WHAT MATTERS FOR THE RACIAL DISPARITY IN CLEAN HEATING TECHNOLOGY ADOPTION? EVIDENCE FROM U.S. HEAT PUMPS

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Overview

A growing body of literature has documented that minority groups have installed fewer clean energy technologies, but the reasons for the adoption gap are not always clear. This study utilizes household-level demographic and property data to explore the racial disparity in air source heat pump adoption in nine U.S. East Coast states. I quantify the heat pump adoption gap between White and minority households at the ZIP code level, and then use 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. The importance of building age persists even when conditioning on income, possibly due to historic or contemporary discrimination in housing markets. The study also provides causal evidence that an increase in heating and cooling demand and natural gas prices can widen the racial gap in heat pump adoption. Policies may not necessarily alleviate the gap though. Loan programs slightly reduce the gap, while small rebate programs widen the racial gap.

Data

This paper utilizes household-level demographics and property data sourced from DataAxle and CoreLogic to decompose the drivers of the racial disparity in air source heat pump adoption in nine U.S. East Coast states, namely South Carolina (SC), North Carolina (NC), Virginia (VA), Maryland (MD), Delaware (DE), Pennsylvania (PA), Connecticut (CT), Rhode Island (RI), and Massachusetts (MA). In this study, I got a sample consisting of a total of 13,622,001 households across nine states.

Decomposing the drivers of racial inequality

First, I create an standardized variable to measure the level of adoption inequality at the cross-sectional ZIP-code level in 2021 and employ a two-step data driven approach to decompose the drivers of the inequality. I use the Z-statistic score to measure the difference in heat pump adoption rates between majority households (White) and minority households (Hispanic and Black). Then, relying on a stylized model of energy-efficiency investments, I comprehensively review the factors related to heat pump adoption (such as income and wealth disparities, home ownership gap, education gap, market share, temperature, energy prices, incentives, building attributes, and others). Drawing on the cross-sectional variations in these factors and the heat pump adoption gap, this study decomposes the contributions of these factors. I first use LASSO regression to select the optimal specification for predicting the adoption gap with the least Mean Squared Error (MSE), then apply Shapley Value regression to decompose the contribution of each selected predictor to the R2.

The results of the pooled cross-section regression indicate that building age gap, income gap, cooling degree days, natural gas price, and heat pump market share are the five most significant predictors, sorted by their R2 contribution. The within-state-variation and within-county-variation regression analyses reveal that building age gap and income gap are the two most important predictors. In all three specifications, building age gap emerges as the single most crucial predictor, with the largest R2 contribution, rather than income gap, wealth gap, homeownership gap, or education gap. Specifically, I discover that, even conditional on income, low-income Black and Hispanic families are more likely to own older properties than low-income White families. This discrepancy can be attributed to the historical discriminatory housing policies and practices in the U.S. The presence of poor insulation, limited electrical wiring, and outdated building structures in older buildings contributes to the higher upfront cost of heat pump installations and lower future fuel savings, presenting significant obstacles to heat pump adoption.

Temperature, energy prices, and racial inequality

The cross-sectional decomposition analysis identifies temperature (cooling degree days) and energy price (natural gas price) as crucial secondary contributors to adoption disparities. Thus, I investigate causal evidence of temperature and energy price's impact on the adoption disparity in the second analysis. Using panel data of heat pump adoption

from 2010 to 2021 at the household-year level and a linear probability model with two-way fixed effects, the impacts of annual average temperature and natural gas prices on the probability of new heat pump installation are estimated. The results indicate that White households are more responsive to the annual average temperature than Black and Hispanic households in warm regions (SC and NC). Specifically, my findings indicate that the gap in new heat pump adoption probability between White and Black households increased by 1.3 percentage points, and between White and Hispanic households increased by 0.6 percentage points, when the local annual average temperature decreased from 61 ˚F to 57 ˚F. In warm regions where heat pumps are currently suitable for use, a decrease in temperature can lead to higher heating demand and higher fuel savings for heat pumps, but it can also exacerbate inequalities in heat pump installations. In contrast, the study finds no significant temperature responsiveness in heat pump adoption in colder regions (the other seven states).

With respect to energy prices, the analysis is focused on the impact of natural gas price, rather than electricity price, given the complexity of electricity price effects. According to the linear probability model, in states where natural gas and electricity are the primary heating fuels (such as SC, NC, VA, MD, DE), this study finds that a 1% increase in the annual average natural gas price can result in a 0.018%, 0.011%, and 0.003% increase in the probability of new heat pump adoption among White, Hispanic, and Black households, respectively. Thus, an increase in the natural gas price can exacerbate the heat pump adoption gap across racial groups.

The estimated impacts of temperature and natural gas prices above are identified based on within-location annual variations and could be attributed to residents' psychological expectations of future fuel savings across different years (Busse et al. 2015; He et al. 2022; Loewenstein et al. 2003). It should be noted, however, that these impacts may 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. Nevertheless, the causal evidence derived from short-term annual variations provides significant support for the hypothesis presented in this paper. In summary, the empirical evidence highlights that the benefits of using heat pumps are higher when triggered by changes in temperature, or energy prices, leading to increased incentives for adoption. However, the increase in heat pump adoption can be differentiated across racial groups, exacerbating the existing racial inequality in adoption.

Public policy and racial inequality

To promote the adoption of heat pumps, various incentives have been provided by the government and local electric utilities, with rebate and loan programs being the two most widely used incentives for heat pumps in the U.S. There is evidence of the positive impact of the incentives on heat pump adoption (Shen et al. 2022). However, few studies have investigated whether these incentives reduce or exacerbate adoption inequality. In the last part of analysis, I explore the role of loan and rebate programs on the racial disparities in heat pump adoption. Specifically, I estimate the causal impact of a loan incentive in MD on heat pump adoption by racial groups using a difference-in-differences approach in conjunction with matching and geographic discontinuity along the border between MD and VA. Loan programs can alleviate credit constraints for low-income and minority groups, which is a common reason for "energy efficiency gap", but these groups may also experience an information gap and face higher application costs in accessing loan programs. The result of this study indicates that the loan program can increase the probability of households having heat pumps by 0.11% for the overall population within a period of two years, while the impact is more significant for Hispanic and Black populations, with an increase of 0.02% compared to White populations. The estimated effect is relatively small, as the average adoption rate in the sample is approximately 10%. This finding echoes the results of the decomposition analysis, which indicates that the loan incentives are not selected by the LASSO regression. Nonetheless, the findings suggest that the loan program can slightly reduce the racial gap in heat pump adoption.

Lastly, this study presents suggestive evidence on the relationship between rebate programs and racial inequality in heat pump adoption. Specifically, the study examines the 2010 State Energy-Efficient Appliance Rebate Program (SEEARP) and the Massachusetts Clean Energy Center (MACEC) rebate program between 2014 and 2019. Rebate amounts range from $100 to $600 per ton (or 12,000 BTU/hr) in the programs studied. To investigate the potential racial disparities in these programs, I match rebate recipients' home addresses with household demographic data for the Massachusetts program and ZIP code level demographic data for the SEEARP program in SC, NC, VA, MD, and DE. The findings suggest that a disproportionately smaller share of Black and Hispanic families received the heat pump rebate compared to White families. This indicates a potential racial disparity in access to these rebate programs and underscores the need for further investigation to better understand the barriers to equitable participation.