# What matters for the racial disparity in clean heating technology adoption? Evidence from U.S. heat pumps

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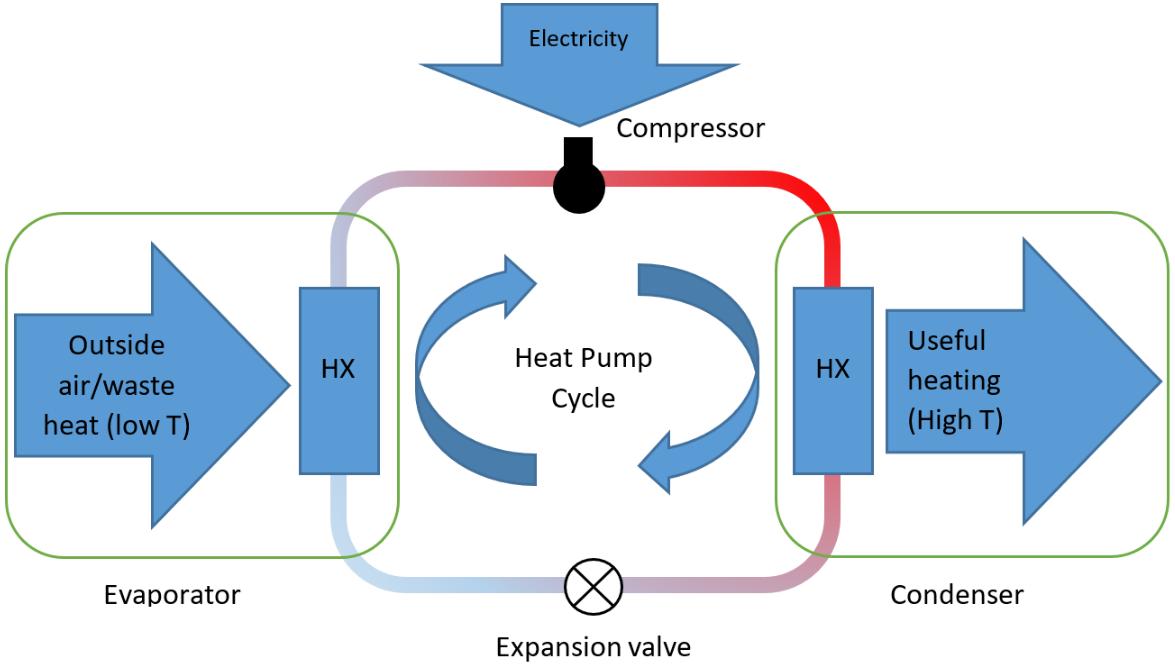
# Air source heat pumps

- Electric
- Cooling and heating
- Energy efficient – save bills
- Increase home sales prices

