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

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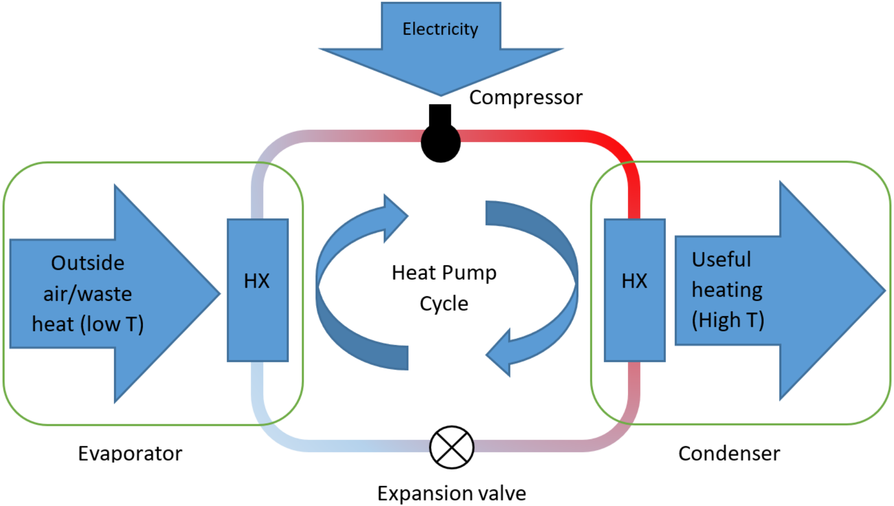
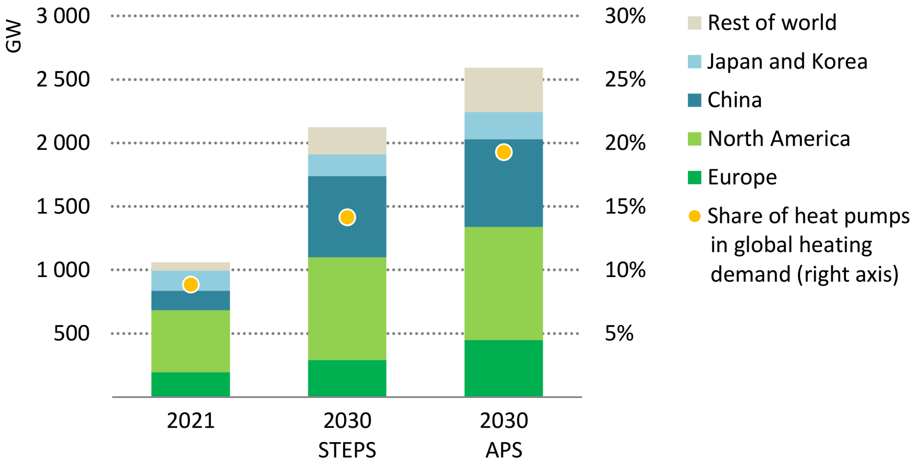
Air source heat pumps



Heat pump capacity in buildings by country/region and scenario, 2021 and 2030



STEPS: Stated Policies Scenario; APS: Announced Pledges Scenario

Figure source: The Future of Heat Pumps, IEA 2022

Heat pump adoption by state

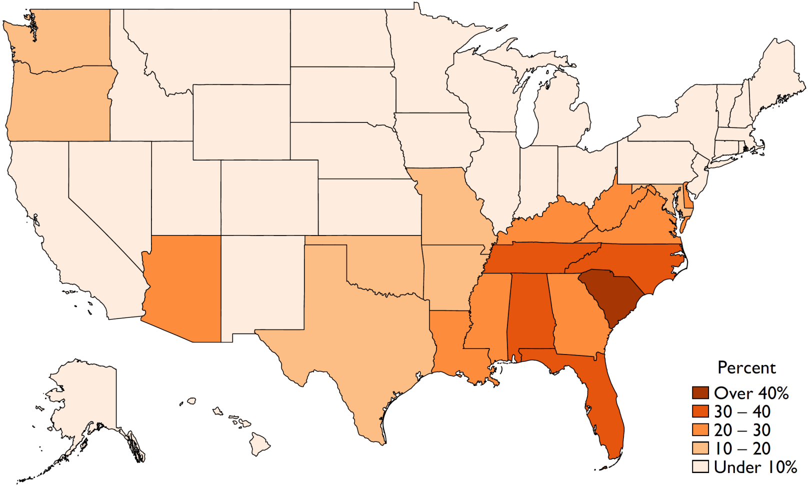


Figure source: Davis 2023

Data source: Residential Energy Consumption Survey 2020

Air source heat pumps - lifetime fuel cost savings

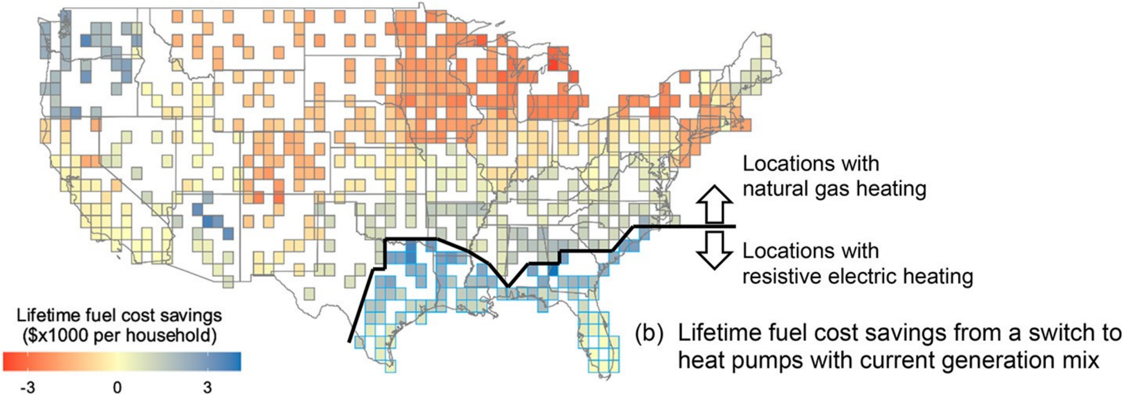


Figure source: Vaishnav & Fatimah, 2020

Air source heat pumps raise home prices

ARTICLES
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nature energy

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Estimation of change in house sales prices in the United States after heat pump adoption

Xingchi Shen[1,4], Pengfei Liu[2,4], Yueming (Lucy) Qiu[1,4] ✉, Anand Patwardhan[1] and Parth Vaishnav[3]

Electrifying most fossil-fuel-burning applications provides a pathway to achieving cost-effective deep decarbonization of the economy. Heat pumps offer a feasible and energy-efficient way to electrify space heating. Here, we show a positive house price premium associated with air source heat pump installations across 23 states in the United States. Residences with an air source heat pump enjoy a 4.3–7.1% (or US$10,400–17,000) price premium on average. Residents who are environmentally conscious, middle class and live in regions with mild climate are more likely to pay a larger price premium. We find that estimated price premiums are larger than the calculated total social benefits of switching to heat pumps. Policymakers could provide information about the estimated price premium to influence the adoption of heat pumps.

