Electricity Pricing for the Energy Transition

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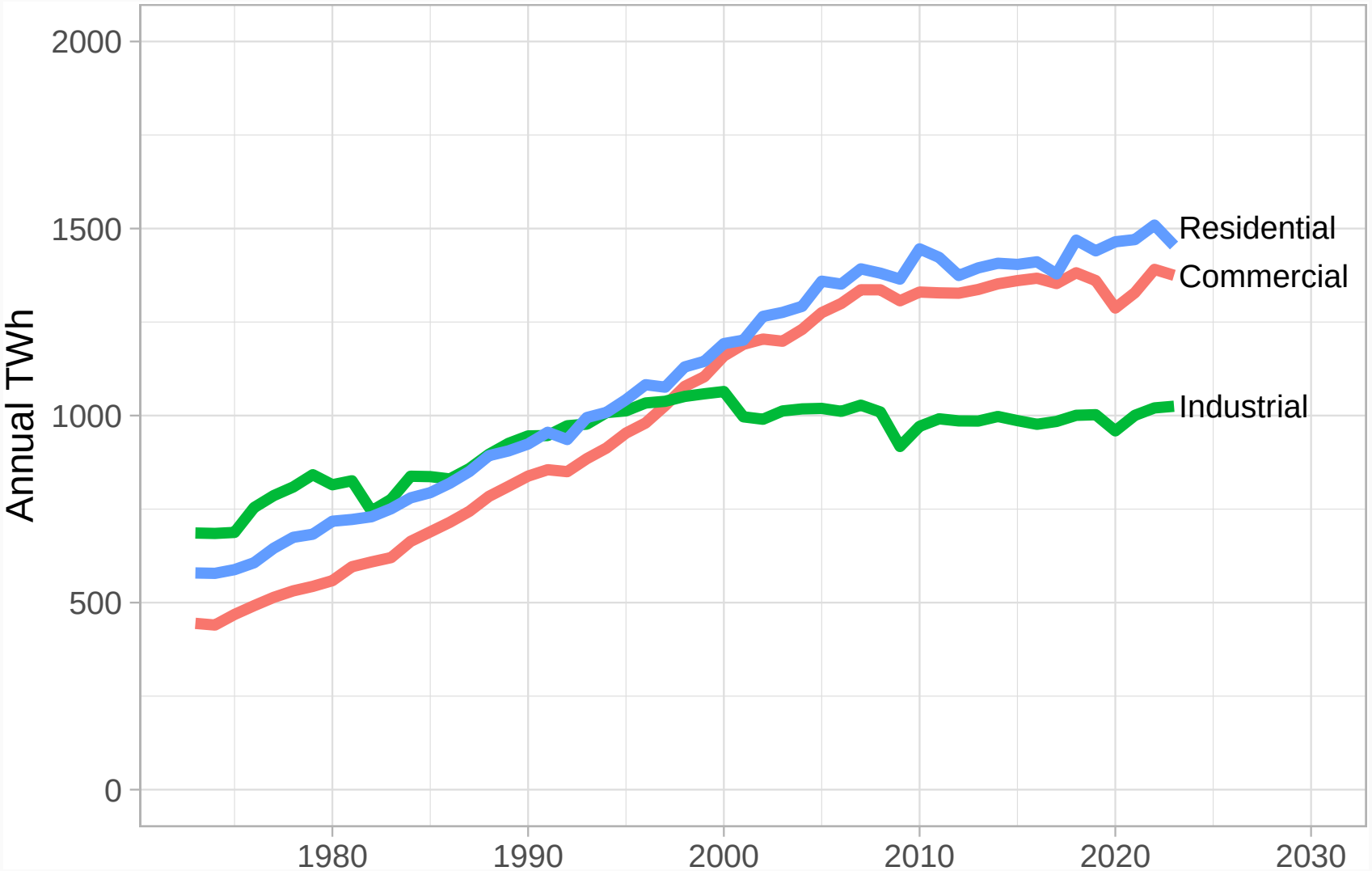
Most electricity is used in the non-residential sector



Non-residential electricity consumption will continue to rise

Resurgent US electricity demand sparks power grid warnings

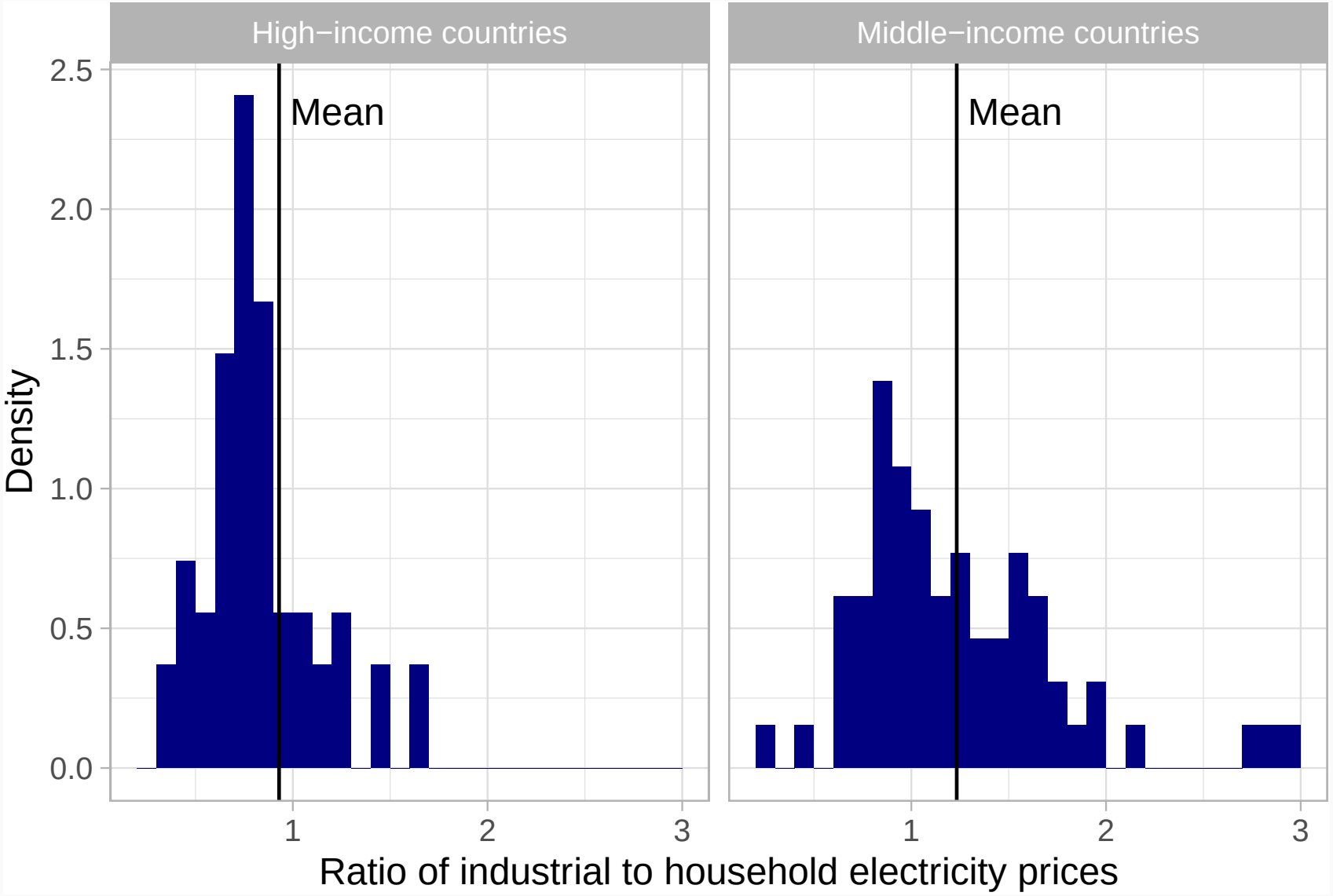
Boom in AI data centres, industrial reshoring and electric vehicles burdens networks

Artificial intelligence + Add to myFT

Booming AI demand threatens global electricity supply

Tech chiefs warn that power-hungry data centres are a bottleneck in developing artificial intelligence

Non-residential users pay a higher price in many countries



What are the effects of price distortions?

