# Monetary and Non-Monetary Barriers to Accessing Environmental Public Benefit Programs: Evidence from California

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**Session: Environmental Justice and Distributional Equity**

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# Motivation: climate risk and environmental justice

- Deaths from wildfire smoke projected to be the **largest source of climate change damages** in U.S. (Qiu et al., 2025)
- Improving **indoor air quality** important:
  1. 90% of time spent indoors (Chen and Zhao, 2011)
  2. Indoor air may be more cost-effective to improve
- One policy: **subsidized air purifiers**
- Yield the largest benefits when targeted to:
  - **high pollution burden**
  - **low-income** groups (who wouldn't otherwise purchase)
- **Policy question:** how to design a program that targets these people?

# This paper

## Research questions

1. **Can reducing costs improve take-up?**
2. **How do non-monetary vs. non-monetary costs affect take-up? And for whom?**

**What we do:**

- RCT sending mailers inviting applications for a subsidized air purifier
- 90,000 households in California
- Randomly vary two kinds of costs:
  1. **Monetary cost** (subsidy rate)
  2. **Non-monetary cost** (administrative hassles)

**Research agenda:** build evidence on how to design targeted programs

# Contributions

1. **Administrative hassles and targeting in U.S. safety-net programs.**
   - Hassles can improve targeting (Nichols and Zeckhauser, 1982; Schuck and Zeckhauser, 2007; Finkelstein and Notowidigdo, 2019; Shepard and Wagner, 2025; Rafkin et al., 2025)
   - Or worsen it (Herd and Moynihan, 2019, 2025; Shepard and Wagner, 2025; Deshpande and Li, 2019; Gazze, 2022; Homonoff and Somerville, 2021)
   - Nature of programs means no variation in price.
   - $\Rightarrow$ **Randomly vary price** so can benchmark burdens against price increases.

# Contributions

1. **Administrative hassles and targeting in U.S. safety-net programs.**
2. **RCTs varying prices and hassles for health products in low- and middle-income countries.**
   - Price (Cohen and Dupas, 2010; Ashraf et al., 2010)
   - Hassles (Alatas et al., 2016), or both (Dupas et al., 2016)
   - Higher prices cut demand; targeting effects mixed.
   - $\Rightarrow$ **New setting**: environmental good in a high-income country.

# Contributions

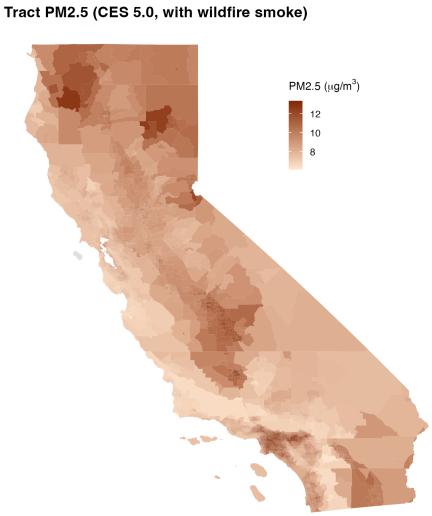
1. **Administrative hassles and targeting in U.S. safety-net programs.**
2. **RCTs varying prices and hassles for health products in low- and middle-income countries.**
3. **Access costs and targeting for environmental goods.**
   - Weatherization (Fowlie et al., 2015, 2018), lead testing (Gazze, 2020), EV subsidies (Muehlegger and Rapson, 2022).
   - Costs reduce access and do not improve targeting.
   - $\Rightarrow$ **New evidence on air purifiers**: a lower-cost adaptation measure.

# Empirical setting

## Setting

- 90,179 California households, sampled from commercial mailing list
- Randomly assigned to one of nine letter treatments
- Rollout Feb-Mar 2026

▸ Design table ▸ Arm details ▸ Sampling ▸ CA maps
▸ Randomization ▸ Protocol

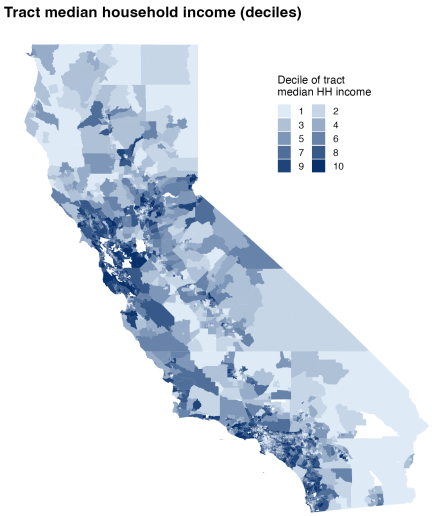


# Empirical setting

## Setting

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- Randomly assigned to one of nine letter treatments
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▸ Design table ▸ Arm details ▸ Sampling ▸ CA maps
▸ Randomization ▸ Protocol