Source: Shen, Liu, Qiu, et al., 2021

Heat pump sales in U.S. surged past gas furnaces in 2022

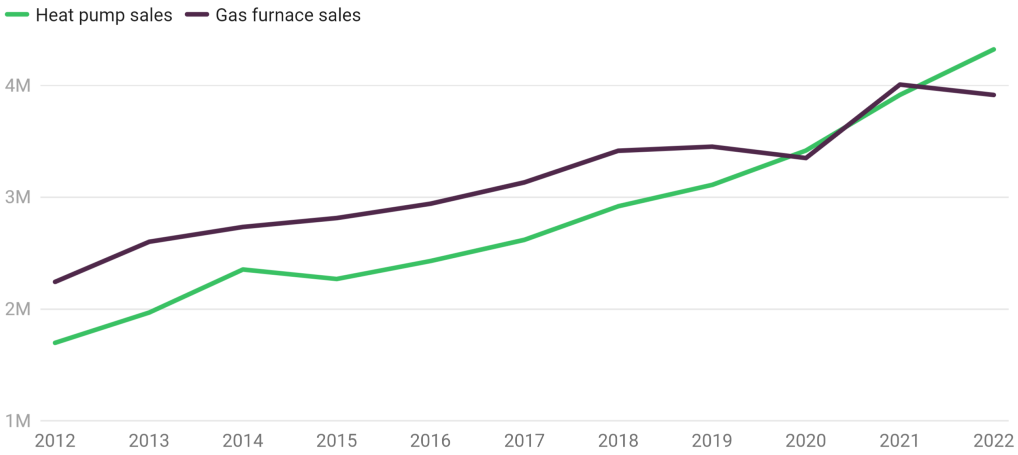
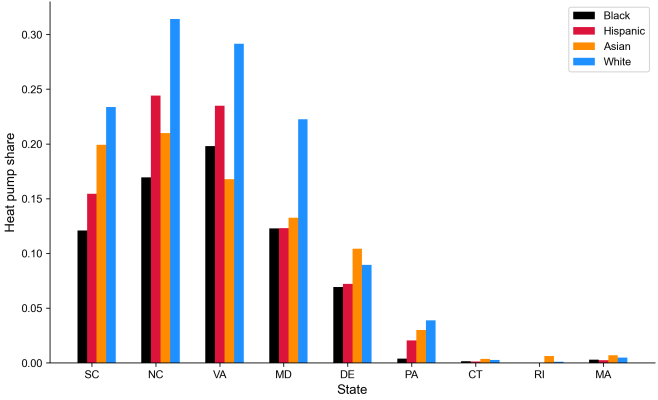


Figure source: Canary Media 2023

Data source: Air-Conditioning, Heating, and Refrigeration Institute

Minority people install fewer heat pumps

- Minority groups installed much fewer heat pumps disproportionately in the U.S. (Edwards et al. 2023).
- However, the degree of racial disparity may vary across locations.
- Additionally, few studies have investigated the underlying causes of this racial disparity in heat pump adoption.



Data source: 2021 CoreLogic & DataAxle

HP by income

Research questions

- What is the distribution of racial inequality in the adoption of air source heat pumps?
- What can explain the racial inequality in the adoption of air source heat pumps?
- Why do minority groups have less access to air source heat pumps?

In this paper,

- I quantify the heat pump adoption gap between White and minority households at the ZIP code level.

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- I employ a machine learning approach to decompose the contributors to the racial disparity.
- The gap in building age is the most important contributor, followed by income gap, cooling degree days, and natural gas prices or access.
- Leveraging within-location annual variations, I provide causal evidence that an increase in heating demand and natural gas prices can widen the racial gap in heat pump adoption.

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- The gap in building age is the most important contributor, followed by income gap, cooling degree days, and natural gas prices or access.
- Leveraging within-location annual variations, I provide causal evidence that an increase in heating demand and natural gas prices can widen the racial gap in heat pump adoption.
- Then I explore the role of public policies. Loan programs slightly reduce the gap, while small rebate programs widen the racial gap.

Literature review

- Inequality in accessing clean energy technologies, such as rooftop solar panels, electric vehicles, energy-efficient appliances, and housing units, exists among different racial and income groups. (Barbose et al. 2020; Borenstein and Davis 2016; Brown 2022; Davis 2019; Edwards et al. 2023; Gao and Zhou 2022; Hsu and Fingerman 2021; Min et al. 2023; Paulos 2017; Sunter et al. 2019).

- Common policies promoting clean energy technology can negatively affect lower-income groups (Bennear 2022; Borenstein and Davis 2016; Bento et al. 2009; Davis and Knittel 2019; Jacobsen 2013; Levinson 2019; Bruegge et al. 2019).

- Targeted programs for low-income groups can boost clean energy adoption within that demographic (Muehlegger and Rapson 2018; O'Shaughnessy et al. 2020).

Data

Household property data

- source: CoreLogic
- years 2009-2021, all the land parcels in the U.S.
- address, building structure, building and land size, year built, and heating and cooling equipment, among other features

Household demographics data

- source: DataAxle
- year 2021, nation-wide households
- address, income, wealth, purchasing power, age of the household head, number of children, homeownership, ethnicity

Education levels of individuals

- source: L2, a voter data provider
- year 2021, nation-wide voters

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

▸ Robustness

Decomposing the drivers of racial inequality

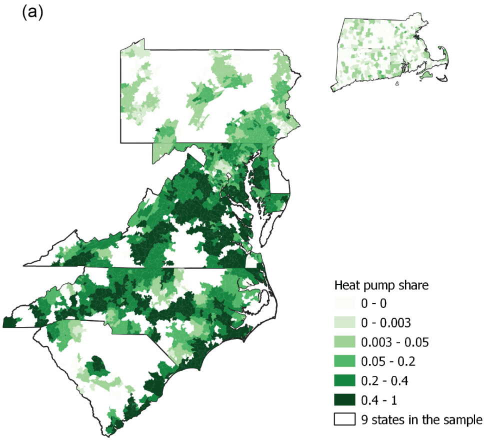
Measuring heat pump adoption racial inequality

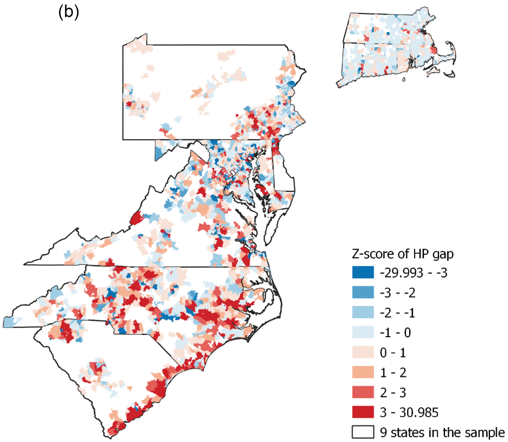
To measure the heat pump adoption gap in a standardized way, I borrow the idea from the Z statistic test commonly used to test the difference between two binomial distributions.

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

where $\hat{p} = \frac{n_w p_w + n_m p_m}{n_w + n_m}$; p_w and p_m are the heat pump adoption rates of White families and minority families, respectively; n_w and n_m are the number of White families and minority families, respectively.