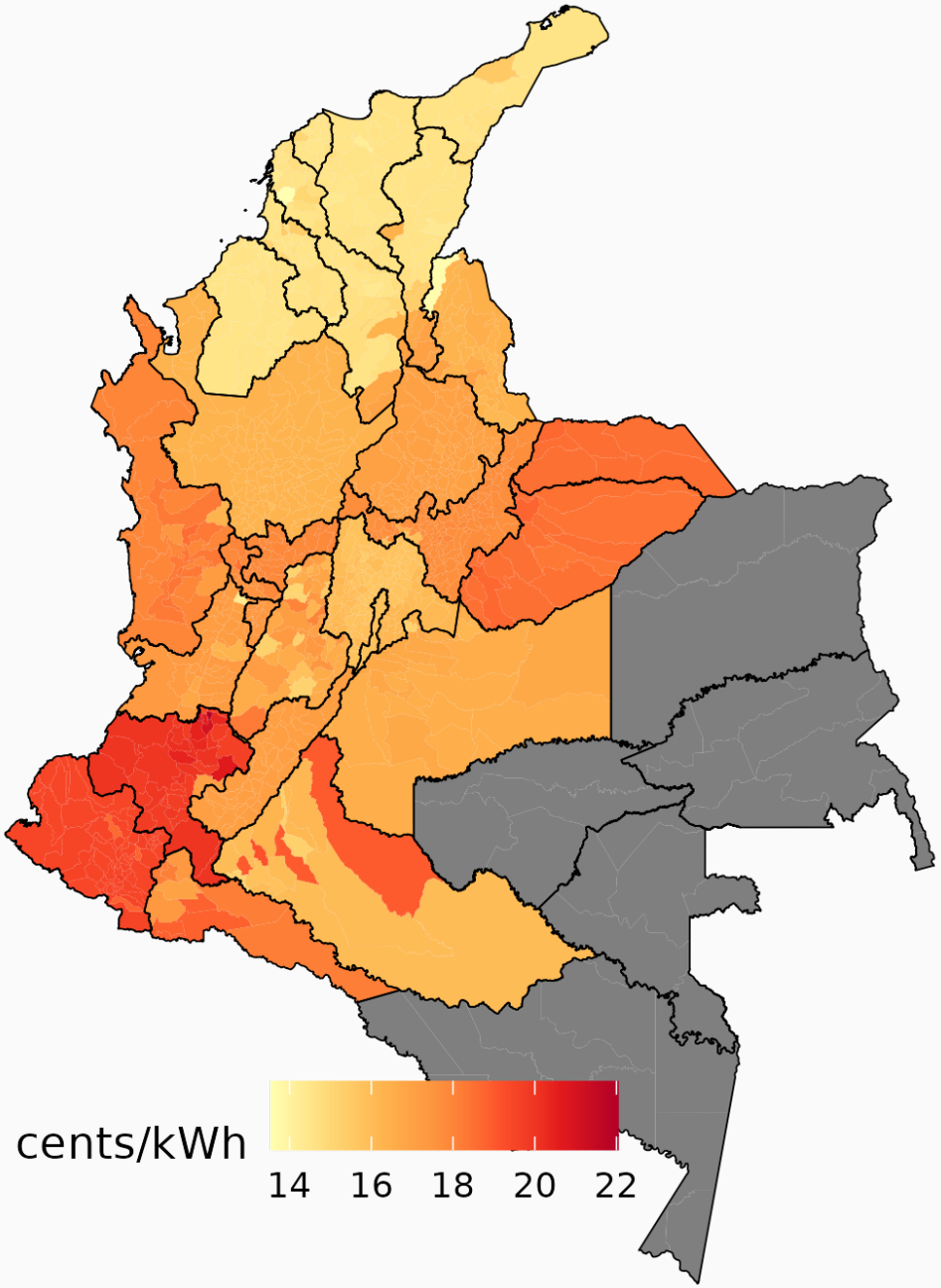
- Existing prices create **incentive** for firms to make costly (and potentially inefficient) investments in self-generation to reduce their electricity consumption
- Existing prices create **disincentive** for firms to replace fossil fuels with electricity for other energy services

This paper: simulate electricity price reform in Colombia

- Describe the distortion from marginal cost pricing for electricity consumers in Colombia
  - Industrial and commercial customers pay a 20% tax on their electricity bills to fund a residential subsidy
  - Small businesses pay the highest electricity prices
- Propose an alternative system of electricity tariffs to eliminate the distortions
  - Two-part tariff: marginal cost pricing plus fixed charge in proportion to estimated willingness-to-pay
- Main idea: eliminate all distinctions across customer classes