# Treatment arms I: monetary cost (subsidy rate)

**A subset of treatment arms only vary monetary cost**

| Subsidy | Price to household |
|---|---|
| 0% | $150.00 |
| 50% | $75.00 |
| 75% | $37.50 |
| 95% | $7.50 |
| **100% — reference** | **free** |

- Otherwise identical: same letter, same website, same ∼5-minute form
- Comparing arms traces response to price
  - Including potential jump from free to small non-free price

▸ Full design table

# Treatment arms II: non-monetary costs and information

**A subset of treatment arms hold monetary cost constant at $0 and change *non-monetary* cost**

| Arm | Applicant experience | Cost added |
|---|---|---|
| **Free (reference)** | Letter offers a free purifier; ∼5-minute online form | — |
| + Time cost | Same letter; form has extra questions, ∼15 minutes instead of ∼5 | ∼10 minutes of time |
| + Proof of residence | Same letter; must photograph and upload a document showing name and address (e.g. a utility bill) | Find, photograph, upload a document |
| + AQ + health info | Letter adds health effects of air pollution and the county's count of poor-air-quality days (EPA AQI report); same ∼5-minute form | None (information only) |

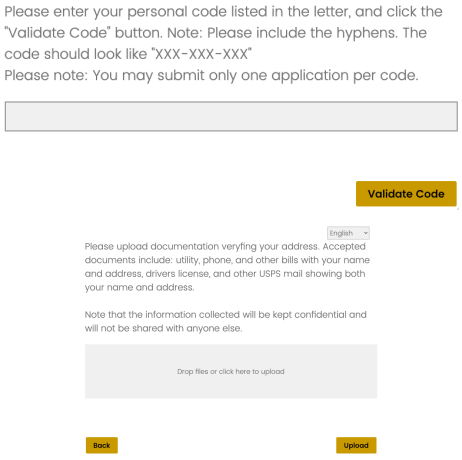
▸ Full design table

# Experimental procedure

## The offer letter




## The online application form




Left: offer letter for the 100% subsidy (reference) arm. Right: applicants enter their personal code, which validates the mailer and routes them to their arm's version of the form; only the proof-of-residence arms reach a document-upload step. The baseline form takes about 5 minutes; the time-cost arm extends it to about 15 minutes.

# Regression specification

$$Y_{ik} = \sum_{(s,c) \neq (100,\varnothing)} \beta_{sc} \mathbf{1}[s_i = s,\ c_i = c] + \gamma_k + \varepsilon_{ik}$$

- $Y$ applied (1 if yes; 0 otherwise)
- $i$ household
- $s_i \in \{0, 50, 75, 95, 100\}$ subsidy percent
- $c_i \in \{\varnothing, \mathrm{TC}, \mathrm{PR}, \mathrm{PRI}, \mathrm{AQ}\}$ non-monetary cost ($\varnothing$=none, TC=time cost, PR=proof of residence, PRI=PR+info, AQ=air quality)
- $(s, c)$ indexes the eight non-reference arms; $\beta_{sc}$ is the effect of arm $(s, c)$ relative to the reference
- reference arm $(100, \varnothing)$: 100% subsidy with no additional non-monetary cost
- $\gamma_k$ strata fixed effects

▸ HTE ▸ Alt. notation

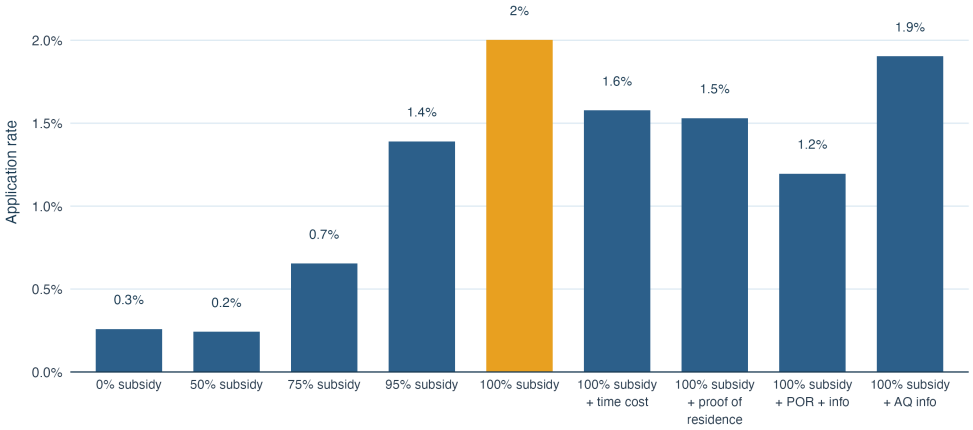
# Applicants skew higher income, less pollution-exposed