The distribution of heat pumps and racial adoption gaps by ZIP codes





13 million households

States: SC NC VA MD DE PA CT RI MA

Theoretical model

Following Allcott and Greenstone (2012); Berkouwer and Dean (2022); Shen et al. (2022), 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:

$$\underbrace{u(P_h - P_c)}_{\text{initial costs}} < \underbrace{\sum_{t=1}^{T} [\delta^t \cdot u(\sigma_{ct} - \sigma_{ht})]}_{\text{fuel savings}} \quad + \quad \underbrace{u(\tau_h)}_{\text{warm glow}} \tag{2}$$

$$WTP = P_c + \sum_{t=1}^{T} \delta^t \sigma_t + \tau_h \tag{3}$$

Minority groups install fewer heat pumps:

$$\frac{1}{N^w} \sum_{i=1}^{N^w} \mathbb{1}\{WTP_i^w > P_{h,i}^w\} > \frac{1}{N^m} \sum_{i=1}^{N^m} \mathbb{1}\{WTP_i^m > P_{h,i}^m\} \tag{4}$$

Observed covariates at the ZIP code level

Initial installation costs:

- building remodeling costs $\rightarrow$ the average and racial gap of building attributes (year built, total living area, and housing type)
- searching costs $\rightarrow$ education level and gap
- incentives $\rightarrow \sum_{t=1}^{10} rebate_{t,z}$; $\sum_{t=1}^{10} loan_{t,z}$
- equipment and labor costs $\rightarrow$ county fixed effects

"Warm glow" effects:

- opinion about climate change
- education level and gap

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

(Implicit) discount rates:

- income and wealth levels and gaps
- $\sum_{t=1}^{10} loan_{t,z}$

▸ Summary statistics

Two-step data-driven approach

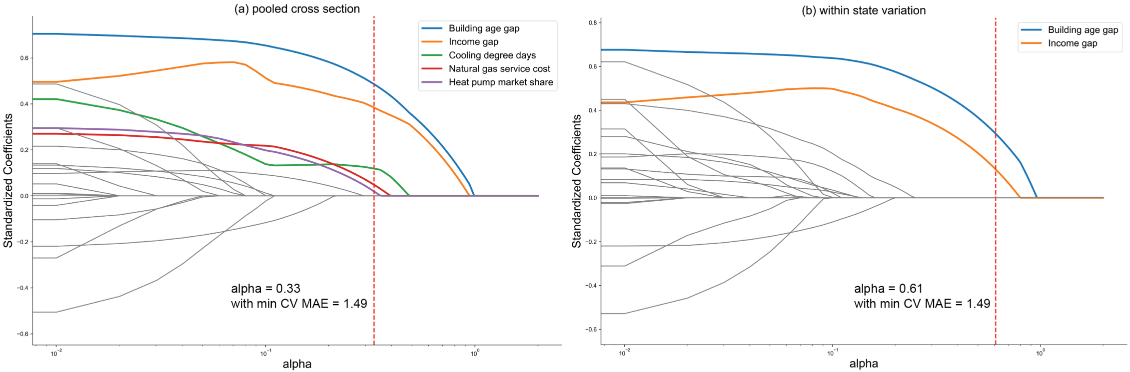
Step 1: Use LASSO regerssion to select the best specification by choosing the one with minimum 10th-fold cross-validated Mean Absolute Error (MAE):

$$\hat{\beta}_{lasso} = \operatorname{argmin}_{\beta} \left\{ \sum_{i=1}^{n} (z_i - \beta_0 \sum_{j=1}^{p} \beta_j x_{ij})^2 + \alpha \sum_{j=1}^{p} |\beta_j| \right\} \tag{5}$$

Step 2: Use Shapley Value regression to decompose the R^2 of the model selected by LASSO:

$$\varphi_i(\nu) = \frac{1}{|N|} \sum_{S \subseteq N \setminus \{i\}} \binom{|N|-1}{|S|}^{-1} (\nu(S \cup \{i\}) - \nu(S)) \tag{6}$$

Variables selection using LASSO



‣ Within county variation

‣ Robustness checks

R^2 decomposition

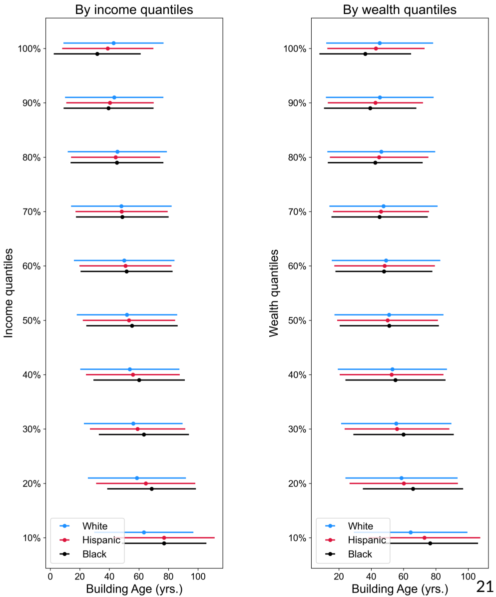
	Pooled cross section		Within state variation	
	(1)	(2)	(3)	(4)
	Lasso	R^2 share	Lasso	R^2 share
Year built gap	0.7772***	0.43	0.6328***	0.57
	(0.1377)		(0.1429)	
Income gap	0.5765***	0.35	0.6855***	0.43
	(0.1227)		(0.1286)	
CLDD	0.1883**	0.08		
	(0.0738)			
Natural gas price/access	0.2868***	0.08		
	(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.



▸ By states

Temperature, energy prices, and racial inequality

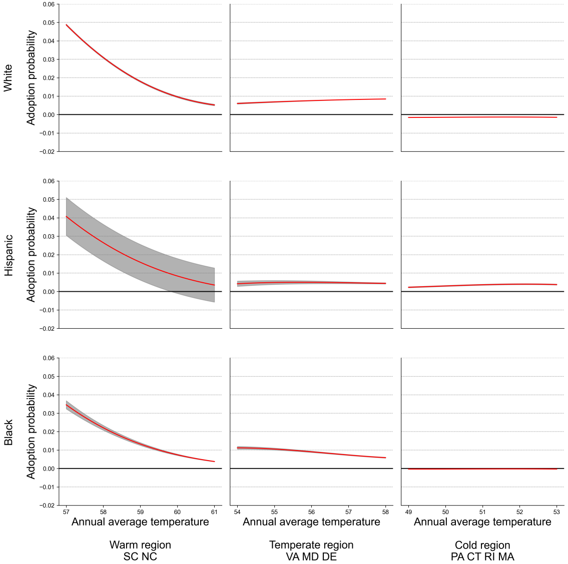
Impact of temperature change on racial inequality

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

$$\Delta Y_{ijst} = g(\boldsymbol{T}_{it}, R_j, C_s) + \boldsymbol{Elec}_{it} + \alpha_{st} + \delta_i + \epsilon_{ijst} \tag{7}$$

