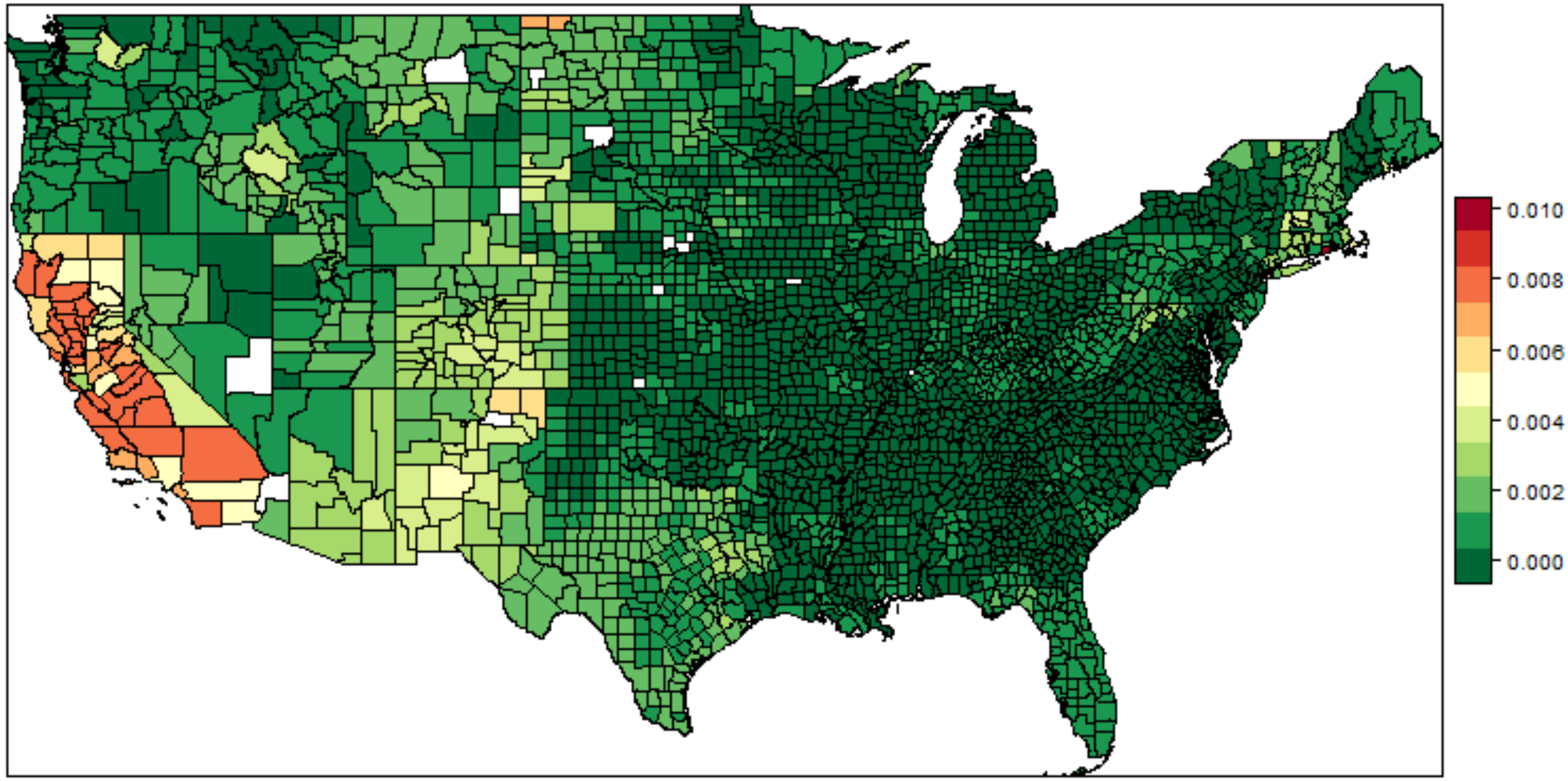
Deadweight loss decomposition

$$DWL_{avg} = \frac{1}{2\hat{s}}[\sum_h Q_h \cdot (\bar{P} - \overline{SMC_w})^2]$$