Institutional background

Base tariffs vary by distribution network in Colombia

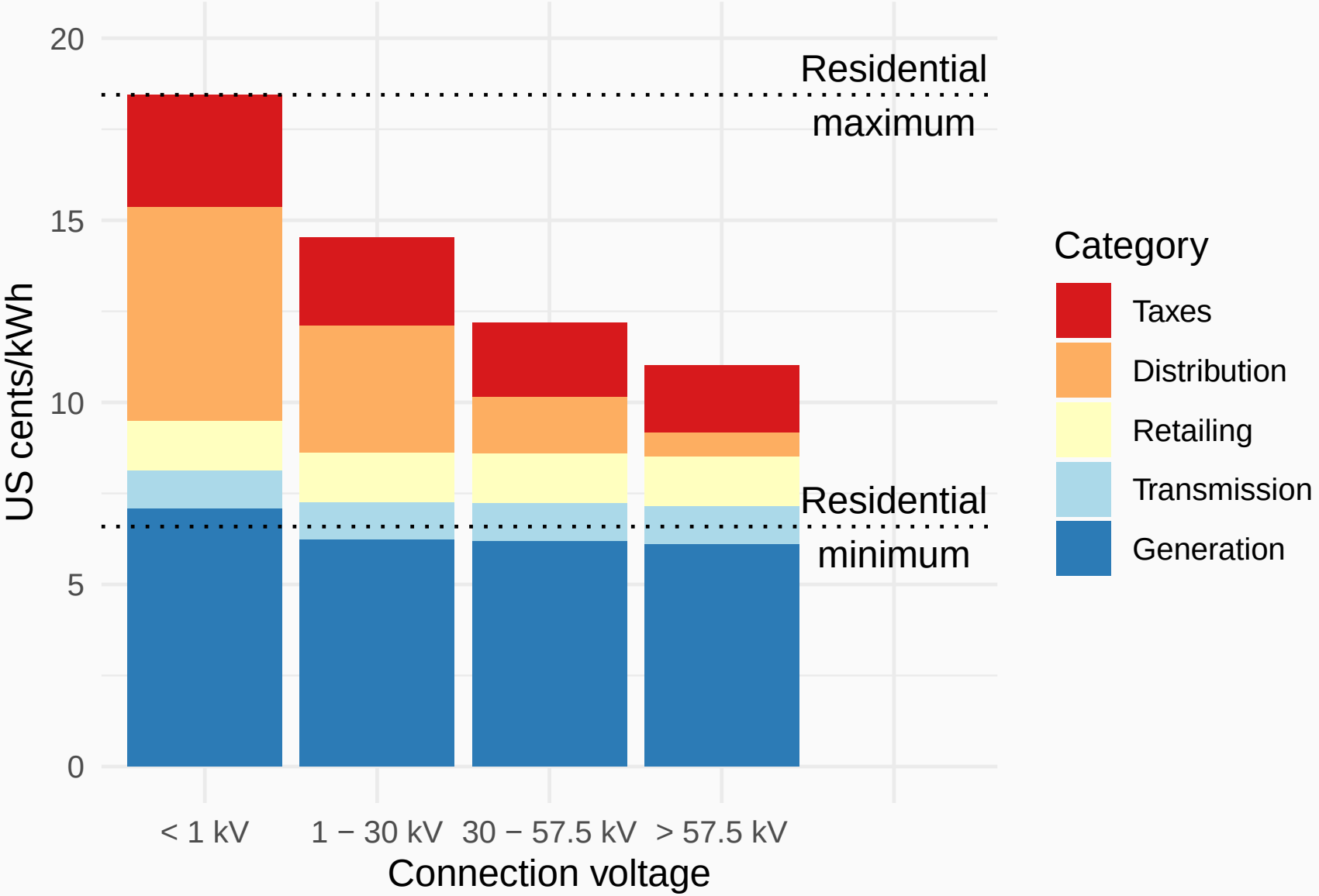


- Base electricity tariffs regulated by energy regulator (CREG)
- Set to recover cost of six tariff components
- Distribution and retailing components vary most across distribution networks

Electricity cross-subsidy program in Colombia

- Most residential users pay an increasing block tariff with geographically targeted subsidies
  - Six "strata" based on neighborhood characteristics
- Households in Strata 1-3 receive a subsidy on their initial monthly electricity consumption (either 130 or 173 kWh)
- Households in Strata 5-6, along with commercial and industrial users, pay a 20% tax on the base tariff to fund these subsidies