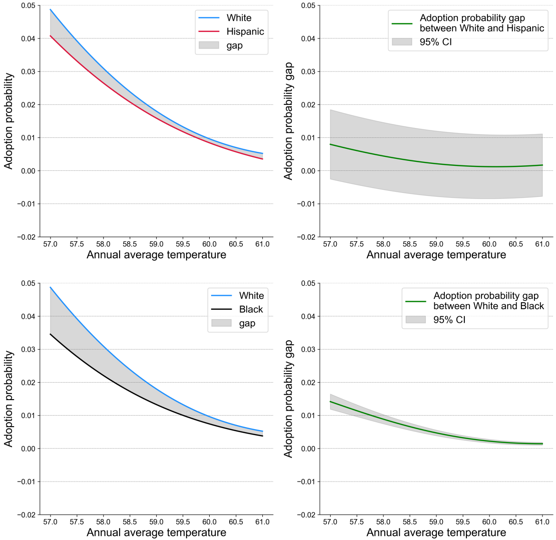
- Y_{ijst}, dummy indicating heat pump adoption status of households
- $\boldsymbol{T}_{it}$, fourth-order polynomials of annual average temperature ($^\circ$F)
- R_j, the racial identity, and C_s, the climate regions ▸ Plot
- α_{st}, state-by-year fixed effects
- δ_i, individual household fixed effects, isolate random within-location year-to-year variations in weather patterns

Impact of temperature change on adoption probability of heat pumps by race and region



▸ Robustness: HDD+CDD

The association between temperature change and heat pump adoption probability gap in NC and SC



‣ Robustness: homeowners only

Impact of natural gas prices on racial inequality

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.

$$\begin{aligned} \Delta Y_{ijst} &= \beta \log(Ng_{st}) + \boldsymbol{Elec}_{it} + \boldsymbol{HDD}_{it} + \boldsymbol{CDD}_{it} + \alpha_t + \delta_i + \epsilon_{ijst} \\ \text{with } j &= \{\text{White, Hispanic, Black}\} \end{aligned} \tag{8}$$

- Ng_{st}, natural gas price in state s and year t ▸ Variation
- $\boldsymbol{Elec}_{it}$, fourth-order polynomials of the annual electricity price at the utility level
- $\boldsymbol{HDD}_{it}$ and $\boldsymbol{CDD}_{it}$, fourth-order polynomials of annual heating and cooling degree days
- α_t and δ_i, year and household fixed effects

Impact of natural gas price change on heat pump adoption by race

- β is the percentage change in the probability of new heat pump adoption resulting from a one percent increase in natural gas prices.

- $\beta_{white} - \beta_{hispanic}$, $\beta_{white} - \beta_{black}$ can be interpreted as the change in the heat pump adoption gap resulting from a one percent increase in natural gas prices.

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

Robustness: homeowners only

Notes

- Mechanisms:
  - (1) **Projection bias**: People may utilize the temperature/energy prices of the year as a basis for inferring future energy consumption/bills for heating and cooling purposes (Busse et al. 2015; He et al. 2022; Loewenstein et al. 2003).
  - (2) **Salience**: People's attention is directed to fuel consumption, bills, or fuel efficiency. (Chetty et al. 2009; Bordalo et al. 2013).
- The impacts based on within-location annual variations can be relatively small when compared to those resulting from long-term, constant changes, such as the geographic cross-section variations discussed in the above decomposition analysis.

Public policy and racial inequality

Be SMART financing program

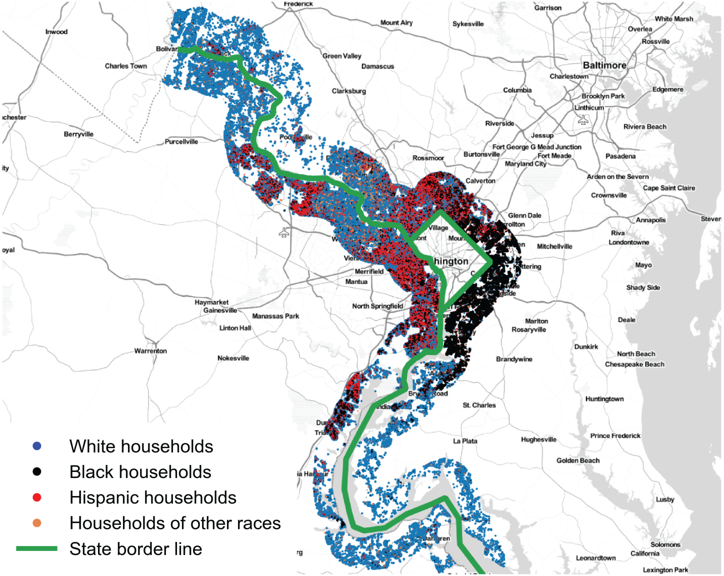
- Launched by the Maryland Department of Housing and Community Development in February 2011.
- Support energy upgrades in residential, affordable multifamily, and small commercial buildings.
- Offers loans with a low interest rate of 6.99% and up to $30,000 in financing for energy efficiency measures such as air source heat pumps.

Maryland
DEPARTMENT OF HOUSING AND COMMUNITY DEVELOPMENT

BESMART
FINANCING ENERGY EFFICIENCY UPGRADES FOR YOUR HOME

Difference-in-differences (DID) with geographic discontinuity

- The sample of households for estimating loan effects in the buffer area (5 miles each side) along the border between Maryland and Virginia.
- Study period: 2009 - 2013
- No other incentives for heat pumps, except for State Energy-Efficient Appliance Rebate Program (SEEARP) in 2010 ▸ Details.



Matching+DID

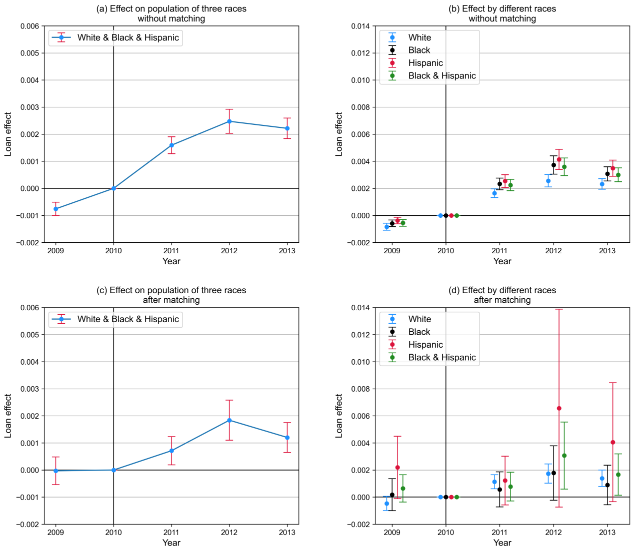
- A generalized DID matching estimator (Heckman et al. 1997; Heckman et al. 1998; Fowlie et al. 2012):

$$\hat{\beta}_{DID} = \frac{1}{N_1} \sum_{j \in \mathcal{I}_1} \left\{ \left(Y_{j,t^1}(1) - Y_{j,t^0}(0) \right) - \sum_{k \in \mathcal{I}_0} w_{jk} \left(Y_{k,t^1}(0) - Y_{k,t^0}(0) \right) \right\} \tag{9}$$

- K-Nearest-Neighbors propensity-score matching (K=5)

- Matching covariates: household income, wealth, purchasing power, home ownership, children count, house head age, building type (e.g., single-family housing and multi-family housing), and building year built. ▸ Balance checks

Event study



- Note: In subplot (b), the control groups for all specifications consistently comprise all households from VA present in my sample.