| | Mailed sample | Applicants |
|---|---|---|
| *Panel A. Income* | | |
| Household income, mean | \$73,669 | \$80,641*** |
| Household income, median | \$62,500 | \$62,500 |
| Share of households below \$75k | 66.0% | 60.2%*** |
| Share below 100% Federal Poverty Line | 9.3% | 7.5%** |
| Share below 200% Federal Poverty Line | 26.8% | 23.3%*** |
| *Panel B. Pollution exposure* | | |
| Tract PM2.5, mean ($\mu$g/m$^3$, CES 5.0 with fire) | 9.56 | 9.43*** |
| Share in top statewide PM2.5 quartile | 25.3% | 21.3%*** |
| Share in top statewide PM2.5 decile | 9.8% | 8.1%** |
| *Panel C. Demographics* | | |
| Share White non-Hispanic | 37.3% | 40.3%** |
| Share English at home | 58.6% | 63.2%*** |
| Households ($N$) | 90,179 | 1,233 |

Vendor-measured characteristics. Stars: heteroskedasticity-robust $p$-values from regressing each characteristic on an applicant indicator over the mailed sample ($^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$; the median and $N$ rows carry no test). Every tested characteristic differs significantly: applicants skew higher-income, whiter, more English-speaking, and lower-exposure.

Urban vs. rural

# Application rates by treatment arm




Gold bar = reference arm (100% subsidy, no extras). Raw application rates; see ITT results for regression-based inference.

Raw application rates. $N = 90{,}179$ households; 1,233 applications (1.37% overall). Lit. benchmark

# Regression results

| | Submitted |
|---|---|
| 0% subsidy | -0.017*** |
| | (0.001) |
| 50% subsidy | -0.018*** |
| | (0.001) |
| 75% subsidy | -0.013*** |
| | (0.001) |
| 95% subsidy | -0.006*** |
| | (0.002) |
| 100% subsidy + time cost | -0.004** |
| | (0.002) |
| 100% subsidy + proof of residence | -0.005*** |
| | (0.001) |
| 100% subsidy + POR + info | -0.008*** |
| | (0.002) |
| 100% subsidy + AQ info | -0.001 |
| | (0.002) |
| Ref. group mean (100% subsidy) | 0.020 |
| $N$ | 90179 |
| $R^2$ | 0.0063 |

* p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01

**Take-up falls with price**

- 0% subsidy: $-1.7$ppt (85%)
- 50% subsidy: $-1.8$ppt (90%)
- 75% subsidy: $-1.3$ppt (65%)
- 95% subsidy: $-0.6$ppt (30%)

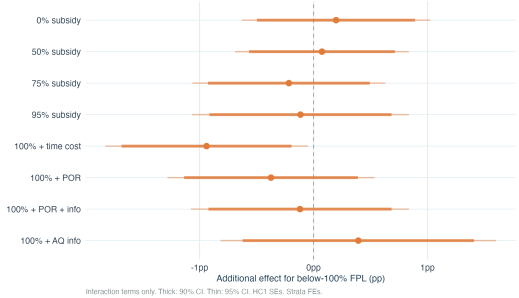
**Hassles deter applicants**

- Time cost: $-0.4$ppt (20%)
- Proof of res.: $-0.5$ppt (25%)
- POR + info: $-0.8$ppt (40%)

▸ Full table

# Hassles may worsen targeting

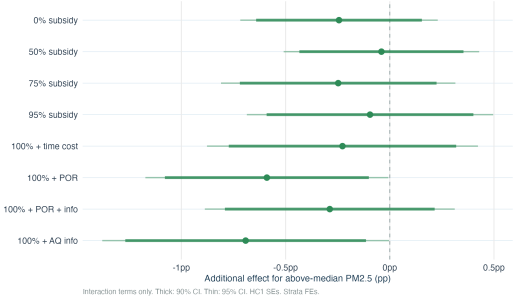
**5a: By federal poverty level (<100% FPL)**




T4 (time cost): $-1.2$ppt for below-100% FPL vs. $-0.3$ppt for above-100% FPL.