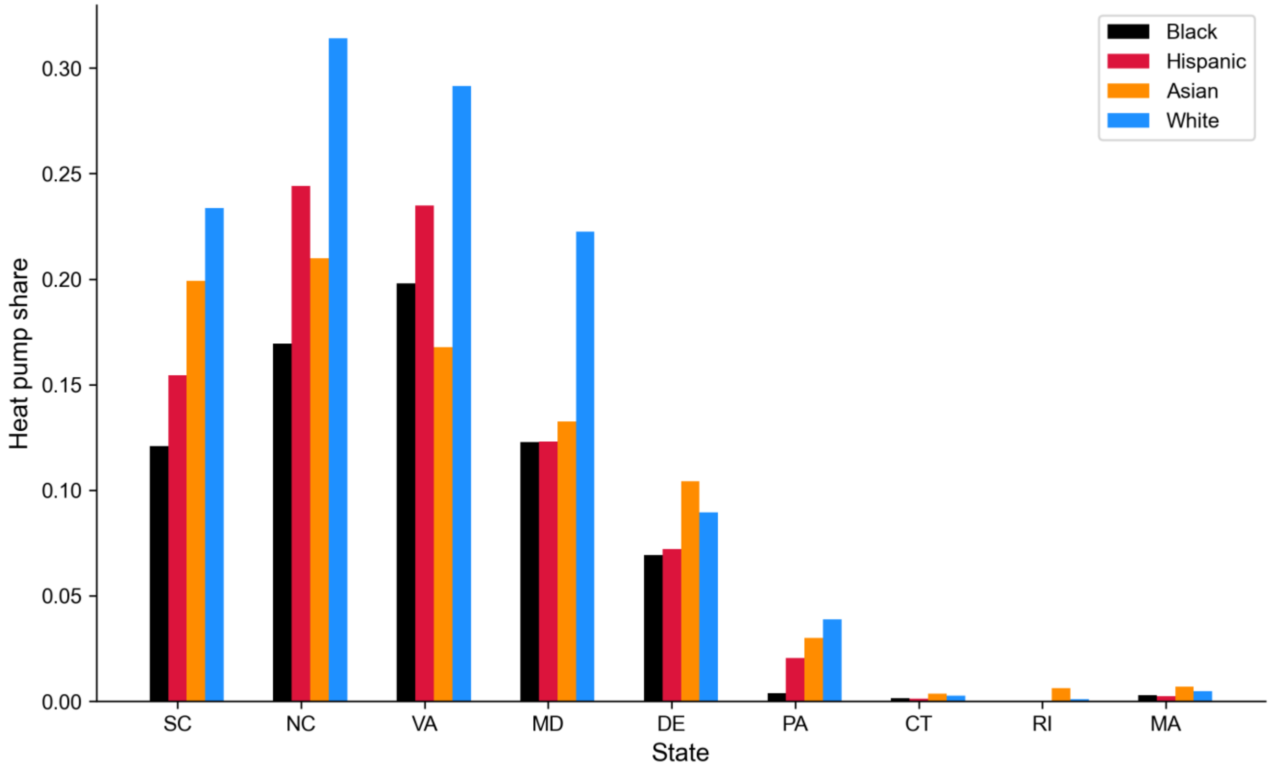


# Minority people install fewer heat pumps

- In the U.S., minority groups have disproportionately installed fewer heat pumps **on average** (Edwards et al. 2023).
- Few studies have explored the underlying **reasons**.
- The degree of racial inequality is **heterogeneous**.

## Research questions:

- What is the distribution of racial inequality in the adoption of air source heat pumps?
- What can explain the heterogeneity of racial inequality?
- Why are minority groups less likely to adopt air source heat pumps?




Heat pump adoption share by race.
Data source: CoreLogic & DataAxle, 2021

# Data

- Household property data 2009 -2021 (CoreLogic)
    - Address, building structure, building and land size, year built, and heating and cooling equipment, among other features

- Household demographic data 2021 (DataAxle)
    - Address, income, wealth, purchasing power, age of the household head, number of children, homeownership, ethnicity

- Education levels of individuals 2021 (L2)

- Public data
    - HDD and CDD from NOAA, Sales and revenues of electric utilities from EIA 861, Natural gas price from EIA, Utility service territory from HIFLD, Energy efficiency incentives from DSIRE & websites, Yale Program on Climate Change Communication

# Heterogeneity in the racial gap of heat pump adoption

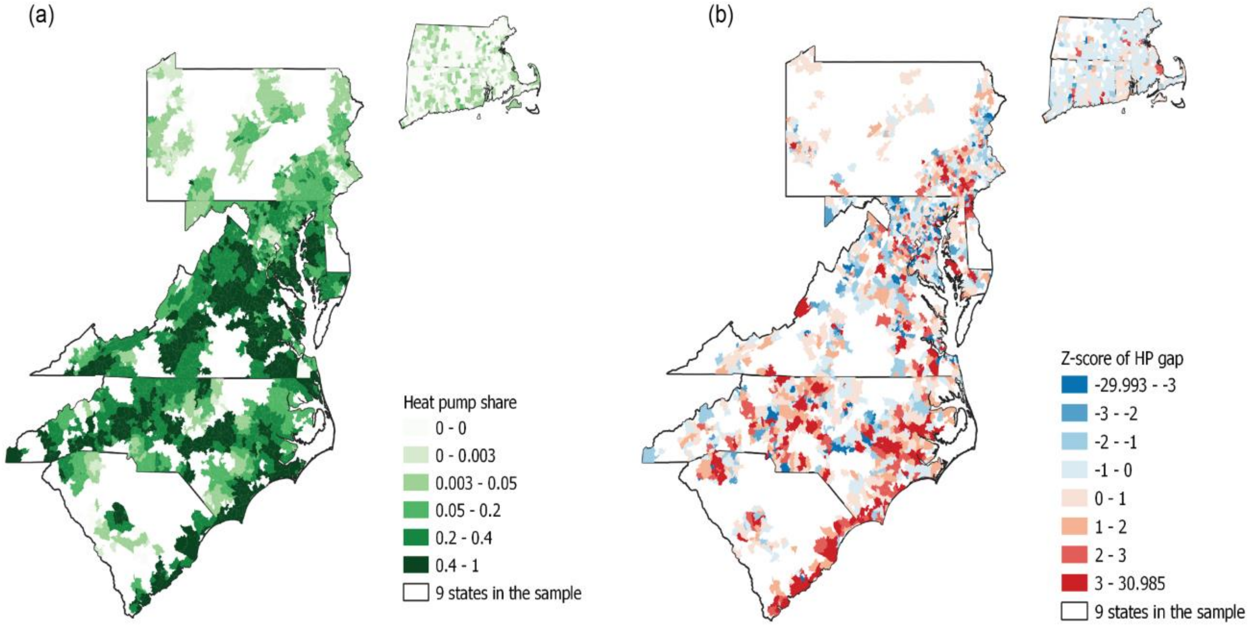
## Measurement – Z score

- To measure the heat pump adoption gap in a standardized way, I borrow the idea from the Z statistic test commonly used to test the difference between two binomial distributions.

$$Z\text{-score} = \frac{p_w - p_m}{\sqrt{\hat{p}(1-\hat{p})\left(\frac{1}{n_w} + \frac{1}{n_m}\right)}}$$

- The minority households in this analysis refers to Hispanic and Black households.
- Positive score means White households are more likely to adopt heat pumps.