- In subplot (d), for each treated racial group in MD, the corresponding control group consists of households in VA that have been matched based on observable covariates

DDD estimator: the disparity in loan effects across racial groups

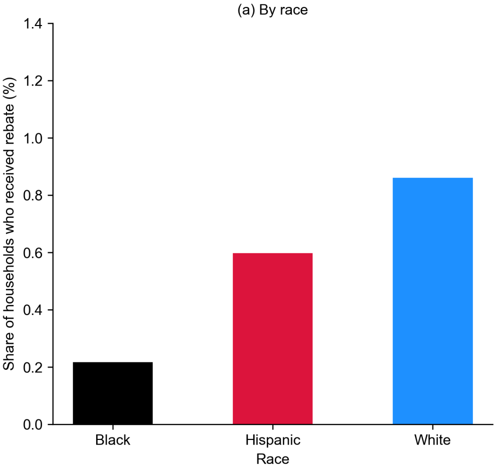
	DID			Matching + DID		
	(1)	(2)	(3)	(4)	(5)	(6)
loan	0.0029***	0.0029***	0.0029***	0.0012***	0.0012***	0.0012***
	(0.0002)	(0.0002)	(0.0002)	(0.0004)	(0.0004)	(0.0004)
Loan × Minority		0.0001***			0.0002**	
		(0.0000)			(0.0001)	
Loan × Black			0.0001***			0.0002**
			(0.0000)			(0.0001)
Loan × Hispanic			0.0001***			0.0002**
			(0.0000)			(0.0001)
Constant	0.0495***	0.0493***	0.0493***	0.0610***	0.0608***	0.0608***
	(0.0029)	(0.0029)	(0.0029)	(0.0064)	(0.0065)	(0.0065)
Rebate control	Yes	Yes	Yes	Yes	Yes	Yes
Electricity price control	Yes	Yes	Yes	Yes	Yes	Yes
Natural gas price control	Yes	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Number of observations	2,095,226	2,095,226	2,095,226	1,814,742	1,814,742	1,814,742
Number of households	426,026	426,026	426,026	367,143	367,143	367,143

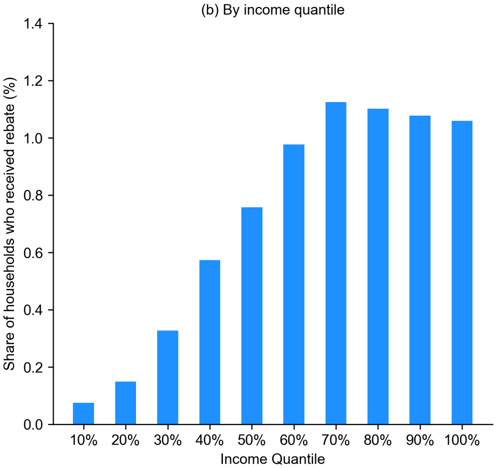
Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Outcome is a dummy denoting heat pump adoption status for households.

Massachusetts Clean Energy Center (MACEC) rebate program

- The MACEC data, which includes project addresses, installed heat pump system information, and rebate payment amounts for 20,094 recipients between 2014 and 2019
- I match them with household demographic data sourced from DataAxle.
- The recipients included 16,389 White households, 1,522 Asian households, 1,459 Hispanic households, and 376 Black households.
- On average, the rebate payment amount was approximately $600 per ton, and the total amount paid was 28 million dollars.
- Program was designed to give higher rebate amounts per installed heat pump to low income.
  ▸ Details

Inequality in access to MACEC rebate program





State Energy-Efficiency Appliance Rebate Program (SEEARP)

- The 2010 SEEARP program is a federal initiative that allocates funding to states, allowing them to design their own rebate schemes.

- States, including SC, NC, VA, MD, DE, provided rebates for air source heat pumps.

- NC and VA: $300 per system, DE: $400 per system, SC and MD: $500 per system. Back to loan

- I retrieve the data from the Open Energy Data Initiative (OEDI), U.S. Department of Energy, containing information on rebate payment amounts, and project ZIP codes.

Racial gap in accessing SEEARP rebates in SC, NC, VA, MD, DE

	Outcome: Total amount of rebate payment ($) at ZIP level					
	(1)	(2)	(3)	(4)	(5)	(6)
Black household %	-28.86***	-16.92***	-30.21***	-20.73***	-41.05***	-34.74***
	(3.15)	(2.98)	(3.25)	(3.13)	(5.28)	(5.33)
Hispanic household %	-124.99***	-115.88***	-94.32***	-89.88***	-66.70***	-51.46***
	(18.08)	(17.51)	(16.14)	(15.99)	(15.16)	(14.72)
Asian household %	117.60***	-14.10	56.55	-43.71	15.07	6.45
	(36.07)	(37.16)	(34.95)	(36.92)	(39.67)	(40.79)
Number of households	0.45***	0.45***	0.48***	0.47***	0.45***	0.45***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Median Household Income		0.04***		0.03***		0.02***
		(0.00)		(0.00)		(0.01)
Constant	774.72***	-1245.64***	-548.75*	-2573.80***	-475.06	-1620.55***
	(80.30)	(220.15)	(314.28)	(430.80)	(386.84)	(509.76)
State FE	No	No	Yes	Yes	No	No
County FE	No	No	No	No	Yes	Yes
R-squared	0.25	0.28	0.30	0.33	0.59	0.59
Number of observations	2,600	2,572	2,600	2,572	2,586	2,560

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

Summary of findings

What matters for the racial disparity in heat pump adoption?

- The gap in building age is the most important contributor, followed by income gap, climate, and natural gas prices or access.
- The building age gap net of income can be due to discrimination in housing markets.
- An increase in heating and cooling demand and natural gas prices can widen the racial gap.
- Loan programs slightly reduce the gap, while small rebate programs widen the racial gap.

Policy implications

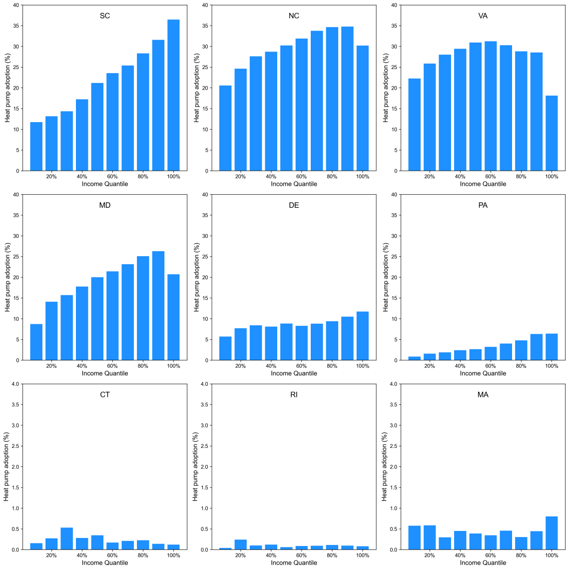
- Enact more targeted policy interventions that promote building retrofits, particularly in older structures where low-income minority populations are disproportionately represented.

- The 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.