Most of non-residential price is fixed cost allocation

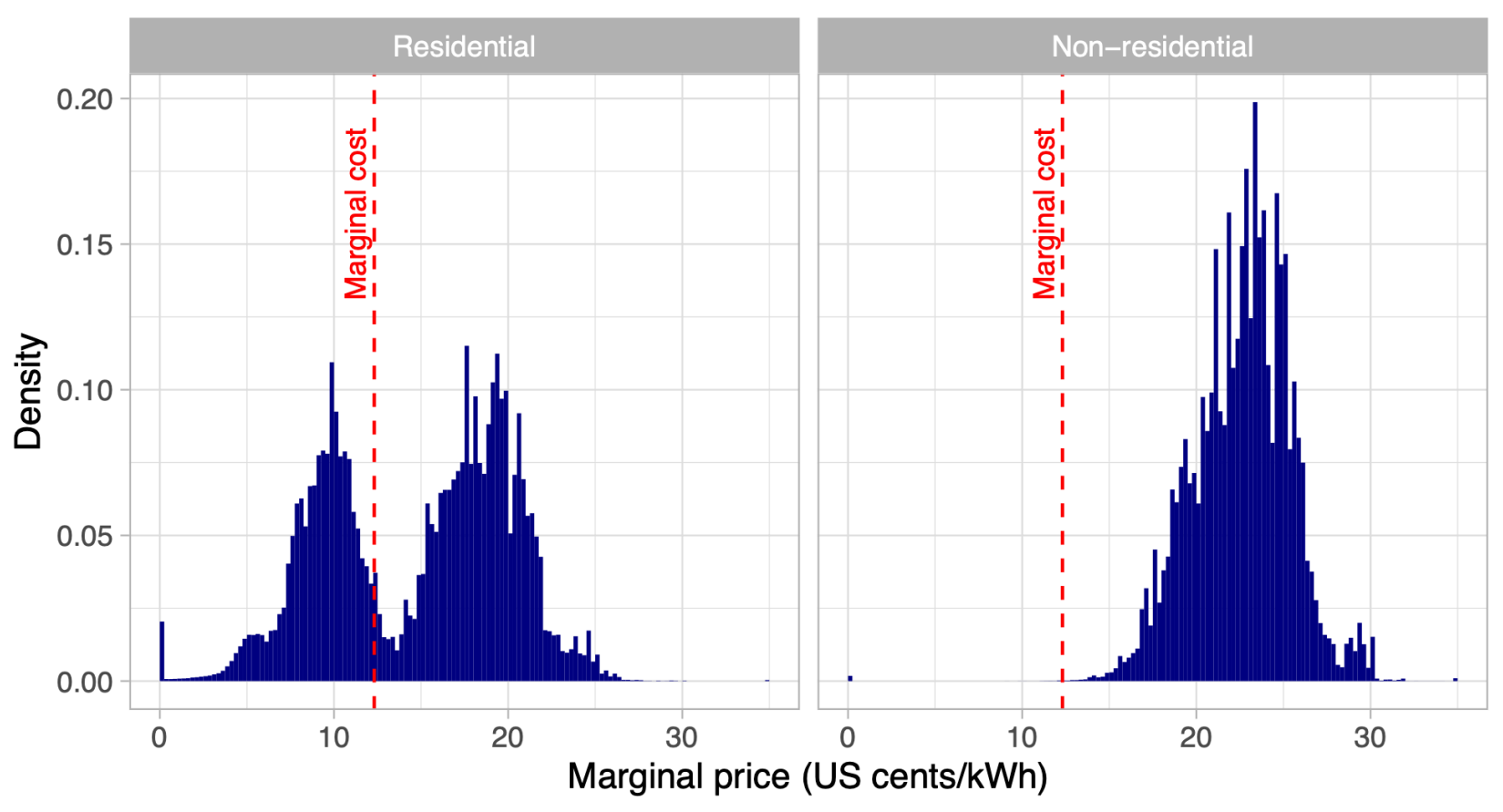


Existing price distortions

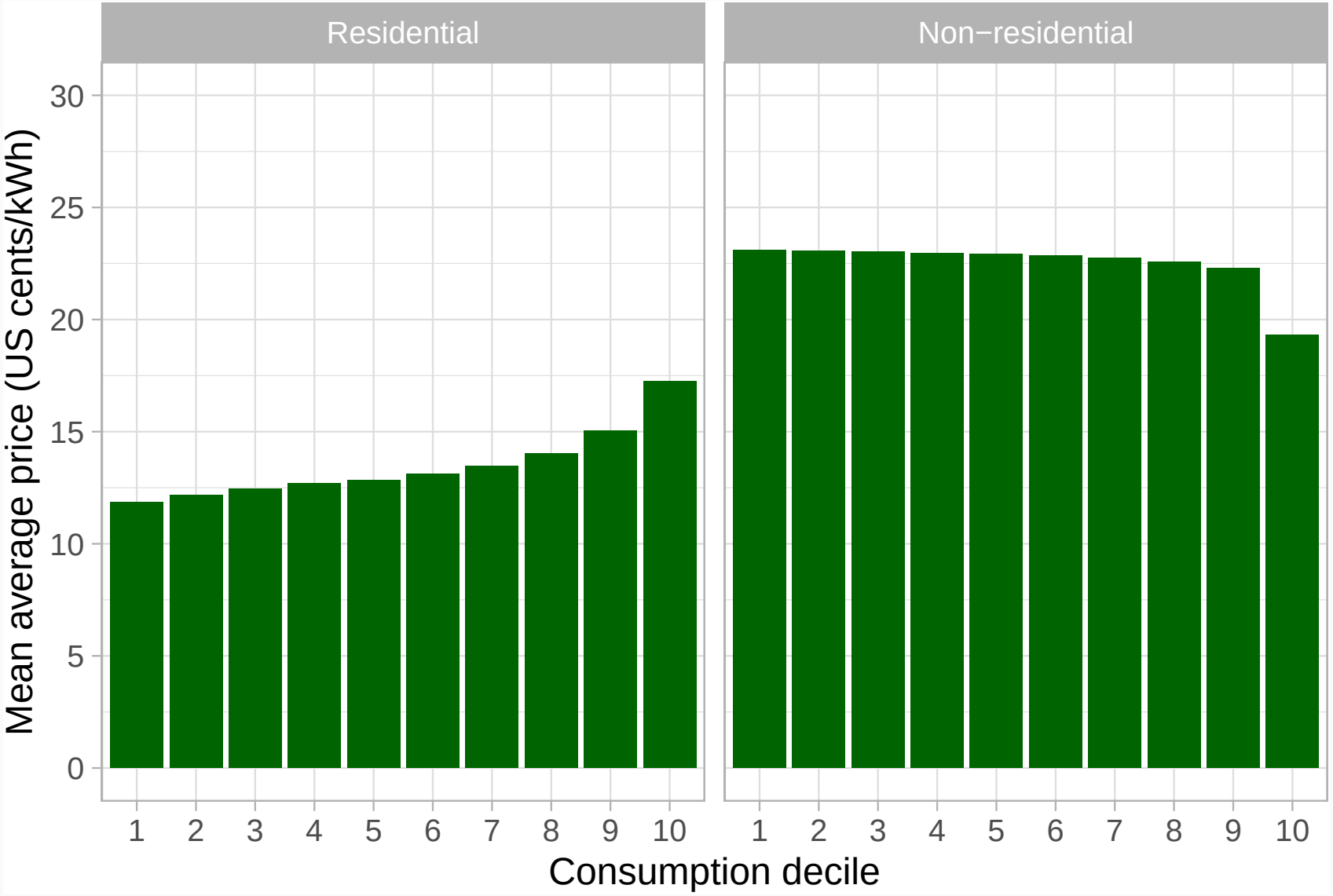
Comprehensive data on all electricity consumers

- Monthly billing data for all electricity consumers in Colombia
  - 11.6 million residential (median cons. 3.9 kWh/day)
  - 1.1 million non-residential (median cons. 6.6 kWh/day)
  - Focus on 2014 for this analysis
- Information includes monthly billed consumption and a breakdown of the total bill calculation (including taxes or subsidies)
- Supplement with hourly metered consumption data
  - Largest electricity users in Colombia (about 4000)
  - Hourly distribution network withdrawals

