Do Energy Efficiency Investments Deliver? Evidence from the Weatherization Assistance Program by Fowlie et al. (2018)

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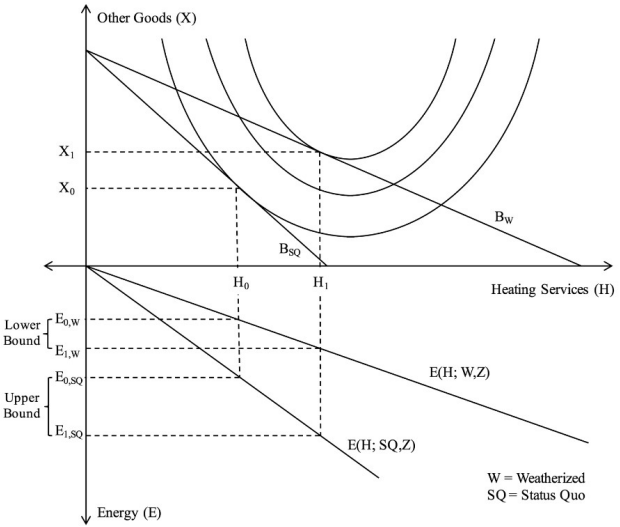
May 17, 2024

Introduction

- Energy efficiency investments are believed to offer win-win opportunity: energy-saving and environmental friendly.
- "Efficiency gap": real investment is dramatically less than the theoretical level.
- This paper studies whether the gap really exists: measure the welfare gains from investment in house energy efficiency improvement.
- Low-income households apply for the Weatherization Assistance Program (WAP), which pays for their weatherization (e.g. furnace replacement).
- The paper uses experimental and quasi-experimental variation in participation in the program to identify the returns.

Conceptual Framework



1. Reduce energy expenditure $(X_1 - X_0)$
2. "Rebound" effect: increase demand for the energy service $(H_1 - H_0)$

WAP

- WAP starts in 1976. All household at or below 200% of the poverty line were eligible to apply for assistance.
- Process:
  1. Applicants submit paperwork documenting their eligibility.
  2. CAAs identify and rank potential eligible applicants. CAAs assign household a high rank if it has an elderly resident, a person with disabilities, or child, or faces a high energy burden.
  3. CAAs conduct an energy audit of the home. Then they give recommendations of cost-effective energy-efficiency retrofit measures.
  4. Eligible applicants receive energy efficiency investment for a weatherization retrofit (on average \$5,150).

Research Design

- Obtain causal estimates of the effect of participation in the WAP program on energy consumption and indoor heating demand.

$$\ln(y_{imt}) = \beta \mathbf{I}\{WAP\}_{imt} + \alpha_{im} + \alpha_{mt} + \epsilon_{imt} \tag{1}$$

  - y_{imt}: energy consumption (natural gas, electricity or combination) at household i in month m and year t.
  - $\mathbf{I}\{WAP\}_{imt}$: switch from 0 to 1 in the month after a household's weatherization retrofit is complete.

- It is a DID design that compares the change in energy consumption after weatherization to before, relative to consumption among households that have not weatherized during sample period.

Experiment

- Encourage intervention from 2011 March to Feb 2012: increase the probability of treatment household' participation in WAP.
- Experimental sample comprised 34,161 households that were eligible for WAP. Approximately one quarter were randomly assigned as treatment group.
- The random assignment to encouragement is an IV:

$$\mathbf{I}\{WAP\}_{imt} = \theta \mathbf{I}\{Encourgaed\}_{imt} + \delta_{im} + \delta_{mt} + \eta_{imt} \tag{2}$$

- $\mathbf{I}\{Encourgaed\}_{imt}$ switches to 1 for the treatment group after March 2011.
- Period: June 2008 – May 2014, including at least two years of preretrofit data for all weatherized households.

Data Source

- Energy Consumption Data: monthly natural gas and electricity consumption data.
- Demographic data: census-block-level data (balance treatment and control group)
- Efficiency Audit Data: Compare realized costs with projections.

Results: First Stage

TABLE III

RANDOMIZED ENCOURAGEMENT: RETURN ON EFFORT

	Application (1)	Efficiency audit (2)	Weatherization complete (3)
Base rate	0.02**	0.01**	0.01**
	(< 0.01)	(< 0.01)	(< 0.01)
Encouragement	0.13**	0.05**	0.05**
	(< 0.01)	(< 0.01)	(< 0.01)
Households	28,888	28,888	28,888

Results: Second Stage

TABLE IV

EXPERIMENTAL ESTIMATED IMPACTS OF WEATHERIZATION ON HOUSEHOLD ENERGY CONSUMPTION

	Total energy		Gas	Electricity
	OLS-FE (1)	IV-FE (2)	IV-FE (3)	IV-FE (4)
Panel A: Dependent variable is monthly energy consumption (in logs)				
WAP	−0.10**	−0.20*	−0.21**	−0.10
	(0.01)	(0.08)	(0.08)	(0.10)
Imputed counterfactual consumption MMBtu/month		7.52	6.39	2.13
F-statistic	—	267.41**	261.06**	266.78**
Households	27,990	27,229	26,054	27,115
Observations	1,662,781	1,653,583	1,528,526	1,638,337

Panel B: Present value of (discounted) savings

Time horizon	Discount rate		
	3%	6%	10%
10 years	$1,983	$1,711	$1,428
16 years	$2,920	$2,349	$1,819
20 years	$3,459	$2,666	$1,979

1. Smaller than the projected savings ($9,810 among compliers)
2. Smaller than the upfront costs ($4,585 among compliers)