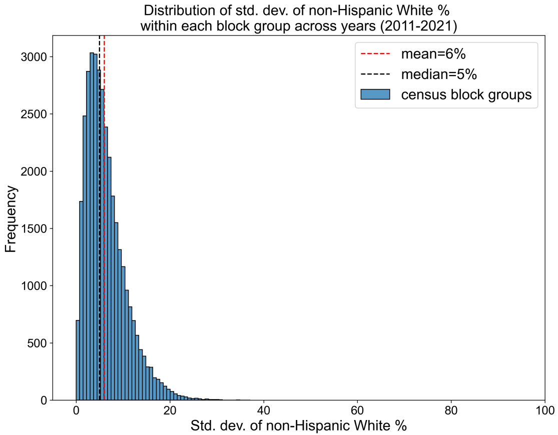
Appendix!

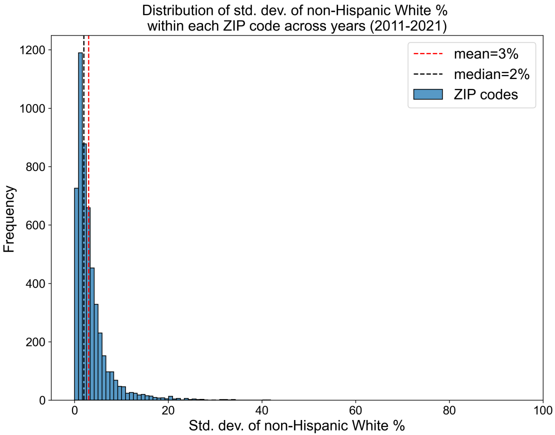
Heat pump adoption percentage by income in nine states in 2021



▸ Back

The racial composition of local communities has changed little over the past decade





Data source: US census ACS

Note: census block group ≈ 400 households; ZIP code ≈ 4,000 households

▸ Back

Summary statistics for cross-sectional decomposition analysis

Variable	Unit	Mean	Std. Dev.	Min.	Max.	N
Z score of heat pump gap		0.438	2.99	-29.993	30.985	2356
heat pump market share		0.172	0.214	0	0.943	2362
Inferred electricity price	$ per kWh	0.145	0.037	0.093	0.321	2358
Natrual gas service cost	$ per mcf	2491.494	4313.353	12.01	9999	2362
HTDD		4544.552	1098.117	1535.89	6877.405	2357
CLDD		1174.8	376.089	439.683	2581.482	2357
T score of income gap		5.498	9.122	-61.651	80.180	2353
Average income	$K	97.605	58.249	7.687	404.369	2362
T score of wealth gap		9.244	10.85	-31.054	94.447	2353
Average wealth	$K	1934.76	591.902	437.629	3900.396	2362
T score of ownership gap		4.017	5.659	-76.131	39.332	2353
Average owner status		8.226	0.731	1.333	8.926	2362
Z score of SF housing gap		0.747	4.767	-25.886	49.284	2340
Single-family housing ratio		0.921	0.129	0	1	2362
Climate opinion	%	72.493	6.006	50.98	85.837	2357
Z score of edu gap		4.9	4.337	-4.307	28.493	2349
Percentage above bachelor	%	0.284	0.111	0	1	2356
T score of year built gap		0.462	6.066	-99.595	73.406	2354
Average year built		1967.908	18.773	1896.989	2012.21	2362
T score of living area gap		1.111	3.269	-9.221	34.021	2353
Average living area	sq feet	2001.731	555.092	919.628	10366.497	2362
Rebate	$/ton*yrs.	1235.888	1600.215	0	4775	2362
Loan	yrs.	5.943	4.525	0	10	2362

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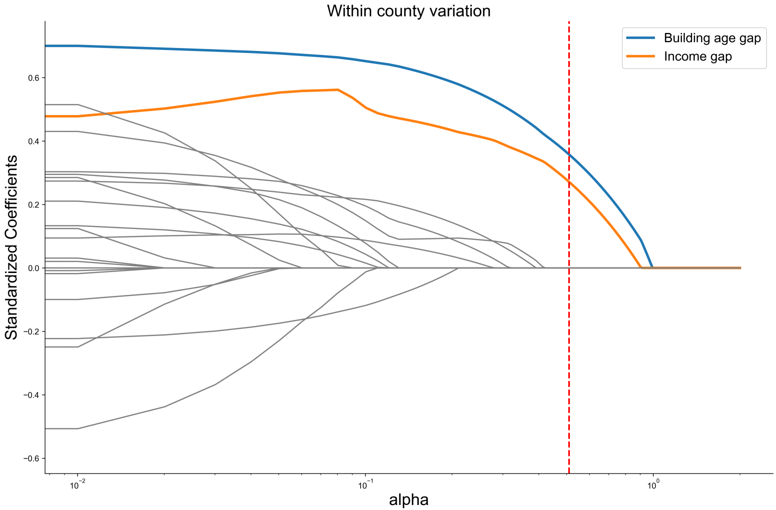
Variables selection using within county variation



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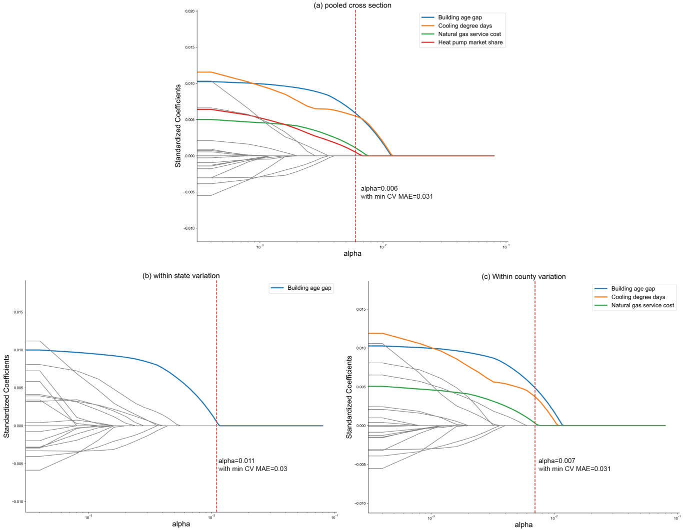
Variables selection using LASSO

Simple differences are employed to measure the gap in heat pump adoption rate and related socio-demographic characteristics.



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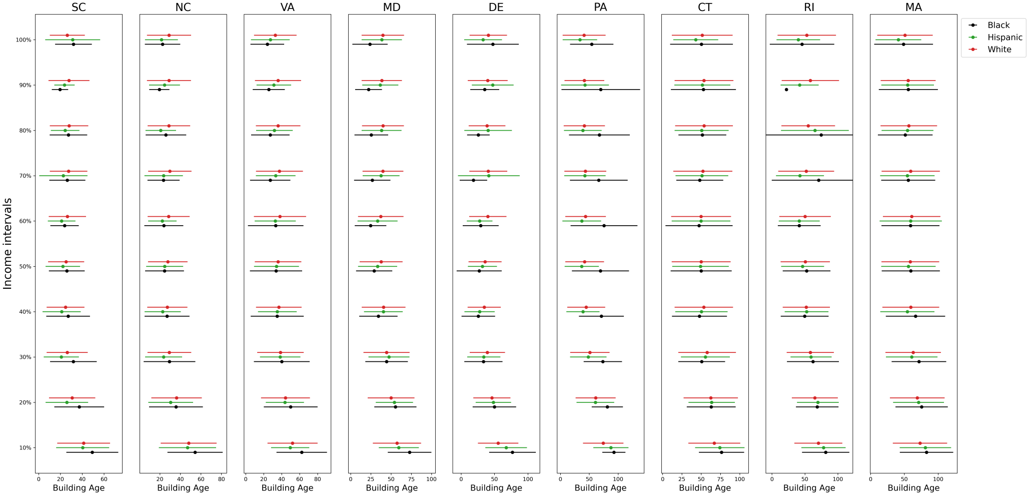
Building age by race and income in 2021, categorized by the nine states