▸ HTE PM2.5 table ▸ HTE FPL (<100%) table

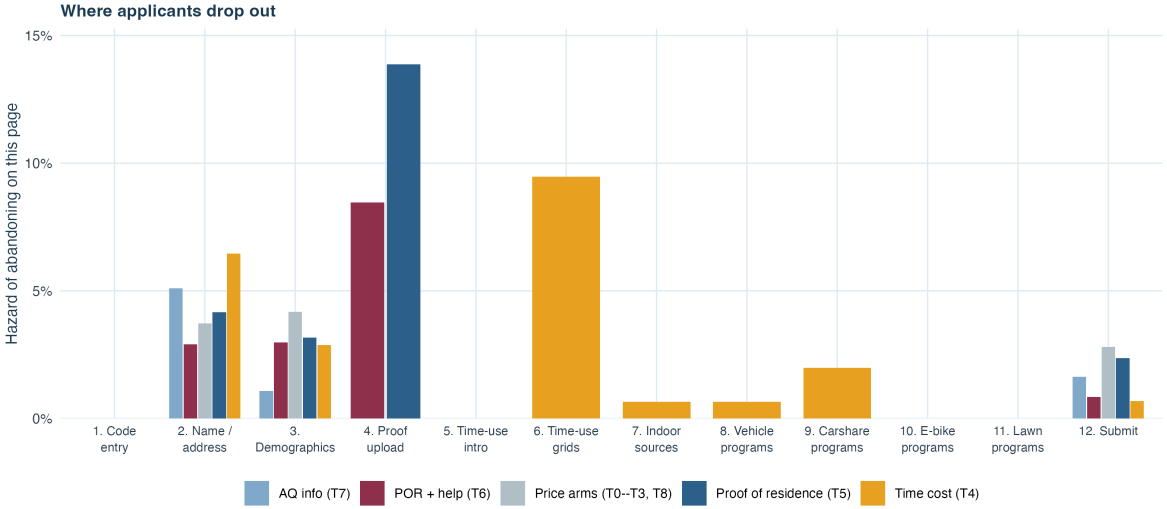
**5b: By PM2.5 exposure (above median)**




T5 (proof of res.): $-0.8$ppt for above-median PM2.5 vs. $-0.2$ppt for below-median PM2.5.

# Where do people drop out?



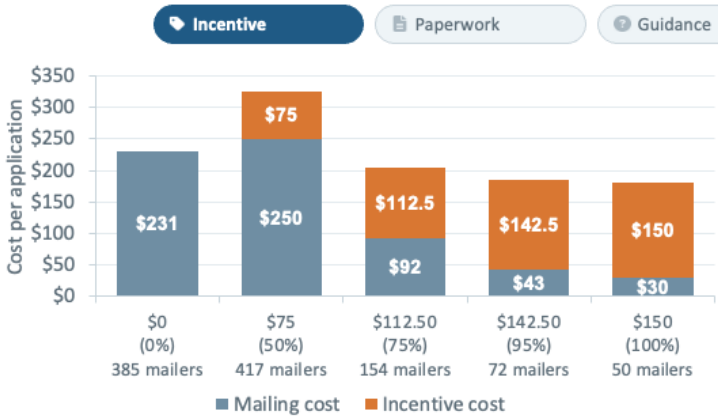



Conditional hazard: share of those reaching a page who go no further. Cells with fewer than 20 at risk are suppressed.
The upload page (T5/T6) and the time-use module (T4) are the arm-specific ordeal pages.

PROGRAM COSTS

# A larger incentive can be less expensive

$0.60 per mailer; mailing + incentive costs for finding an applicant and providing incentive.




**Mailing costs are significant when response rates are low:**
$0.60 x 385 = $231 per application

**Incentives can reduce cost per application:**
$0.60 x 50 + $150 = $180

# Conclusion

1. Costs—both monetary and non-monetary—deter applicants

2. No evidence that they improve targeting; suggestive evidence they may worsen it

3. **Policy implication:** Reducing administrative burden improves uptake and equity, particularly for the most disadvantaged households.

## QR code to my website

mspitzerbrooks.github.io

msbrooks@ucdavis.edu

**Thanks!**

# Appendix: Experimental design table

| 0% subsidy | 50% subsidy | 75% subsidy | 95% subsidy | 100% subsidy | Time cost | Proof of residence | App. info | AQ + health info |
|---|---|---|---|---|---|---|---|---|
| ✓ | | | | | | | | |
| | ✓ | | | | | | | |
| | | ✓ | | | | | | |
| | | | ✓ | | | | | |
| | | | | ✓ | | | | |
| | | | | ✓ | ✓ | | | |
| | | | | ✓ | | ✓ | | |
| | | | | ✓ | | ✓ | ✓ | |
| | | | | ✓ | | | | ✓ |

*Notes*: Each row is a treatment arm; checkmarks indicate features included. "X% subsidy": subsidy rate on offer, plus free shipping. "Time cost": longer application form (∼15 min vs. ∼5 min). "Proof of residence": applicants must upload an address document. "App. info": letter includes application process details and a helpline link. "AQ + health info": letter includes EPA AQI data for the applicant's county. T3 = reference arm.