Wide variation in marginal prices under existing tariff



Small businesses pay high average price under existing tariff

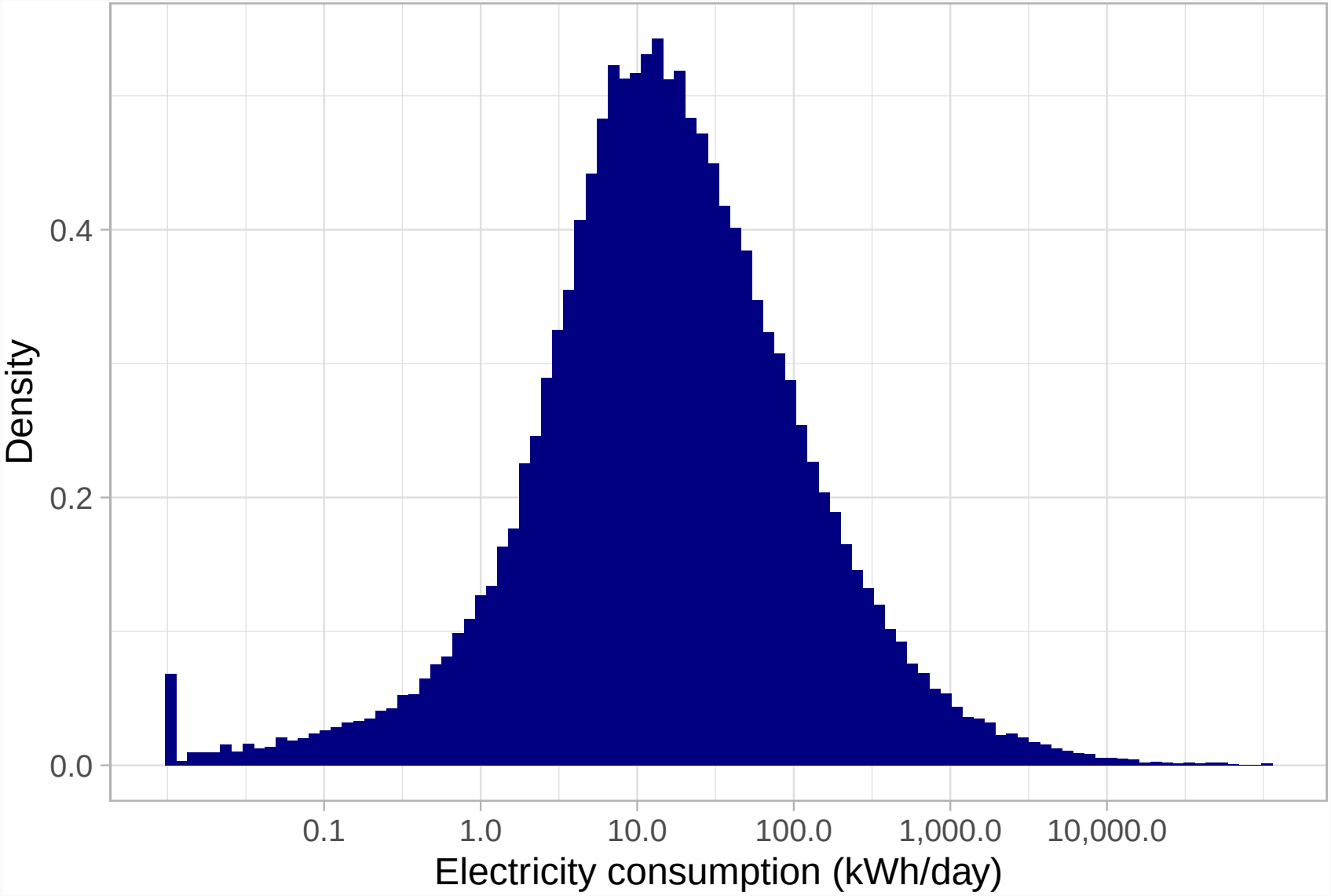


Analysis of industrial exemption

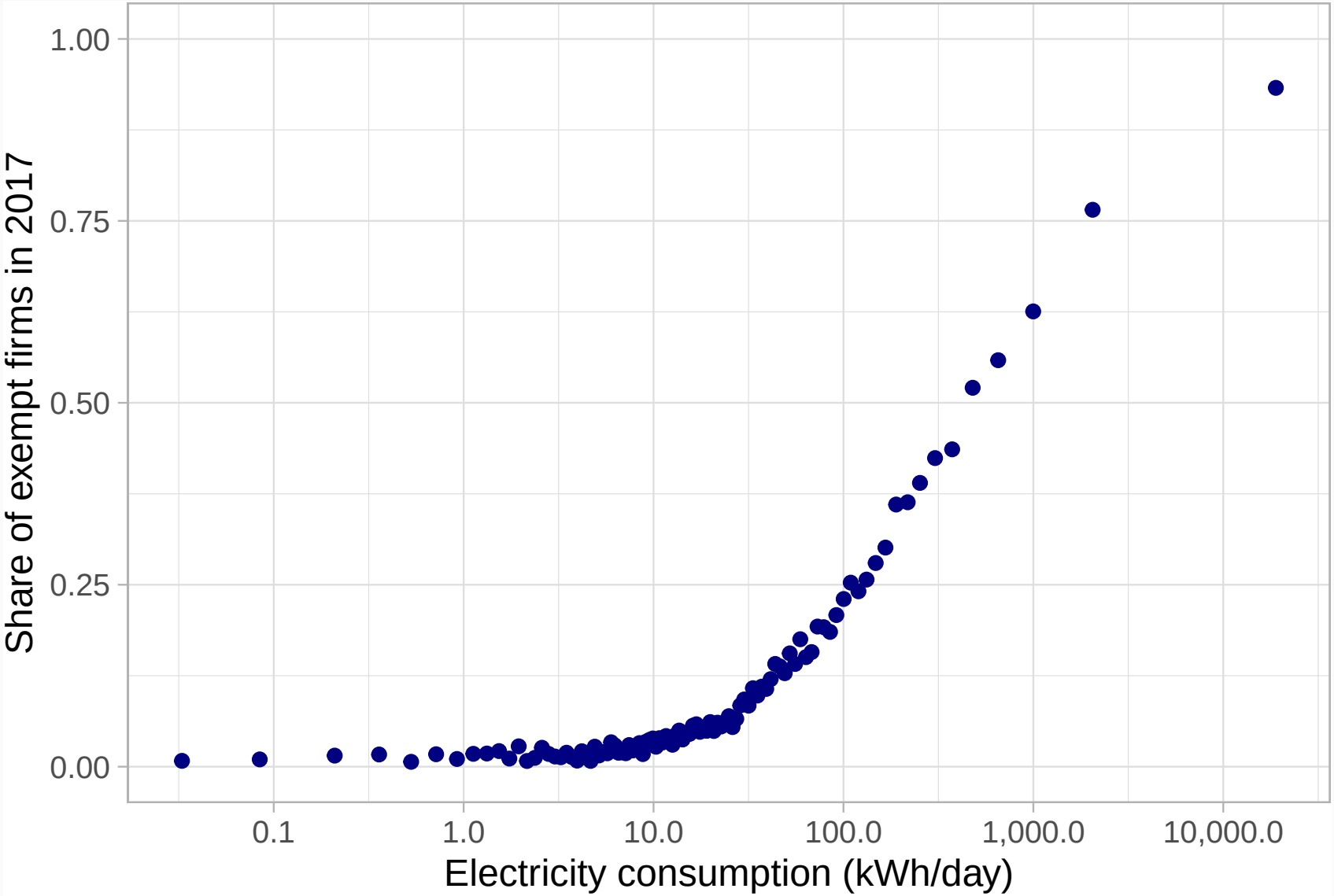
Exemption from 20% tax of industrial users

- As part of a 2010 fiscal reform, the 20% contribution was eliminated for industrial customers starting 2012
- Exempted sectors include agriculture, mining, manufacturing, utilities, construction, and publishing
- Exemption is not automatic: firms must apply to their distribution utility and provide evidence of their eligibility

Most industrial users have low levels of consumption



Exemption rates for small firms are very low



Why might take-up of the exemption be so low?

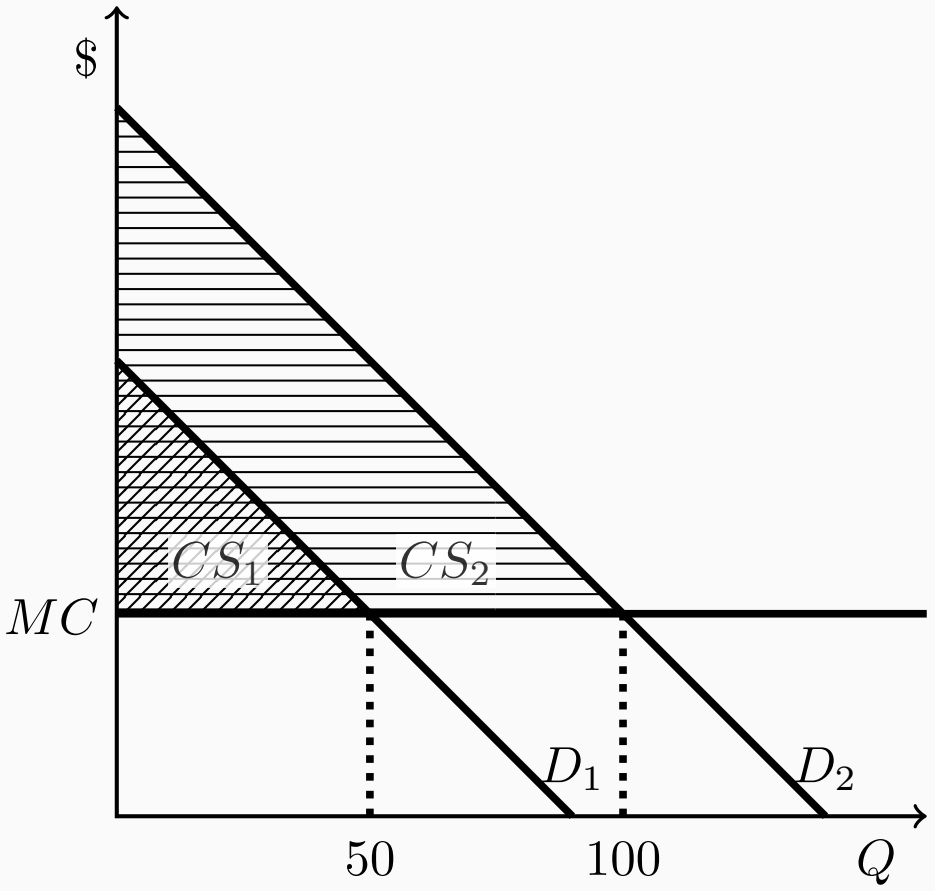
- Small industrial firms may not have formal paperwork required for the applications
- Many small firms may rent rather than own the premises where their operations are based
  - Utility bills typically in name of landlord, not tenant
- Fixed cost of applying for the exemption may be high relative to the potential savings
  - Potential cost of inspection ($10-$25)
  - Paperwork and time cost
  - Process needs to be repeated every six months

Alternative tariff proposal

Empirical simulation of an alternative efficient electricity tariff

- Marginal electricity price set equal to social marginal cost each hour
  - Generation costs (including price of emissions) + transmission and distribution losses
- Fixed charges recover all remaining costs of electricity supply
- Proposal: allocate fixed charges in proportion to users' estimated expected hourly willingness-to-pay (EEHWTP) for electricity (Wolak, 2018; McRae and Wolak, 2021)
- Key idea: remove all customer class distinctions
  - Bill depends only on hourly pattern of consumption, not on whether you are a household or hospital or factory

How to estimate the expected hourly willingness-to-pay?