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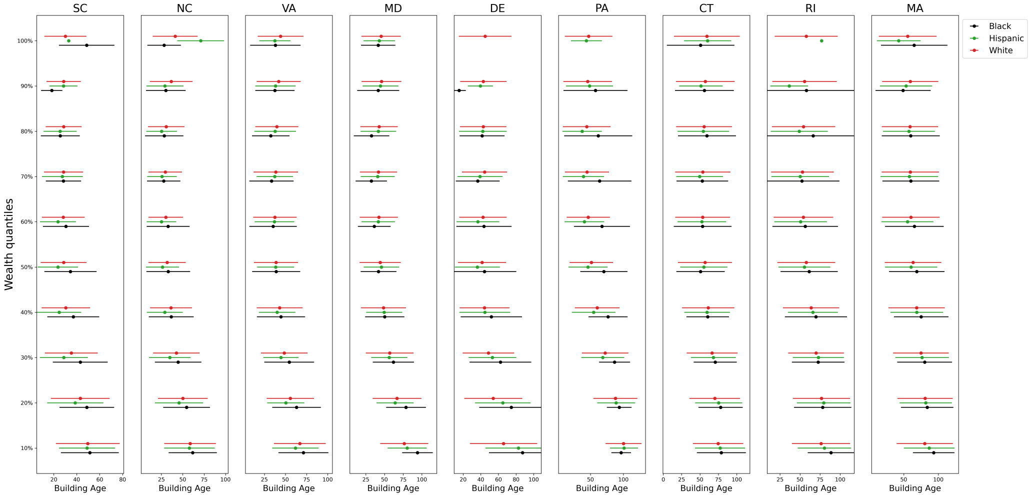
Building age by race and wealth in 2021, categorized by the nine states



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Summary statistics for panel regression analyses

Variable	Unit	Mean	Std. Dev.	Min.	Max.	N
First diff. in heat pump existence		0.003	0.059	0	1	89,940,888
Annual average temperature	°F	55.374	4.270	45.76	67.79	109,907,804
Annual heating degree days (HDD)		4697.342	1179.489	1309	7687	109,907,804
Annual cooling degree days (CDD)		1212.434	428.9599	342	2681	109,907,804
HDD + CDD		5909.776	814.5094	3729	8151	109,907,804
Inferred electricity price	$ per kWh	0.152	0.031	0.092	0.392	109,889,064
Natural gas price	$ per mcf	2183.287	4117.723	11.239	9999	109,937,313

Note: The unit of observation for regressions is at the household-year level. The sample includes White, Hispanic, and Black households located in South Carolina, North Carolina, Virginia, Maryland, Delaware, Pennsylvania, Connecticut, Rhode Island, and Massachusetts from 2010 to 2021.The temperature, heating degree days, and cooling degree days data are at the ZIP code level, while the electricity price is at the utility level and the natural gas price is at the state level. These data have been matched to the households. For households without access to utility gas, the natural gas price is set to an extreme value of 9999.

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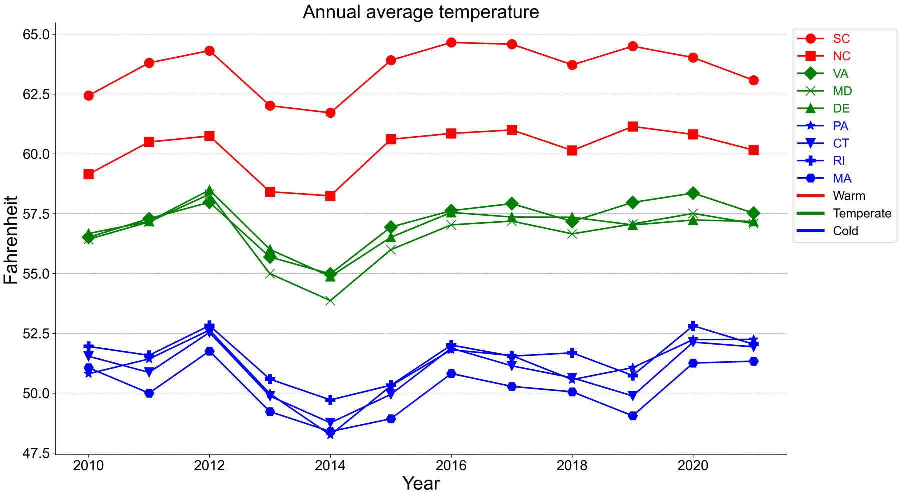
The variation of annual average temperature by state



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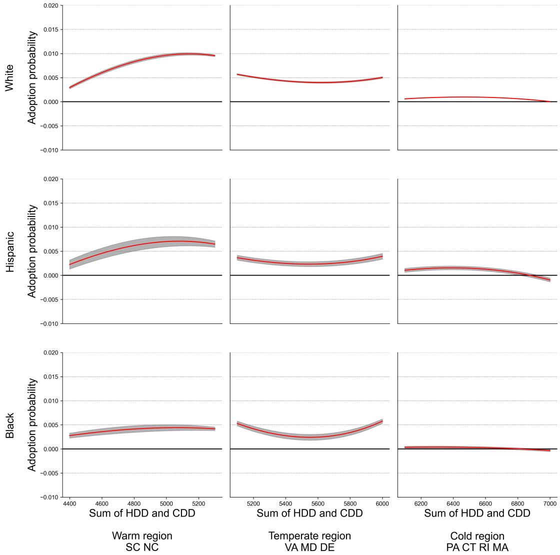
The impact of the sum of heating and cooling degree days on the adoption probability of heat pumps by race and region



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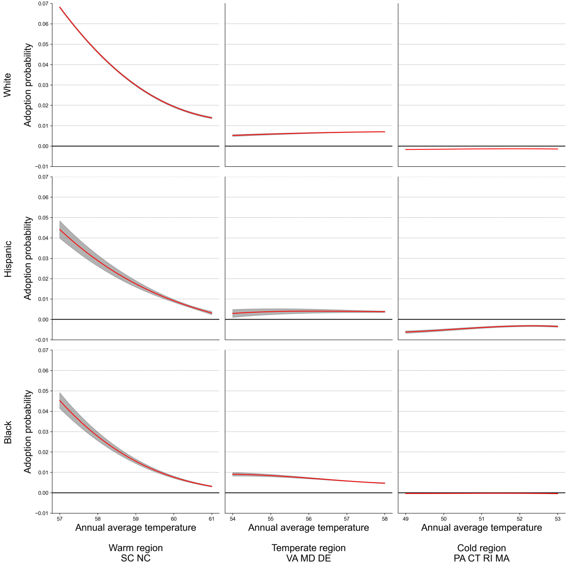
The impact of the average annual temperature on the adoption probability of heat pumps by race and region (homeowners only)