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# Appendix: Treatment arms

- 0% subsidy

# Appendix: Treatment arms

- 0% subsidy
- 50% subsidy

# Appendix: Treatment arms

- 0% subsidy
- 50% subsidy
- 75% subsidy

# Appendix: Treatment arms

- 0% subsidy
- 50% subsidy
- 75% subsidy
- 95% subsidy

# Appendix: Treatment arms

- 0% subsidy
- 50% subsidy
- 75% subsidy
- 95% subsidy
- 100% subsidy **(reference)**

# Appendix: Treatment arms

- 0% subsidy
- 50% subsidy
- 75% subsidy
- 95% subsidy
- 100% subsidy **(reference)**
- 100% subsidy + time cost (longer form, $\sim$15 min vs. $\sim$5 min)

# Appendix: Treatment arms

- 0% subsidy
- 50% subsidy
- 75% subsidy
- 95% subsidy
- 100% subsidy **(reference)**
- 100% subsidy + time cost (longer form, $\sim$15 min vs. $\sim$5 min)
- 100% subsidy + proof of residence

# Appendix: Treatment arms

- 0% subsidy
- 50% subsidy
- 75% subsidy
- 95% subsidy
- 100% subsidy **(reference)**
- 100% subsidy + time cost (longer form, ∼15 min vs. ∼5 min)
- 100% subsidy + proof of residence
- 100% subsidy + proof of residence + info

*"You will be asked to provide proof of residence at this address. We accept any pictures of bills (such as utility or phone) and other official documents with your name and address. For additional assistance or questions, go to pcair.ucdavis.edu/instructions."*

# Appendix: Treatment arms

- 0% subsidy
- 50% subsidy
- 75% subsidy
- 95% subsidy
- 100% subsidy **(reference)**
- 100% subsidy + time cost (longer form, $\sim$15 min vs. $\sim$5 min)
- 100% subsidy + proof of residence
- 100% subsidy + proof of residence + info
- 100% subsidy + AQ info

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# Appendix: Treatment arms (full design table)

| Subsidy (price) | Time cost | Proof of residence | POR info | AQ + health info |
|---|---|---|---|---|
| 0% ($150) | | | | |
| 50% ($75) | | | | |
| 75% ($37.50) | | | | |
| 95% ($7.50) | | | | |
| **100% (free) — reference** | | | | |
| 100% (free) | ✓ | | | |
| 100% (free) | | ✓ | | |
| 100% (free) | | ✓ | ✓ | |
| 100% (free) | | | | ✓ |

"Time cost": a longer application form (∼15 minutes vs. ∼5). "Proof of residence": upload of a document showing name and address. "POR info": advance detail on accepted documents, an application-process link, and a phone number. "AQ + health info": health effects of air pollution and county air-quality statistics. The 100% (free) arm is the omitted reference in all regressions; ordeal and information arms hold the price at zero, so each effect is identified relative to a free purifier.

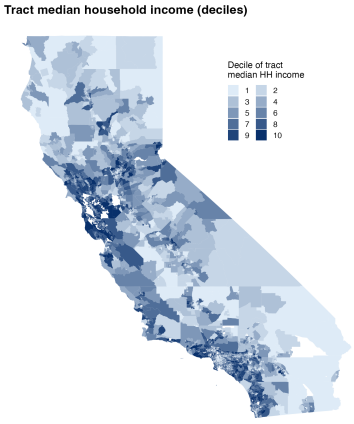
◂ Back: Arms I ◂ Back: Arms II

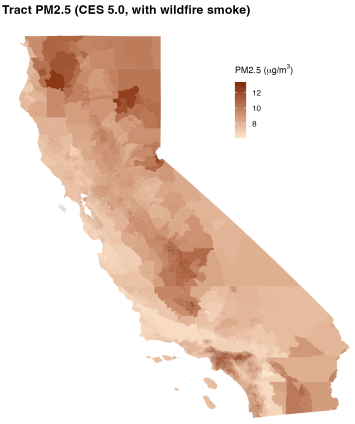
# Appendix: Sampling

- Sample drawn from commercial mailing list of $\sim$12 million California residents
- List provides address, binned income estimates, demographics, GPS coordinates
- Linked to CalEnviroScreen 5.0 via Census Tract for annual average PM2.5
- Sampling procedure:
  1. Randomly sample within income-bin $\times$ PM2.5 decile strata
  2. Oversample low-income households ($<$ \$75k) at 2$\times$ the probability

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# Appendix: Income and PM2.5 distribution in California




Census tracts (2020 geography). Left: deciles of tract median household income (ACS DP03, processed project file). Right: tract PM2.5 including wildfire smoke (CalEnviroScreen 5.0), the project's standard exposure measure. Low income and high exposure overlap in the Central Valley and inland Southern California, the overlap the sampling design targets.