## Distribution of heat pumps and racial inequality




13 million households in SC NC VA MD DE PA CT RI MA

# Decomposing the drivers of racial gap

## Method

1. Review the factors related to heat pump adoption based on a model of energy efficiency investment.

2. Construct the covariates related to heat pump adoption at the ZIP code level based on the theoretical model.

3. A two-step data-driven approach to decompose the drivers:
   - Machine learning - LASSO
   - Shapley Value regression - to decompose R-square

# Covariates

## Model of energy efficiency investment

- When deciding between a heat pump and a classical HVAC system, a rational and time-consistent agent would opt for the heat pump if and only if:

$$\underbrace{u(P_h - P_c)}_{\text{initial costs}} < \underbrace{\sum_{t=1}^{T}[\delta^t \cdot u(\sigma_{ct} - \sigma_{ht})]}_{\text{fuel savings}} + \underbrace{u(\tau_h)}_{\text{warm glow}}$$

- Minority groups install fewer heat pumps:

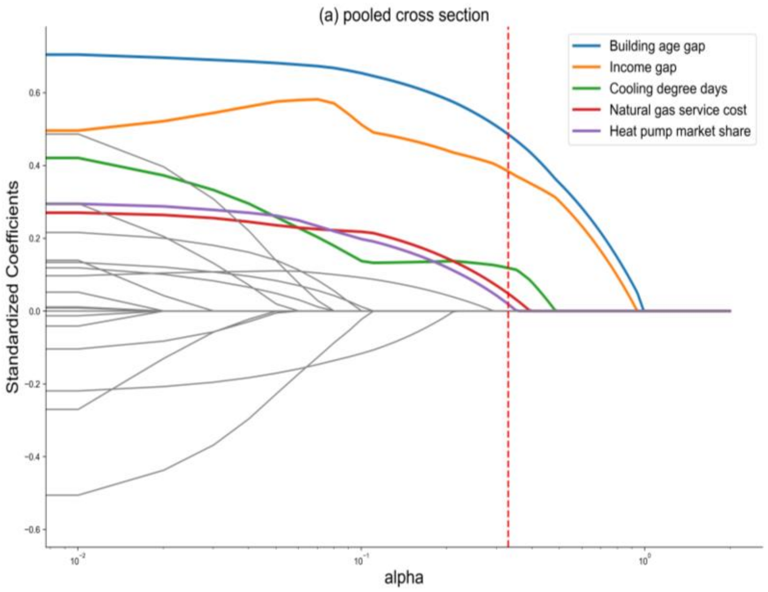
$$\frac{1}{N^w}\sum_{i=1}^{N^w} \mathbb{1}\{WTP_i^w > P_{h,i}^w\} > \frac{1}{N^m}\sum_{i=1}^{N^m} \mathbb{1}\{WTP_i^m > P_{h,i}^m\}$$

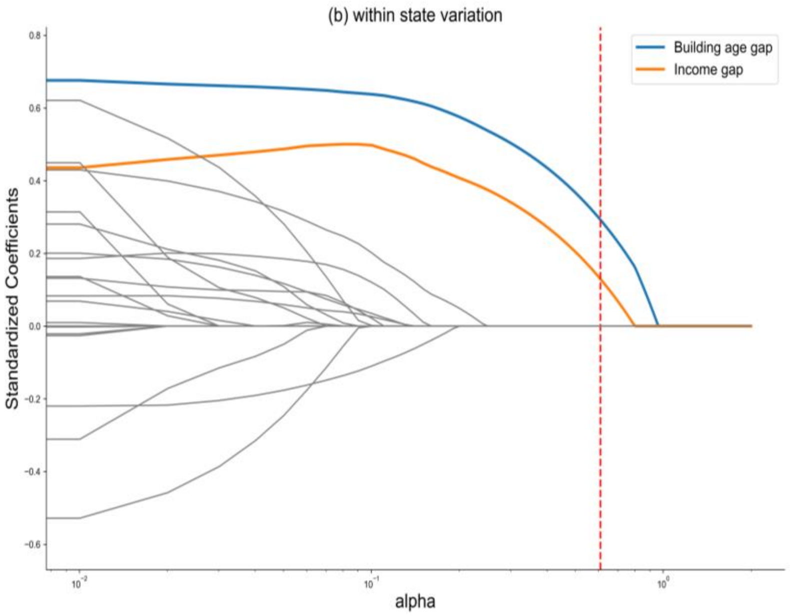
## Observed covariates

- Initial installation costs:
  - Average and racial gap of building attributes (year built, total living area, and housing type), education level and gap, $\sum_{t=1}^{10} rebate_{t,z}$, $\sum_{t=1}^{10} loan_{t,z}$
- Fuel savings:
  - Average HDD and CDD for past decade, average electricity and natural gas price for past decade, utility natural gas access, homeownership level and gap
- Discount rates:
  - Income and wealth levels and gaps, $\sum_{t=1}^{10} loan_{t,z}$
- “Warm glow” effects:
  - Education level and gap
  - Opinion about climate change