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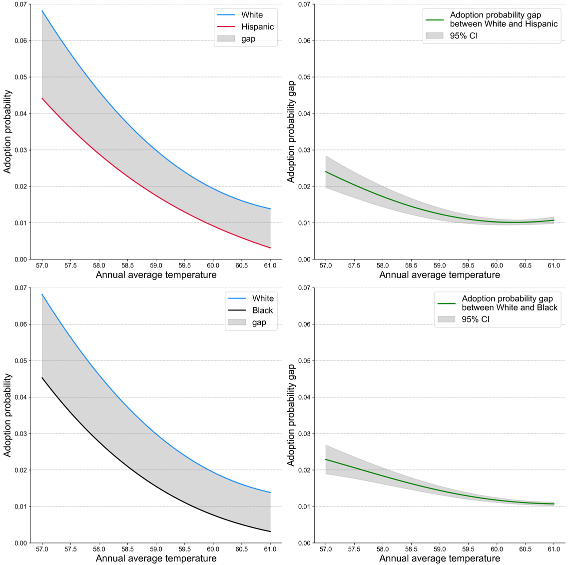
The association between temperature change and heat pump adoption probability gap in NC and SC (homeowners only)



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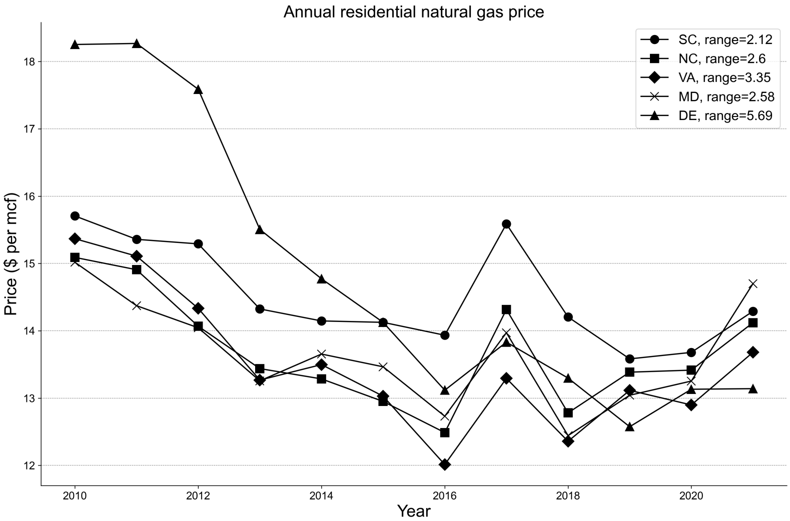
Trends in residential natural gas prices by state (2010-2021)



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Impact of natural gas price change on heat pump adoption by race (homeowners only)

	(1) All	(2) White	(3) Hispanic	(4) Black
log(natural gas price)	0.016***	0.019***	0.011***	0.004***
	(0.0003)	(0.0003)	(0.0012)	(0.0011)
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	0.0089	0.0098	0.004	0.005
Number of observations	28,594,453	23,509,068	1,689,739	3,395,646
Number of households	3,496,158	2,903,003	200,827	392,328

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The outcome is a dummy indicates new heat pump adoption for each year. The model includes households owned by residents located in natural gas utility service territories in South Carolina, North Carolina, Virginia, Maryland, and Delaware. Column (1) includes households from the three racial groups.

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Demographic attributes of households ▸ Back

	Before Matching			After Matching		
	Treated group	Control group	Diff.	Treated group	Control group	Diff.
(a) Three races:						
N of households	220,213	205,844		167,845	199,314	
Household income	145.66	182.59	-36.93***	163.8	172.54	-8.74***
Household wealth	2279.63	2548.8	-269.17***	2456.76	2517.84	-61.08***
Purchasing power	111.84	140.22	-28.38***	125.59	132.62	-7.03***
Single-family housing	0.9	0.76	0.14***	0.89	0.97	-0.08***
Home owner status	8.3	7.97	0.33***	8.3	8.38	-0.08***
Children count	0.51	0.46	0.05***	0.51	0.54	-0.03***
Household head age	55.47	52.42	3.05***	55.32	54.39	0.93***
Building year built	1966.03	1980.88	-14.85***	1968.19	1968.64	-0.45***
(b) White households:						
N of households	107,660			99,184	109,357	
Household income	205.2			203.69	209.51	-5.82***
Household wealth	2784.07			2784.8	2818.21	-33.41***
Purchasing power	159.26			157.36	161.99	-4.63***
Single-family housing	0.91			0.92	0.97	-0.05***
Home owner status	8.4			8.46	8.49	-0.03***
Children count	0.54			0.54	0.58	-0.04***
Household head age	57.02			56.87	55.45	1.42***
Building year built	1964.75			1966.17	1967.67	-1.5***

Note: This table reports the mean values of demographic attributes. The balance checks are also broken down by race in the treated group. Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The units of income, wealth, and purchasing power are expressed in thousands of dollars.

Demographic attributes of households (continued)

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	Before Matching			After Matching		
	Treated group	Control group	Diff.	Treated group	Control group	Diff.
(c) Black households:						
N of households	82,914			50,134	58,494	
Household income	84.7			100.79	110.22	-9.43***
Household wealth	1813.59			1968.54	2047.39	-78.85***
Purchasing power	63.33			75.44	83.18	-7.74***
Single-family housing	0.9			0.86	0.97	-0.11***
Home owner status	8.28			8.14	8.23	-0.09***
Children count	0.51			0.48	0.51	-0.03***
Household head age	56.01			54.29	53.63	0.66***
Building year built	1970.01			1973.48	1972.11	1.37***
(d) Hispanic households:						
N of households	29,639			18,527	31,463	
Household income	99.93			120.73	143.27	-22.54***
Household wealth	1751.06			2021.7	2182.79	-161.09***
Purchasing power	75.25			91.2	109.22	-18.02***
Single-family housing	0.88			0.83	0.96	-0.13***
Home owner status	8			7.91	8.18	-0.27***
Children count	0.38			0.42	0.43	-0.01
Household head age	48.35			49.79	50.8	-1.01***
Building year built	1959.54			1964.71	1964.47	0.24

Note: This table reports the mean values of demographic attributes. The balance checks are also broken down by race in the treated group. Significance levels: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. The units of income, wealth, and purchasing power are expressed in thousands of dollars.

Rebate Amounts in Massachusetts Clean Energy Center - Residential & Small-Scale Air-Source Heat Pump Program

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Year	Rebate amount
2014	$750 per system or ton
2015	$750 per system or ton
2016	base: $625 per system/ton; under 120% state median income: $750 per system/ton; under 80% state median income: $1,500 per system/ton
2017	base: $625 per system/ton; under 120% state median income: $800 per system/ton; under 80% state median income: $1,000 per system/ton
2018	base: $625 per system/ton; under 120% state median income: $800 per system/ton; under 80% state median income: $1,000 per system/ton
2019	base: $500 per system/ton; under 120% state median income: $750 per system/ton; under 80% state median income: $1,000 per system/ton

Note: The rebate amount for single-head heat pumps was per system. For central or multi-head heat pumps, the rebate amount was calculated per ton, which is equivalent to 12,000 BTU/hr. Residents who received electric service from Eversource, National Grid, Unitil, or an eligible municipal light plant were eligible to apply for the rebate.