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# Appendix: Randomization

- Households randomly assigned to treatment within income-bin $\times$ PM2.5 decile strata
- 9 treatment arms; unequal arm sizes by design
- Unequal sizes for two reasons:
  1. More observations in the reference arm (T3) improves power (Muralidharan et al. 2025)
  2. Number of pre-specified hypotheses differs across pairwise comparisons
- Randomization unit: household. SEs are heteroskedasticity-robust (not clustered)

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# Appendix: Experimental protocol

1. Participant receives letter in the mail
2. If they choose to apply, they visit the program website
3. Fill out Qualtrics application form (first entry: unique personal code)
4. After the application window, a random subset of applicants receives an air purifier

**Data collected:**

- *All* households: income bins, PM2.5, demographics (mailing list)
- *Applicants only*: continuous self-reported income, detailed demographics, health conditions (Qualtrics)

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# Appendix: Rural versus urban application-rate gap

| | No controls | + PM2.5 | + Income | + PM2.5 + income |
|---|---|---|---|---|
| Rural (small town, UA pop $<$ 50k) | 0.003* | 0.002 | 0.003** | 0.002* |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| PM2.5 ($\mu$g/m$^3$) | | -0.001** | | -0.000 |
| | | (0.000) | | (0.000) |
| Low income ($<$\$75k) | | | -0.004*** | -0.004*** |
| | | | (0.001) | (0.001) |
| $N$ | 89596 | 89596 | 89596 | 89596 |
| $R^2$ | 0.0000 | 0.0001 | 0.0003 | 0.0003 |

* p $<$ 0.1, ** p $<$ 0.05, *** p $<$ 0.01

Households outside any Census urban area of 50,000 or more people apply at a slightly higher rate than urban households (about 0.3 percentage points, against an overall application rate of 1.6 percent). Linear probability models; outcome is an indicator for a submitted application. Heteroskedasticity-robust standard errors. No strata fixed effects and no treatment-arm dummies. Exploratory; not pre-specified.

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# Lit. benchmark

**Mailed government offers: low single-digit take-up**

- Fowlie et al. (2015, 2018) — *free* weatherization worth ∼$5,000: ∼1% take-up unprompted, <6% with costly outreach.
- Hemmeter et al. (2025) — mailed SSI eligibility letters: 5.4% of letter recipients apply within 3 months.
- Bhargava and Manoli (2015) — IRS mailers to filers owed EITC cash: 14–23%.

**Bottom line:** low uptake is normal for cold mailed offers; our 2% free-arm rate is in range. The **cross-arm gradient**, not the level, is the experimental object.

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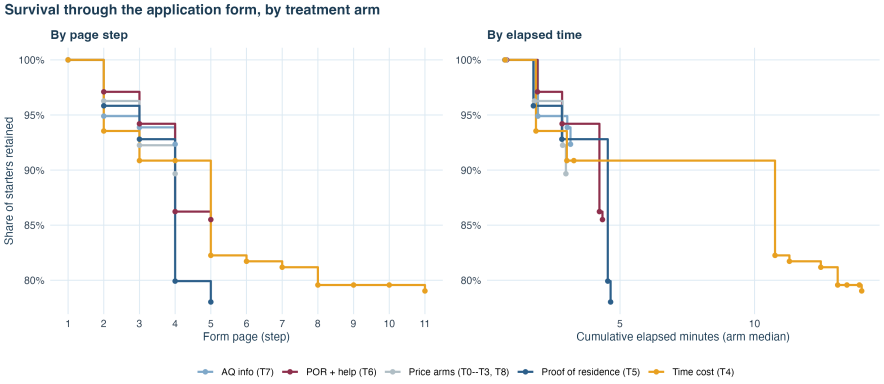
# Appendix: Effect of letter treatments on primary outcomes

| | Submitted (1) | Log income (2) |
|---|---|---|
| 0% subsidy | -0.017*** | 0.396* |
| | (0.001) | (0.237) |
| 50% subsidy | -0.018*** | -0.073 |
| | (0.001) | (0.286) |
| 75% subsidy | -0.013*** | -0.045 |
| | (0.001) | (0.123) |
| 95% subsidy | -0.006*** | 0.135 |
| | (0.002) | (0.089) |
| 100% subsidy + time cost | -0.004** | 0.041 |
| | (0.002) | (0.083) |
| 100% subsidy + proof of residence | -0.005*** | 0.084 |
| | (0.001) | (0.077) |
| 100% subsidy + POR + info | -0.008*** | -0.045 |
| | (0.002) | (0.092) |
| 100% subsidy + AQ info | -0.001 | -0.016 |
| | (0.002) | (0.081) |
| Ref. group mean (100% subsidy) | 0.020 | 11.249 |
| $N$ | 90179 | 1058 |
| $R^2$ | 0.0063 | 0.0075 |
| H1: $\beta_{0,\varnothing} = \beta_{50,\varnothing} = \beta_{75,\varnothing} = \beta_{95,\varnothing}$ (joint) | <0.001 | 0.286 |
| | [0.001] | [0.751] |
| H2: $\beta_{95,\varnothing} = 0$ | <0.001 | 0.131 |
| | [0.001] | [0.751] |
| H3: $\beta_{100,\mathrm{TC}} = 0$ | 0.011 | 0.621 |
| | [0.008] | [0.751] |
| H4: $\beta_{100,\mathrm{PR}} = 0$ | 0.002 | 0.273 |
| | [0.003] | [0.751] |
| H5: $\beta_{100,\mathrm{PRI}} = \beta_{100,\mathrm{PR}}$ | 0.032 | 0.201 |
| | [0.016] | [0.751] |
| H6: $\beta_{100,\mathrm{AQ}} = 0$ | 0.572 | 0.842 |
| | [0.106] | [0.751] |