# Two-step data-driven approach to decompose the contributions

## 1. Model selection - Lasso




## 2. R-square decomposition – Shapley Value

| | Pooled cross section | | Within state variation | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| | Lasso | $R^2$ share | Lasso | $R^2$ share |
| Year built gap | 0.7772*** | 0.43 | 0.6328*** | 0.57 |
| | (0.1377) | | (0.1429) | |
| Income gap | 0.5765*** | 0.35 | 0.6855*** | 0.43 |
| | (0.1227) | | (0.1286) | |
| CLDD | 0.1883** | 0.08 | | |
| | (0.0738) | | | |
| Natural gas price/access | 0.2868*** | 0.08 | | |
| | (0.0555) | | | |
| Heat pump market share | 0.2834*** | 0.06 | | |
| | (0.0711) | | | |
| State FE | No | | Yes | |
| R-squared | 0.1804 | | 0.1396 | |
| Number of observations | 2,351 | | 2,353 | |

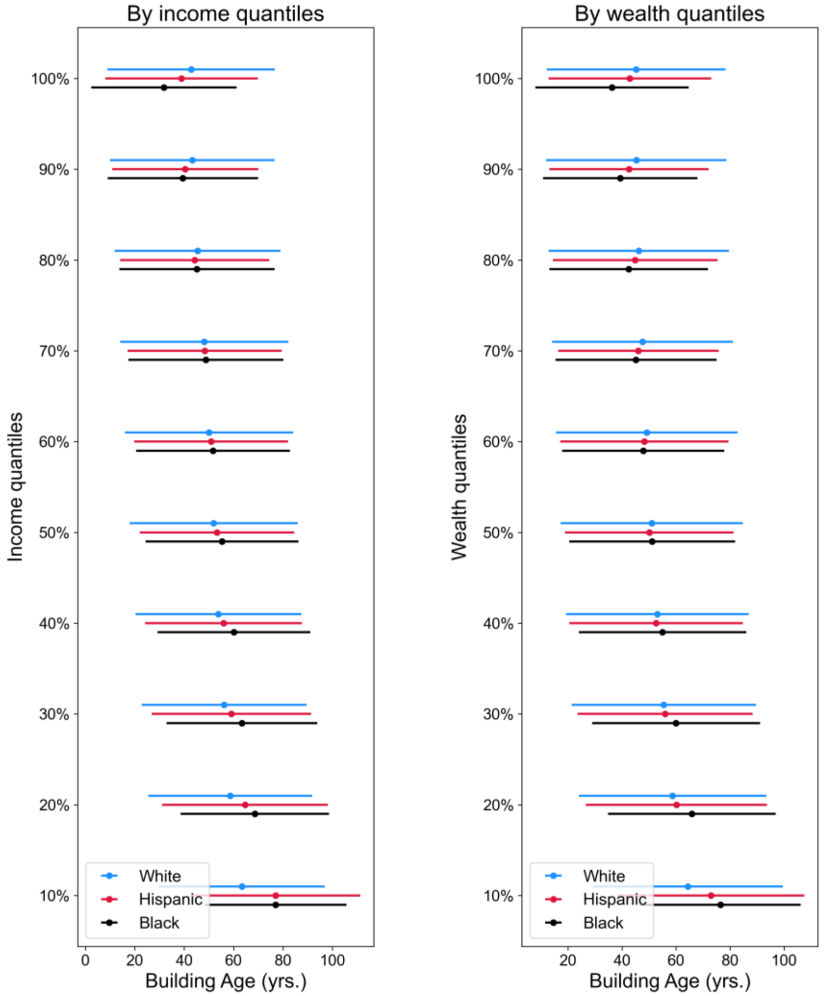
Note: *** p<0.01, ** p<0.05, * p<0.1.

# The racial gap in building age persists after conditioning on income

## Low-income and low-wealth Black and Hispanic populations are more likely to own older buildings compared to low-income and low-wealth White populations.

## Historical or ongoing discriminatory housing market:

- Redlining (Swope et al. 2022)
- Zoning policies (Ellickson 2022)
- Steering (Galster 1990; Christensen and Timmins 2018)
- Intergenerational wealth accumulation (Shapiro et al. 2013)
- and others.