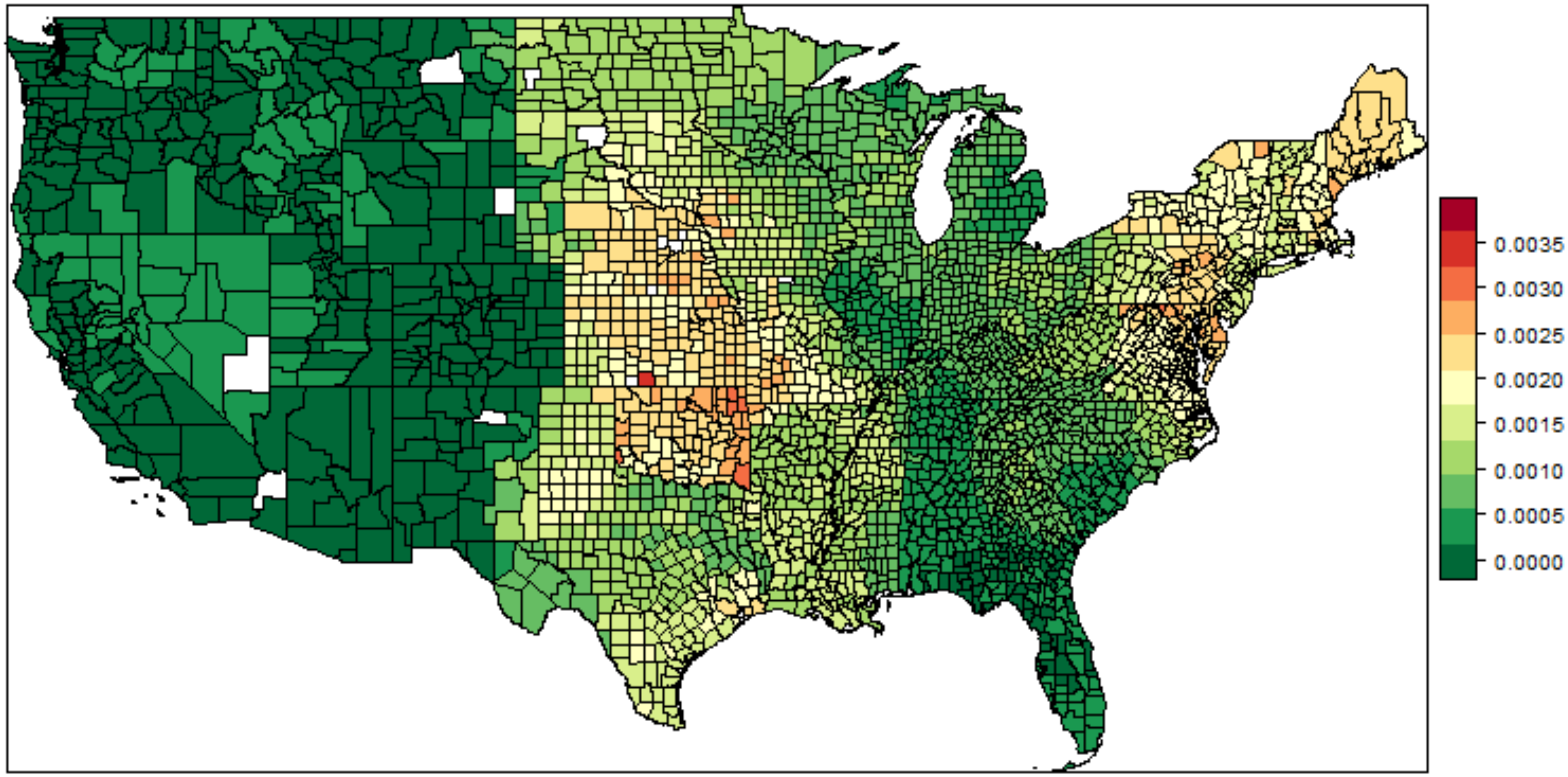
$$DWL_{resid} = \frac{1}{2\hat{s}}[\sum_h Q_h \cdot (\overline{SMC_w} - SMC_h)^2]$$