- Electricity demand for each customer varies for each hour of the year
- Note that expected CS is proportional to $\mathrm{E}[Q^2]$

Allocate required revenue based on EEHWTP

- Given hourly consumption Q_h:

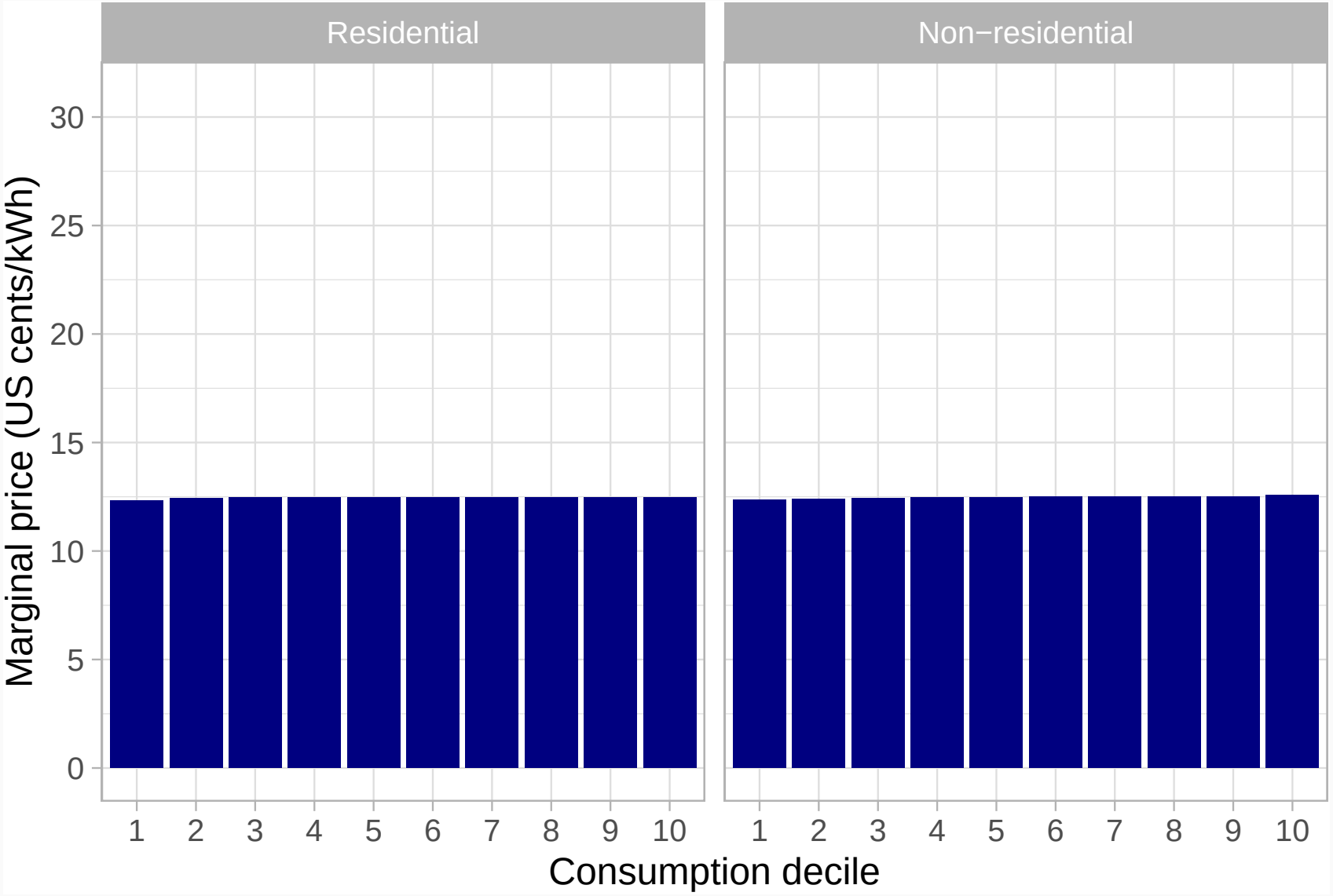
$$EEHWTP = \mathsf{E}[Q_h^2] = (\mathsf{E}[Q_h])^2 + \mathsf{var}(Q_h)$$

- With hourly metered data for the year, this expression can be calculated for every customer
- Total revenue requirement can be allocated proportionally based on $\mathsf{E}[Q_h^2]$
- Customers with (i) higher mean consumption, or (ii) greater variance in their consumption, will be assigned a higher fixed charge

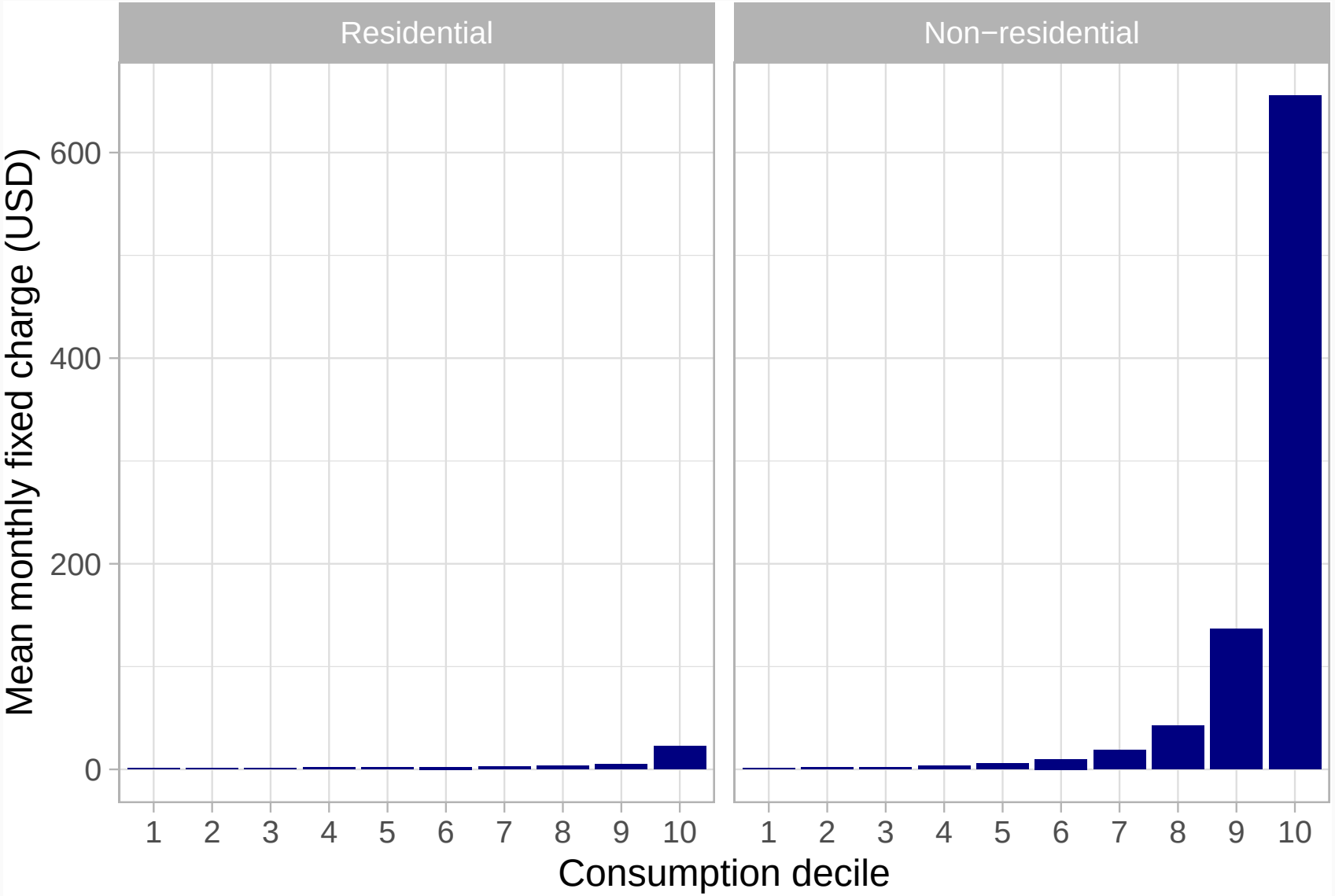
Empirical simulation: show effects of proposed tariff