# Causal evidence: Lower temperature increases racial gap in warm region

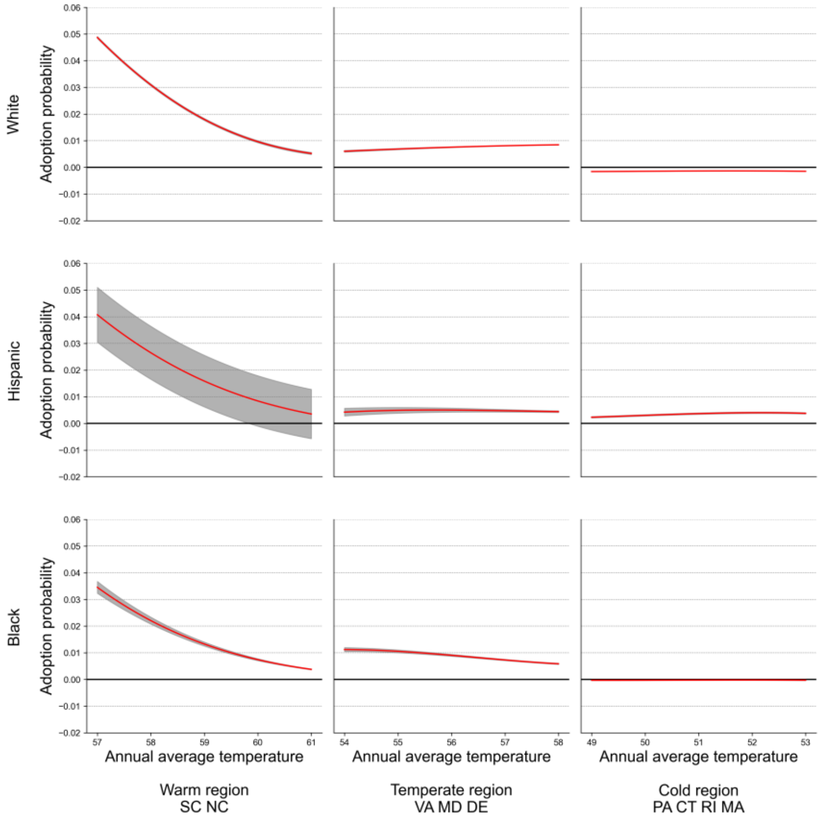
## Identification

I construct a panel data at the individual household level, covering the years from 2010 to 2021. A linear probability model is employed:

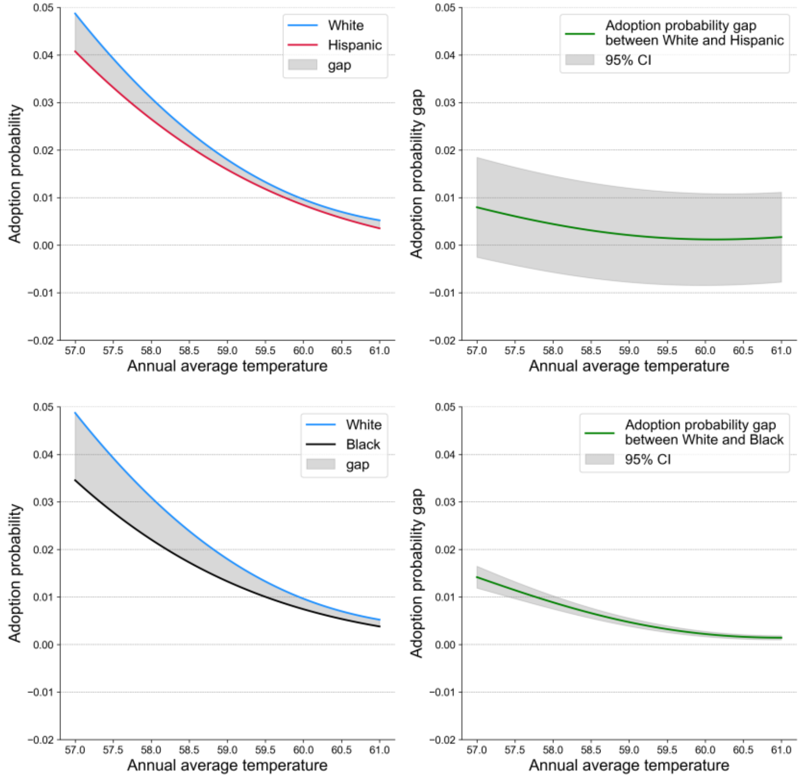
$$\Delta Y_{ijst} = g(\boldsymbol{T}_{it}, R_j, C_s) + \boldsymbol{Elec}_{it} + \alpha_{st} + \delta_i + \epsilon_{ijst}$$

- $Y_{ijst}$ is dummy indicating heat pump adoption status of households
- $T_{it}$, fourth-order polynomials of annual average temperature
- $R_j$, the racial identity
- $C_s$, the climate regions

## Impacts by race and region




## Racial gap in warm region



# Causal evidence: Higher natural gas price increases racial gap

## Identification

- A panel dataset is constructed including households located within natural gas utility service territories in SC, NC, VA, MD, and DE covering the years 2010-2021.
- A LPM model is employed:

$$\Delta Y_{ijst} = \beta \log(Ng_{st}) + \boldsymbol{Elec}_{it} + \boldsymbol{HDD}_{it} + \boldsymbol{CDD}_{it} + \alpha_t + \delta_i + \epsilon_{ijst}$$

with $j = \{\text{White, Hispanic, Black}\}$

- The difference in coefficients between different racial groups can be interpreted as the change in the heat pump adoption gap resulting from a one percent increase in natural gas prices.