- s^ set to yield ε=-0.2 at retail price

Deadweight Loss Per Unit Demand from Price Differing From Average SMC



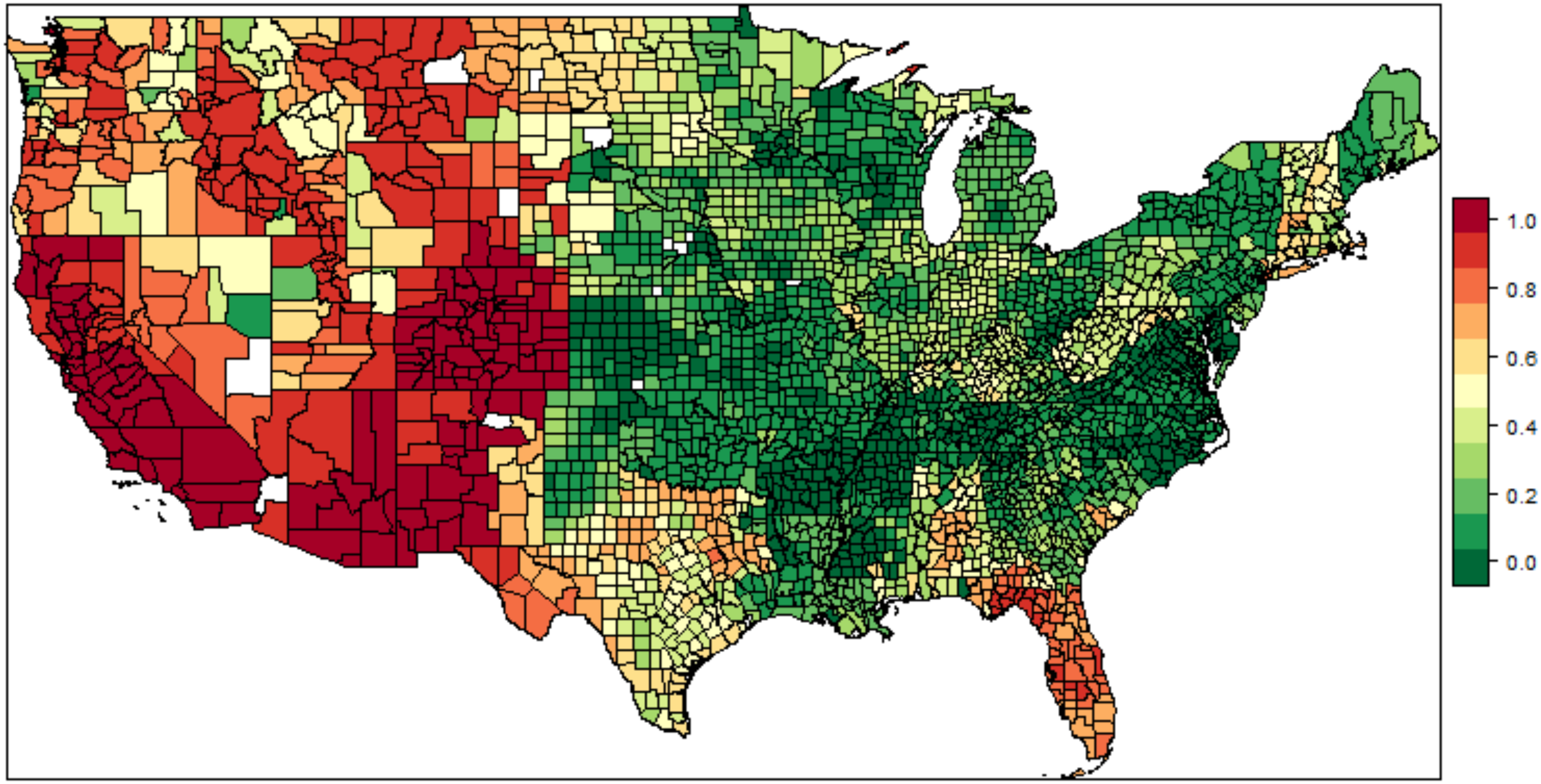
Deadweight Loss Per Unit Demand Due to Time-Varying SMC



Why does SMC variability create so little deadweight loss?

- Excess capacity and system operator use of reserves to dampen wholesale prices
  - => less cost (wholesale price) volatility
- In the short term, this almost certainly overstates DWL from SMC variability
  - Because price responsiveness to hourly price changes is likely small
- In the long term, maybe understates
  - Automated price responsiveness increases price elasticity, load shifting, and value of hourly pricing
  - Less reliance on excess capacity, more on rationing with price

Share of Total Deadweight Loss Due to Price Differing From Average SMC



Conclusion

- Multiple reasons that residential electricity is not sold at the “right” price => SRSMC
- Externalities appear to (currently) comprise more than half of social marginal cost
- Surprisingly (to us) there are nearly as many U.S. utilities with price too low as too high
- Residential prices also virtually never move with time-varying costs, causing DWL
- But DWL due to lack of time variation currently is likely smaller than due to price differing from average social marginal cost

Future Work

- Analysis for 2010-2016 – higher PMCs?
- Improved/updated Utility Rate Database
- Refinement of residential distribution losses
- Greater granularity in external marginal cost

Thank You

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