*Notes:* Heteroskedasticity-robust standard errors in parentheses. Column (1): completed application (linear probability model), all 90,179 mailed households, strata fixed effects. Column (2): log self-reported household income, applicants only, no fixed effects. Bottom panel: $p$-values for the six pre-specified hypotheses, with Benjamini, Krieger and Yekutieli (2006) sharpened $q$-values in brackets. Coefficients $\beta_{s,c}$ are indexed by subsidy rate $s$ (percent) and add-on condition $c$ (TC = time cost, PR = proof of residence, PRI = proof of residence + information, AQ = air-quality information); the omitted arm is the 100% subsidy with no add-on, $(s, c) = (100, \varnothing)$. * p < 0.1, ** p < 0.05, *** p < 0.01.

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# Appendix: Where do people drop out?




Survival through the application form among the 1,481 starters. Left: retention by page step. Right: pages placed at cumulative arm-median elapsed minutes. Legend uses raw arm codes: "POR + help (T6)" is the POR-info arm. The cascades steepen at the arm-specific ordeal pages: the proof-upload page (POR arms) and the time-use module (time-cost arm).

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# Appendix: HTE by PM2.5 exposure

| | Submitted |
|---|---|
| 0% subsidy | -0.016*** |
| | (0.002) |
| 50% subsidy | -0.017*** |
| | (0.002) |
| 75% subsidy | -0.012*** |
| | (0.002) |
| 95% subsidy | -0.006*** |
| | (0.002) |
| 100% subsidy + time cost | -0.003 |
| | (0.002) |
| 100% subsidy + proof of residence | -0.002 |
| | (0.002) |
| 100% subsidy + POR + info | -0.007*** |
| | (0.002) |
| 100% subsidy + AQ info | 0.002 |
| | (0.003) |
| Above-median PM2.5 | 0.001 |
| | (0.004) |
| 0% subsidy × above-med PM2.5 | -0.002 |
| | (0.002) |
| 50% subsidy × above-med PM2.5 | -0.000 |
| | (0.002) |
| 75% subsidy × above-med PM2.5 | -0.002 |
| | (0.003) |
| 95% subsidy × above-med PM2.5 | -0.001 |
| | (0.003) |
| 100% + time cost × above-med PM2.5 | -0.002 |
| | (0.003) |
| 100% + POR × above-med PM2.5 | -0.006** |
| | (0.003) |
| 100% + POR + info × above-med PM2.5 | -0.003 |
| | (0.003) |
| 100% + AQ info × above-med PM2.5 | -0.007** |
| | (0.004) |
| Ref. group mean (100% subsidy) | 0.020 |
| $N$ | 90179 |
| $R^2$ | 0.0064 |

* p < 0.1, ** p < 0.05, *** p < 0.01

Outcome: Submitted. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Heteroskedasticity-robust SEs. Reference: T3.

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# Appendix: HTE by income (<100% FPL)

| | Strata FEs | No FEs |
|---|---|---|
| 0% subsidy | -0.018*** | -0.018*** |
| | (0.001) | (0.001) |
| 50% subsidy | -0.018*** | -0.018*** |
| | (0.001) | (0.001) |
| 75% subsidy | -0.013*** | -0.013*** |
| | (0.002) | (0.002) |
| 95% subsidy | -0.006*** | -0.006*** |
| | (0.002) | (0.002) |
| 100% subsidy + time cost | -0.003* | -0.003* |
| | (0.002) | (0.002) |
| 100% subsidy + proof of residence | -0.004*** | -0.004*** |
| | (0.002) | (0.002) |
| 100% subsidy + POR + info | -0.008*** | -0.008*** |
| | (0.002) | (0.002) |
| 100% subsidy + AQ info | -0.001 | -0.001 |
| | (0.002) | (0.002) |
| Below 100% FPL | -0.003 | -0.001 |
| | (0.006) | (0.003) |
| 0% subsidy × below 100% FPL | 0.002 | 0.002 |
| | (0.004) | (0.004) |
| 50% subsidy × below 100% FPL | 0.001 | 0.001 |
| | (0.004) | (0.004) |
| 75% subsidy × below 100% FPL | -0.002 | -0.002 |
| | (0.004) | (0.004) |
| 95% subsidy × below 100% FPL | -0.001 | -0.001 |
| | (0.005) | (0.005) |
| 100% + time cost × below 100% FPL | -0.009** | -0.009** |
| | (0.005) | (0.005) |
| 100% + POR × below 100% FPL | -0.004 | -0.004 |
| | (0.005) | (0.005) |
| 100% + POR + info × below 100% FPL | -0.001 | -0.002 |
| | (0.005) | (0.005) |
| 100% + AQ info × below 100% FPL | 0.004 | 0.004 |
| | (0.006) | (0.006) |
| Ref. group mean (100% subsidy) | 0.020 | 0.020 |
| *N* | 90179 | 90179 |
| $R^2$ | 0.0064 | 0.0027 |