## Impacts by race

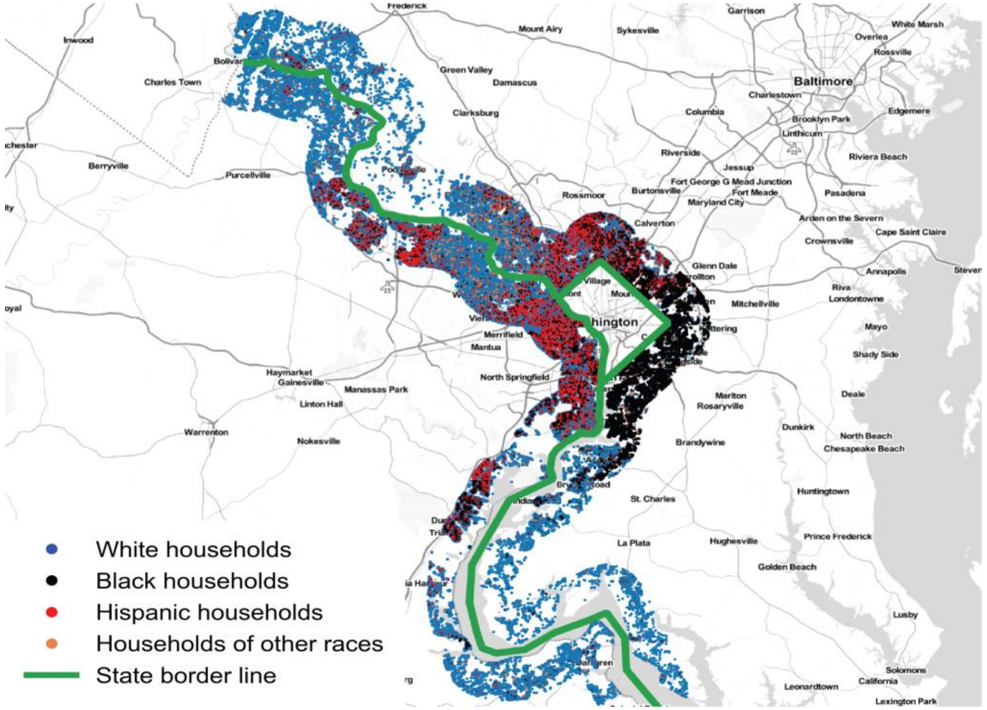
| | (1) All | (2) White | (3) Hispanic | (4) Black |
|---|---|---|---|---|
| log(natural gas price) | 0.015*** | 0.018*** | 0.011*** | 0.003*** |
| | (0.0003) | (0.0003) | (0.0009) | (0.0008) |
| 4th polynomials of elec price | Yes | Yes | Yes | Yes |
| 4th polynomials of HDD | Yes | Yes | Yes | Yes |
| 4th polynomials of CDD | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes |
| Household FE | Yes | Yes | Yes | Yes |
| R-squared | 0.0087 | 0.0096 | 0.0049 | 0.005 |
| Number of observations | 41,296,249 | 33,046,818 | 2,714,485 | 5,534,946 |
| Number of households | 5,148,441 | 4,157,366 | 328,996 | 662,079 |

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

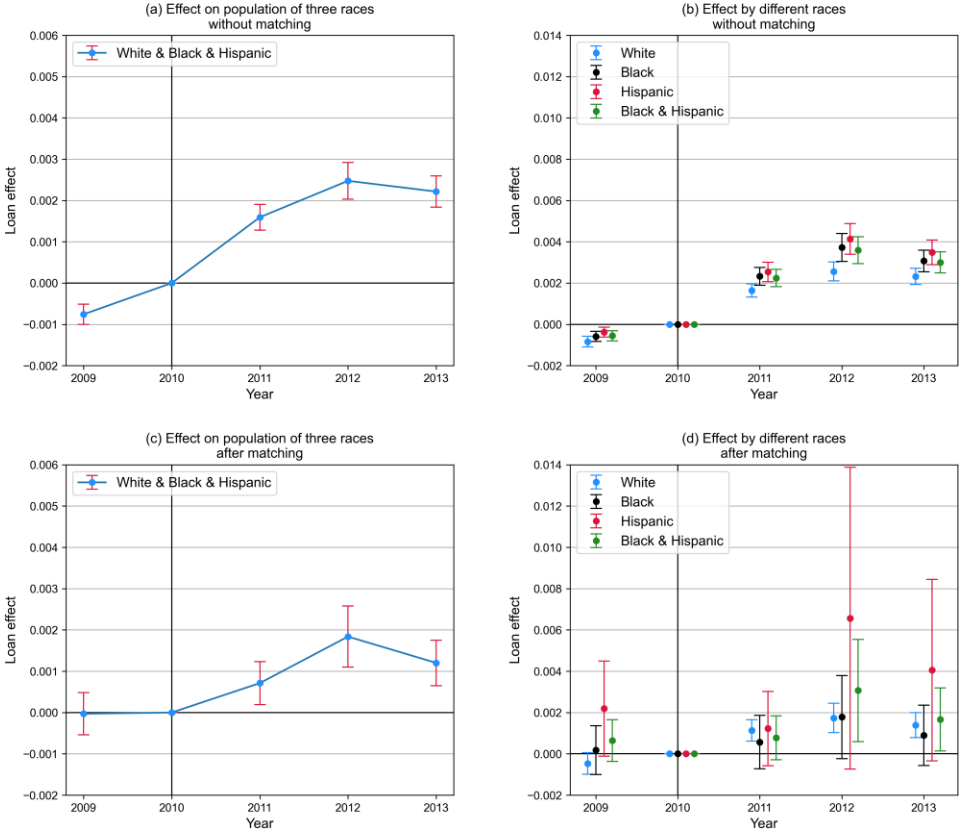
# Loan programs slightly reduce racial gap in heat pump adoption