- Use one year of billing data (2014) for customers (residential and nonresidential) of all distribution utilities in Colombia
- Calculate the contribution to revenue recovery for each customer and aggregate to get total revenue requirement
- Compute $EEHWTP = \mathsf{E}[Q_h^2]$ using the hourly allocation of consumption over the 8760 hours of the year
  - Cap the customer-level EEHWTP at the 99.5th percentile
- Set the fixed charge by allocating the total revenue requirement proportionately based on $\mathsf{E}[Q_h^2]$ for each user
  - Include additional monthly fixed fee based on voltage level

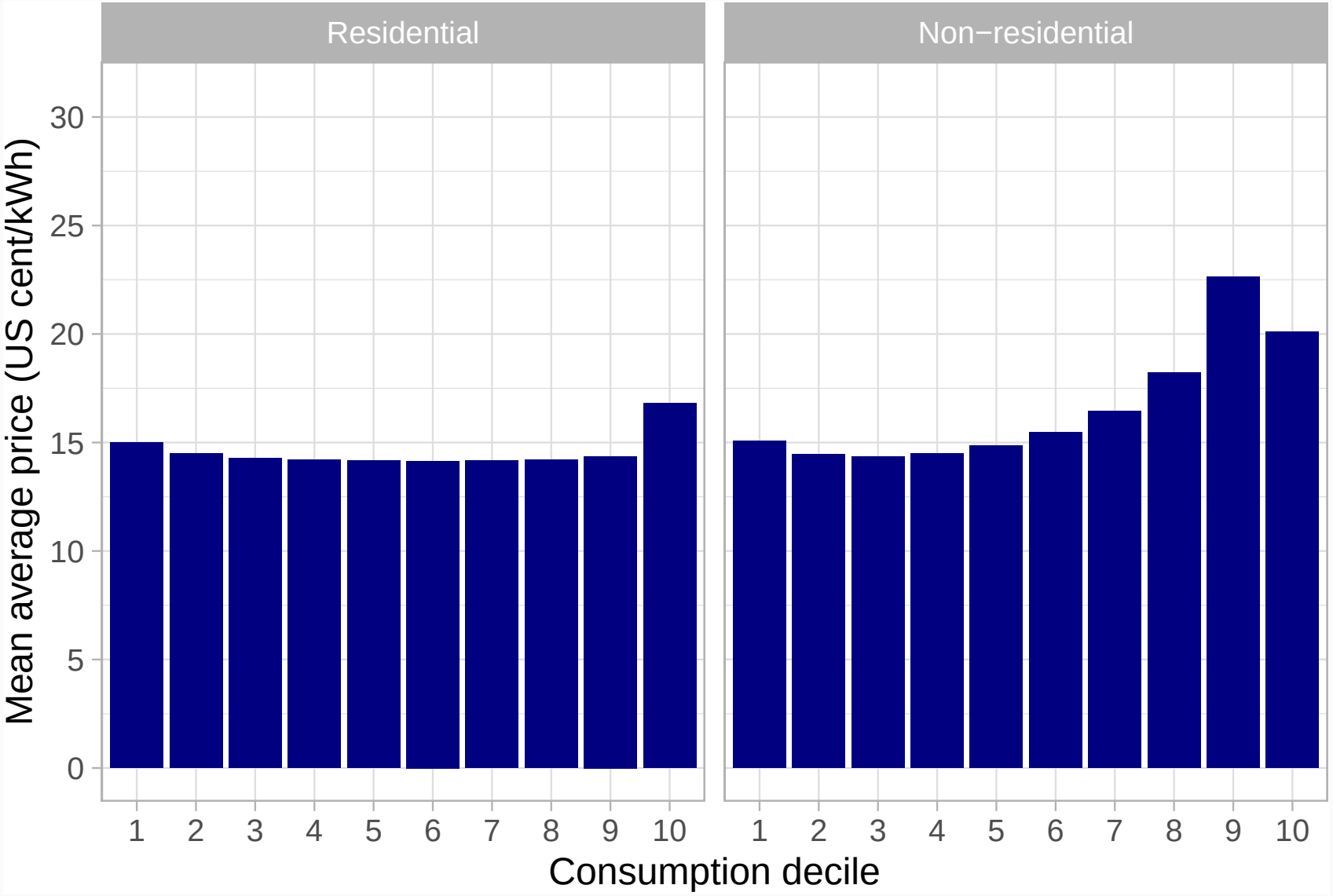
Marginal price is the same for all users under proposed tariff