* p < 0.1, ** p < 0.05, *** p < 0.01

Col. (1): strata FEs. Col. (2): no FEs. $^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$. Heteroskedasticity-robust SEs. Reference: T3.

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# Appendix: Heterogeneous treatment effects

For a given recipient characteristic $X_i$:

$$Y_{ik} = \sum_{s \in \{0,\, 50,\, 75,\, 95\}} (\beta_{s,\varnothing} + \delta_{s,\varnothing} X_i)\, \mathbf{1}[s_i = s] + \sum_{c \in \{\mathrm{TC},\, \mathrm{PR},\, \mathrm{PRI},\, \mathrm{AQ}\}} (\beta_{100,c} + \delta_{100,c} X_i)\, \mathbf{1}[c_i = c] + \mu X_i + \gamma_k + \varepsilon_{ik}$$

- $X_i$: below 100% FPL, or above-median tract PM2.5
- $\delta_{s,\varnothing}$, $\delta_{100,c}$: differential effect of each arm for recipients with $X_i = 1$
- Omitted arm: 100% subsidy with no non-monetary cost, i.e. $(s_i, c_i) = (100, \varnothing)$

$\gamma_k$: fixed effect of $i$'s stratum $k$ (income estimate $\times$ household size $\times$ Census Tract PM2.5). Heteroskedasticity-robust standard errors.

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# Appendix: Regression specifications (alternative notation)

**Application rates:**

$$\begin{aligned}\text{Applied}_{ij} = {} & \beta_1 \mathbf{1}(\text{0\% subsidy}) + \beta_2 \mathbf{1}(\text{50\% subsidy}) + \beta_3 \mathbf{1}(\text{75\% subsidy}) + \beta_4 \mathbf{1}(\text{95\% subsidy}) + \\ & \beta_5 \mathbf{1}(\text{100\% subsidy with time cost}) + \beta_6 \mathbf{1}(\text{100\% subsidy + proof of residence}) + \\ & \beta_7 \mathbf{1}(\text{100\% subsidy + proof of residence + help}) + \beta_8 \mathbf{1}(\text{100\% subsidy + AQ info}) + \gamma_j + \varepsilon_{ij}\end{aligned}$$

**HTE** (let $D_i \equiv \mathbf{1}(\text{below 100\% FPL})$):

$$\begin{aligned}\text{Applied}_{ij} = {} & \beta_1 \mathbf{1}(\text{0\% subsidy}) + \beta_2 \mathbf{1}(\text{50\% subsidy}) + \beta_3 \mathbf{1}(\text{75\% subsidy}) + \beta_4 \mathbf{1}(\text{95\% subsidy}) + \\ & \beta_5 \mathbf{1}(\text{100\% subsidy with time cost}) + \beta_6 \mathbf{1}(\text{100\% subsidy + proof of residence}) + \\ & \beta_7 \mathbf{1}(\text{100\% subsidy + proof of residence + help}) + \beta_8 \mathbf{1}(\text{100\% subsidy + AQ info}) + \alpha D_i + \\ & \delta_1 \mathbf{1}(\text{0\% subsidy}) \times D_i + \delta_2 \mathbf{1}(\text{50\% subsidy}) \times D_i + \\ & \delta_3 \mathbf{1}(\text{75\% subsidy}) \times D_i + \delta_4 \mathbf{1}(\text{95\% subsidy}) \times D_i + \\ & \delta_5 \mathbf{1}(\text{100\% subsidy with time cost}) \times D_i + \\ & \delta_6 \mathbf{1}(\text{100\% subsidy + proof of residence}) \times D_i + \\ & \delta_7 \mathbf{1}(\text{100\% subsidy + proof of residence + help}) \times D_i + \\ & \delta_8 \mathbf{1}(\text{100\% subsidy + AQ info}) \times D_i + \gamma_j + \varepsilon_{ij}\end{aligned}$$

$\gamma_j$: strata fixed effects. Heteroskedasticity-robust standard errors.

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