Quasi-Experiment

- Use data collected from households that applied for WAP after March 2021
- Treatment group: weatherized households;
- Control group: households that applied for WAP but had not been weatherized by mid-2014
- Synthetic control: re-weight control observations to achieve covariate balance across weatherized and unweatherized households.
- Period: June 2008 to May 2014

Data Source

- Energy Consumption Data
- Application Data: data about households collected through the application process. Use to balance across the treatment and control groups.
- Efficiency Audit Data

Results

TABLE V

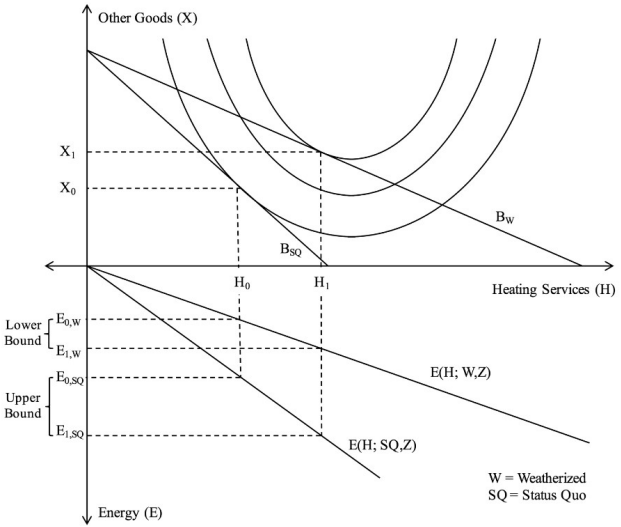
QUASI-EXPERIMENTAL ESTIMATED IMPACTS OF WEATHERIZATION ON HOUSEHOLD ENERGY CONSUMPTION

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Dependent variable is monthly energy consumption (in logs)						
WAP	−0.08**	−0.09**	−0.08**	−0.09**	−0.10**	−0.10**
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Month-of-sample FE	Y	N	Y	N	Y	N
Month-of-sample x county FE	N	Y	N	Y	N	Y
p-score matched sample	N	N	N	N	Y	Y
Adjusted R-squared	0.85	0.86	0.83	0.83	0.80	0.81
Households	5,013	5,013	3,334	3,334	3,404	3,404
Observations	282,196	282,196	183,353	183,353	188,287	188,287

Panel B: Present value of (discounted) savings

Time horizon	Discount rate		
	3%	6%	10%
10 years	$1,393	$1,202	$1,004
16 years	$2,052	$1,651	$1,278
20 years	$2,430	$1,873	$1,391

Conceptual Framework



- Lower bound: $P_E(E_{1W} - E_{0W})$
- Upper bound: $P_E(E_{1SQ} - E_{0SQ})$

Data and Methodology

- Indoor Temperature Data: field survey in March and early April 2013.
- 6400 households were selected from the quasi-experimental sample.
- 899 households allow researchers to record their thermostate set point.
- 688 households allow researchers to collect indoor thermometer readings.
- Method:
  1. Estimate an effect of weatherization on household demand for space heating.
  2. Estimate the energy expenditure for one unit of heating service before and after weatherization

Results: Increased Demand of Heating

TABLE VI

INDOOR TEMPERATURE SURVEY RESULTS

	Thermometer		Thermostat	
	(1)	(2)	(3)	(4)
Indoor temperature response to weatherization				
Base temperature	72.36**	72.17**	69.26**	68.96**
	(0.95)	(1.25)	(0.96)	(1.37)
Weatherized home	0.57	0.67	−0.57	−0.57
	(0.41)	(0.44)	(0.29)	(0.32)
Heating degree days	−0.16**	−0.15**	0.04	0.05
	(0.03)	(0.04)	(0.03)	(0.04)
Propensity score weights?	N	Y	N	Y
R-squared	0.02	0.02	0.01	0.01
Observations	1,359	1,359	899	899

Marginal Cost of Heating

- Regress energy consumption on the heating degree days (HDDs):

$$C_{imt} = \alpha_i + \beta_1 \mathbf{I}\{WAP\}_{imt} + \beta_2 HDD_{mt} + \beta_3 HDD_{mt} \times \mathbf{I}\{WAP\}_{imt} + \beta_4 HDD_{mt}^2 + \beta_5 HDD_{mt}^2 \times \mathbf{I}\{WAP\}_{imt} \quad (3)$$

- Heating degree days is the outdoor temperature.
- Assume that a household's choice of the indoor temperature is independent of outdoor temperatures, thus outdoor temperatures are a valid proxy for the heating services.
- Marginal cost of heating is equal to the marginal decrease in natural gas by one unit of HDD times the average natural gas price in the postencourage period.
- Weatherized: \$1.67; Un-weatherized: \$ 2.17.

Rebound Effects

- The lower bound of welfare gain is $0.67 \times 1.67 = 1.12$ per winter month
- The upper bound is : $0.67 \times 2.17 = 1.45$ per winter month.
- The welfare gains from efficiency-induced rebound in heating demand are very small.

Conclusion

- Weatherization reduced energy consumption by 10-20%.
  1. The upfront cost of the energy efficiency investments are about twice the cost of the realized energy savings.
  2. The projected savings are more than three times the actual savings.
- While the modest energy saving might be attributed to the rebound effect, the paper fails to find evidence of significant increases in indoor temperature at weatherized homes.

References

Fowlie, M., Greenstone, M., and Wolfram, C. (2018). Do energy efficiency investments deliver? evidence from the weatherization assistance program. *The Quarterly Journal of Economics*, 133(3):1597–1644.