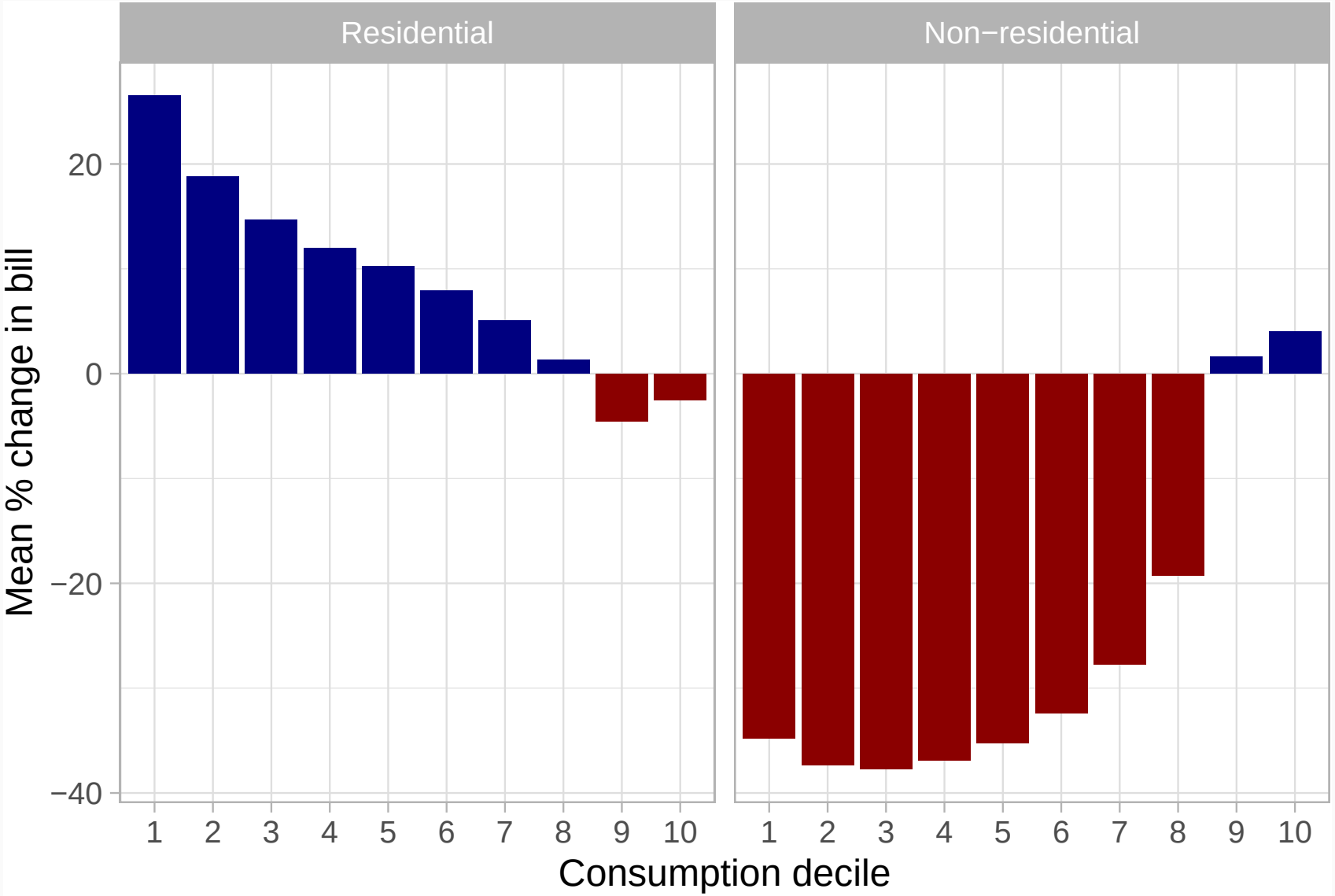
Fixed charges under proposed tariff vary based on EEHWTP



Average price rises for households but fall for small businesses



Most non-residential users better off under proposed tariff



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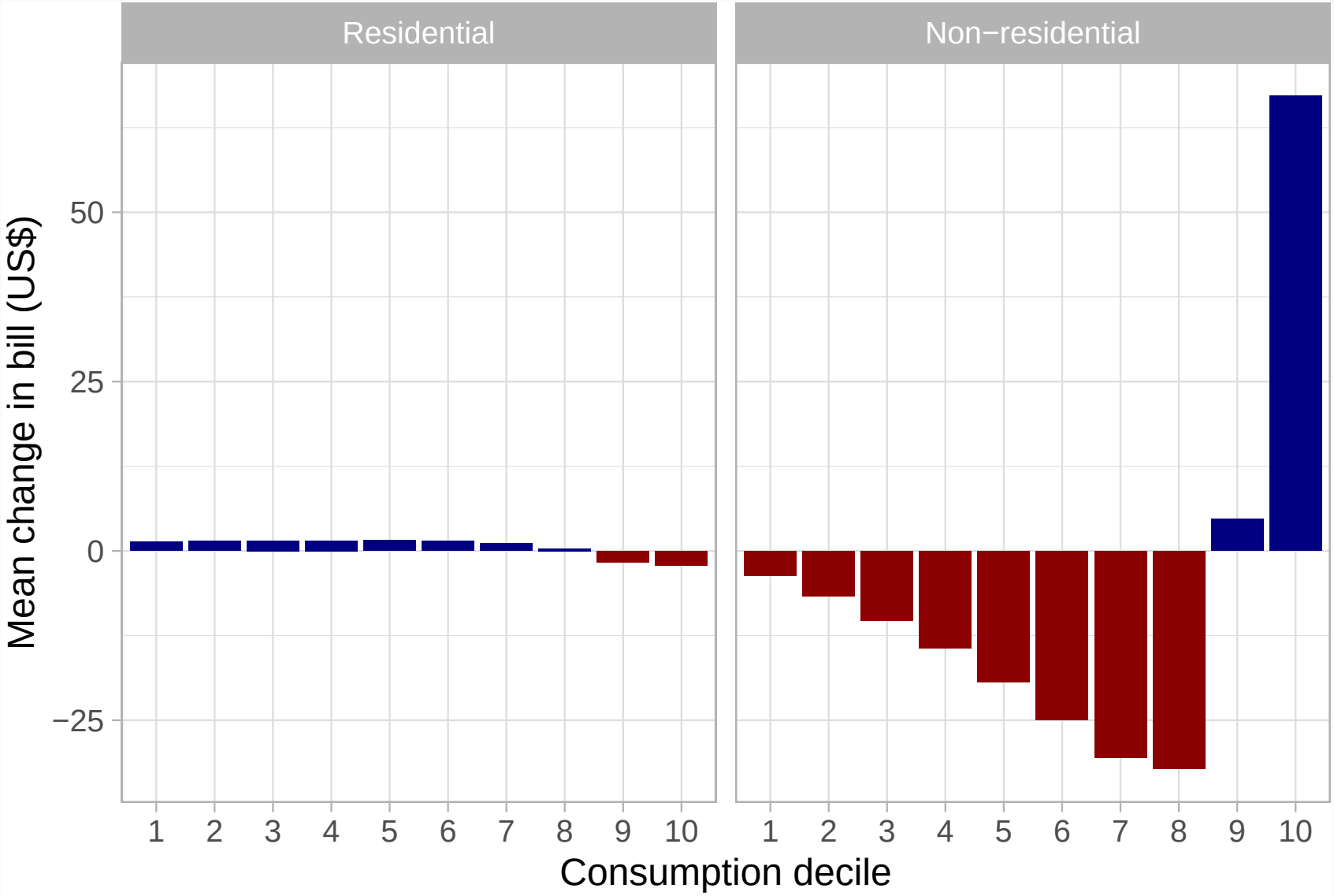

What are the advantages of our proposed tariff?

1. Provides all electricity consumers with the correct time-varying marginal price, including environmental damages
   - Lower marginal price supports increased electrification by households and firms
   - Provides incentive to shift consumption to lower-priced hours
2. Eliminates all differences in tariffs by sector, connection type, and neighborhood
   - Reduced administrative complexity
   - No incentive for strategic behavior to reclassify to a lower tariff

What are the advantages of our proposed tariff?

3. Determines electricity bills solely based on information collected by the utility
   - No need for separate neighborhood classification procedure
   - Avoids collecting household information such as income for means-testing tariffs (c.f. California proposals)
4. Discourages efforts to strategically manipulate consumption to reduce fixed charge component tariff
   - Calculation uses consumption from all 8760 hours of the year
   - Attempts to reduce fixed charge allocation (e.g. by smoothing consumption) likely lead to lower costs for the utility

What are the advantages of our proposed tariff?

5. Supports efficient levels of investment in distributed generation and electricity storage
   - All kWh are bought and sold at the hourly system price
   - Reduced variance of electricity purchases and sales (e.g. using batteries) rewarded through lower fixed charge

Conclusion

Conclusion

- We illustrate the wide variation in marginal prices across residential and non-residential customers in Colombia
- These distort the incentives for investments in (e.g.) electrification and energy efficiency
- We propose an alternative welfare-improving tariff that removes all existing customer class distinctions
    - All consumers would face the same time-varying marginal price
    - Proposed mechanism for allocating fixed charges would provide greatest benefits to small non-residential consumers