## Be SMART financing program in MD

Identification – Difference in differences




## Event study – effects by race

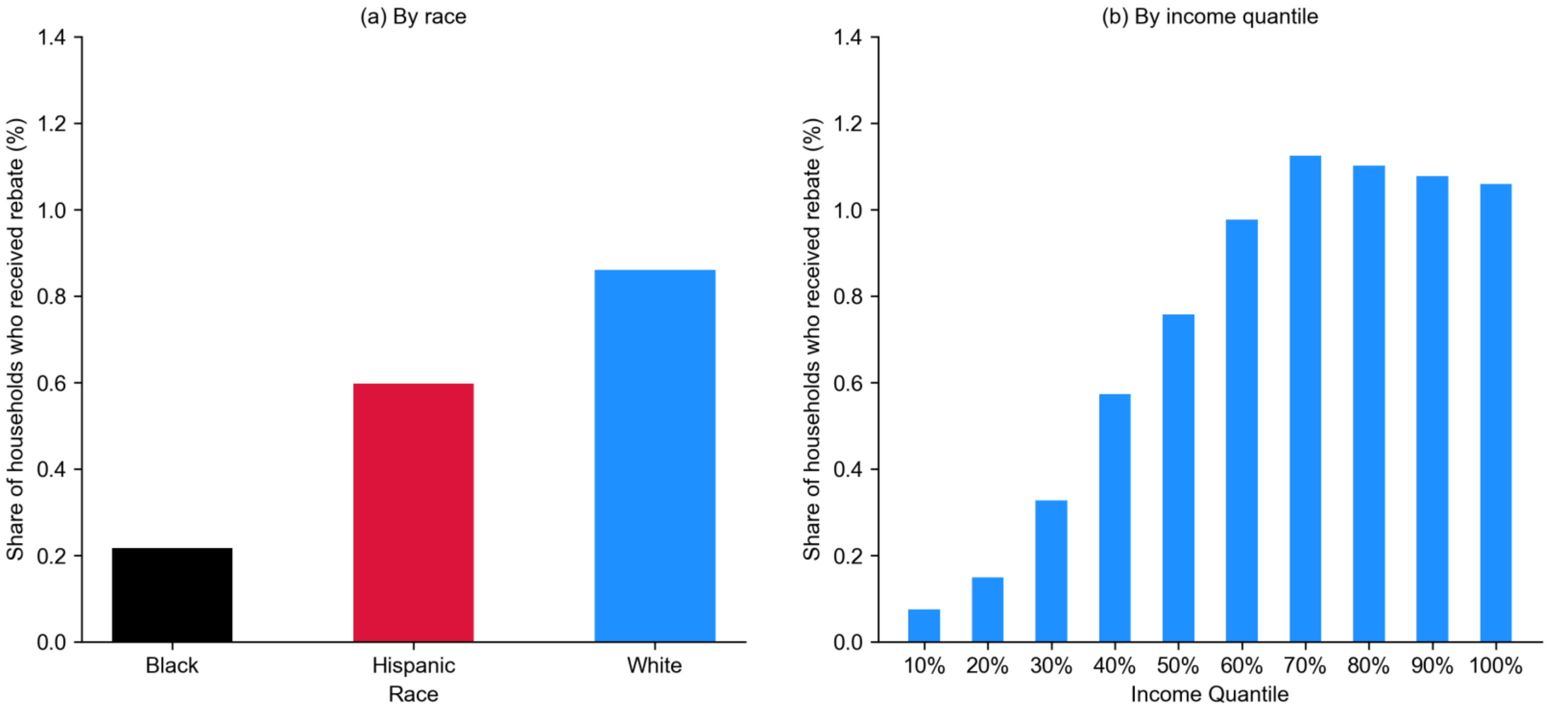


# Minority groups received fewer rebates

## MA Clean Energy Center rebate program

- Rebate amount was about $600 per ton, and the total amount paid was 28 million dollars between 2014 and 2019.
- I match rebate recipients' address with household demographic data sourced from DataAxle.
- The program was designed to give higher rebate amounts per installed heat pump to low income.

## The share of households who received rebate 2014-2019, MA



# Policy implications

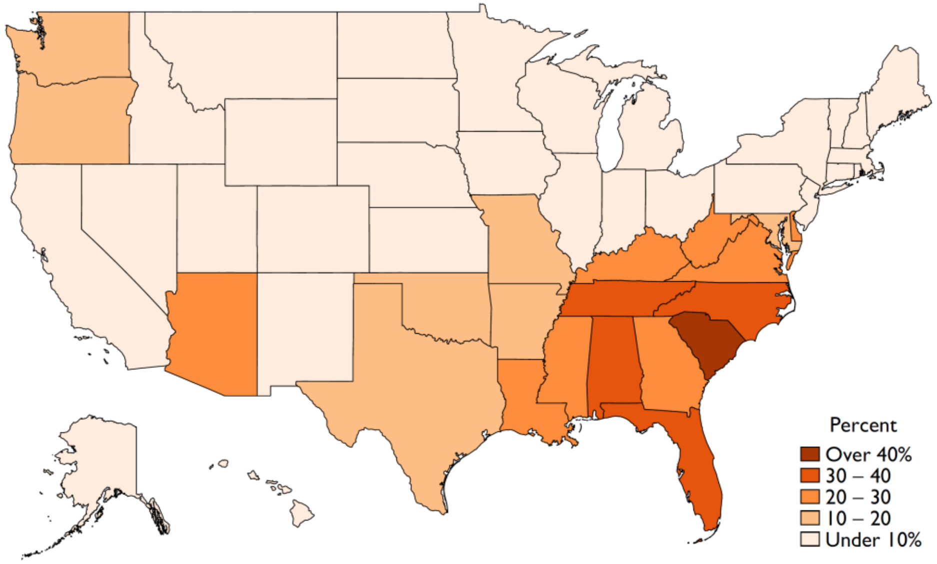
Enact more targeted policy interventions that promote building retrofits, particularly in older structures where low-income minority populations are disproportionately represented.

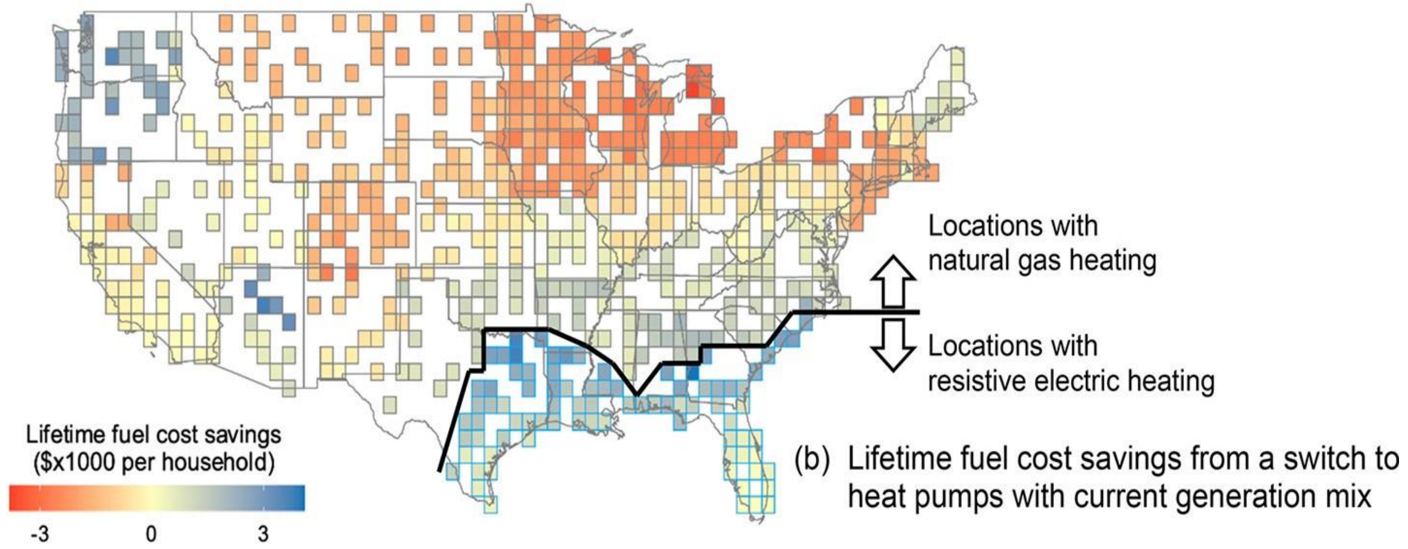
The climate change and increase in natural gas prices (e.g., carbon pricing, outright ban) can amplify the racial disparity in heat pump adoption.

Low-interest loan programs can offer a lower public budget burden while also having the potential to alleviate the racial gap.

# Thank you!

# The distribution of heat pumps and private benefits




Heat pump adoption
Source: Davis 2023

Air source heat pump lifetime fuel cost savings
Source: Vaishnav & Fatimah, 2020