

Does Increasing Energy Efficiency Result in Less Energy Security?

An Analysis of Energy Efficient Upgrades and their Impact on Energy Assistance Programs

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Problem Statement & Objective

Objectives

1. Develop a theoretical model and empirical procedure for examining the **relationship** between **energy efficiency** and **energy security**.
2. Generate an economically robust measure for **energy insecurity**.

What is Energy Insecurity?

- **Energy Insecurity** is driven by:
 - Energy Prices
 - Income
 - Ownership
 - Social Relations
 - Quality & Condition (i.e. Thermal Energy Efficiency)
- **Energy Insecurity** is most common among:
 - Low-Income Households
 - Elderly
 - Disabled
 - Families with children aged 16 and younger.

How is Energy Insecurity Measured?

Expenditure Approach

- $> 10\%$ of Income
- Excludes low-income households that spend less than 10%

Prediction Approach

- How much a household would have to spend on fuel in order to achieve a “livable indoor air temperature.”
- Assumes homogeneity among preferences.

Self-Report Survey

- Series of survey questions related to energy security.
- High income households can self-report as energy insecure.

Theoretical Framework

Household Production Theory

$$\begin{aligned} \text{Max } U_i &= U(X_i, S_i ; HC_i) \\ \text{s.t. } M_i &= P_x \cdot X_i + P_s \cdot S_i \quad \text{and} \quad S_i = S(K, F; \gamma) \end{aligned}$$

Where:

- X_i is a composite commodity (i.e. non-energy services)
- S_i is energy services (i.e. heating, cooling, & refrigeration)
- HC_i is a vector of household characteristics
- M_i is money income
- P_x is the price of the composite commodity
- $P_s = [P(\gamma) + P(F, K)]$ is the price of energy services
- K is fixed capital that uses fuel input F
- $\gamma \in [0, \gamma_{max}]$ is a measure of “technical efficiency”

Theoretical Framework

Assumptions

Constant Returns to Scale:

$$\alpha S = S(\alpha K, \alpha F; \gamma)$$

Technical Efficiency:

$$S_i = S[K(\gamma \cdot F)]$$

Cost to Produce Energy Services:

$$C(S) = [P(\gamma) \cdot K + P(K, F)] \cdot S$$

$$\Rightarrow MC = \frac{\partial C(S)}{\partial S} = [P(\gamma) \cdot K + P(K, F)]$$

Theoretical Framework

Constrained Optimization Problem:

$$\max_{X,S} \mathcal{L} = U[X, S(K, F; \gamma); HC] + \lambda(M - P_x \cdot X - [P(\gamma) \cdot K + P(K, F)] \cdot S)$$

First Order Conditions (F.O.C.)

- (1) $X : U_x[X, S(K, F; \gamma); HC] = \lambda P_x$
- (2) $S : U_s[X, S(K, F; \gamma); HC] = \lambda [P(\gamma) \cdot K + P(K, F)]$
- (3) $\lambda : M - P_x \cdot X = [P(\gamma) \cdot K + P(K, F)] \cdot S$

Implicit Demand Functions:

$$\left\{ \begin{array}{l} X^* = X_i(P_x, P_s, M; HC) \\ S^* = S_i(P_x, P_s, M : HC) \end{array} \right\}$$

Household Energy Security:

$$\Rightarrow S^* = S_i(P_x, P_s, M^*, HC) \equiv e_i$$

(Ogundari, 2017; Feleke et al., 2005)

Energy Security Index

Energy Security Index <i>n</i> = 2,698		Energy Security Measure	Results
Expenditure Approach		> 10% of Income	147 Households
Cook et al. (2008)	1. In the past 12 months, has the electric company sent a letter threatening to shut off the in the house for not paying bills?	Energy Secure (Zero Affirmative Responses)	2,470 Households
	2. In the last 12 months have you ever used a cooking stove to heat the house?	Moderately Energy Insecure (Answer "yes" to Q1)	112 Households
	3. Over the past 12 months, were there any days that the home was not [heated/cooled] because you could not pay the bills?	Severely Energy Insecure (Answers "yes" to any Q2-Q4)	116 Households
	4. Over the past 12 months, has the electric company shut off the electricity for not paying bills?		
Cluster Analysis	USDA ERS (Food Security)	Very Low Energy Security	9 Households
		Low Energy Security	924 Households
		Marginal Energy Security	1,140 Households
		High Energy Security	625 Households
LIHEAP		LIHEAP Eligible	760 Households
		Received Assistance	162 Households
Principal Component Analysis (PCA)		Energy Security Index	736 Households [0, 11.97]

Preliminary Results

Empirical Specification

$$e_i = S_i = \sum_{k=1}^{n=k} \beta_k X_i + \epsilon_i \quad \forall i = 1, \dots, N$$

- Where X_i is a vector of covariates including:
 - Prices
 - Money Income
 - Whether or not the household owns any energy star appliances
 - Other household characteristics affecting energy security

Results

- ⇒ Being a homeowner decreases the likelihood of being energy insecure.
- ⇒ Men are less likely to be energy insecure than women.
- ⇒ Having energy star appliances does have a significant impact on energy insecurity.
- ⇒ Likely need an IV approach.

Thank You

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Results

Table 1: Estimation Results

	LIHEAP	PCA
Ownership Status	0.07 (0.17)	-2.21*** (0.25)
Programmable Thermostat	0.24** (0.12)	-0.80*** (0.23)
Total Sq. ft	8.71×10^{-5} ** (4.17×10^{-5})	-2.95×10^{-4} *** (7.89×10^{-5})
Bedrooms	-0.14* (0.07)	0.56*** (0.13)
Bathrooms	0.04 (0.10)	-1.19*** (0.18)
HH Age	0.01** (0.01)	-0.05*** (0.01)
HH Income (\$)	6.19×10^{-5} *** (4.41×10^{-6})	-1.47×10^{-4} *** (9.11×10^{-6})
kWh (kilowatt hours)	-1.54×10^{-6} (1.53×10^{-5})	-2.73×10^{-5} (2.81×10^{-5})
Electricity Expenditures (\$)	-2.69×10^{-4} (1.69×10^{-4})	8.32×10^{-4} ** (3.24×10^{-4})
Energy Star	-0.01 (0.11)	0.09 (0.19)
Male	-0.07 (0.11)	-0.66*** (0.19)
Employed	0.04 (0.09)	-0.24* (0.14)
Hispanic	-0.64*** (0.18)	1.39*** (0.27)
Observations	2698	2698

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

RECS Survey Questions Used

RECS Energy Security Questions (2005)
1. Did you worry that you wouldn't be able to pay your home energy bill?
2. Did you reduce your expenses for what you consider to be basic household necessities?
3. Did you need to borrow from a friend or relative to pay your home energy bill?
4. Did you skip paying your home energy bill or pay less than your whole home energy bill?
5. Did you have a supplier of your electric or home heating service threaten to disconnect your electricity or home heating fuel service, or discontinue making fuel deliveries?
6. Did you close off part of your home because you could not afford to heat or cool it?
7. Did you keep your home at a temperature that you felt was unsafe or unhealthy at any time of the year?
8. Did you leave your home for part of the day because it was too hot or too cold?
9. Did you use your kitchen stove or oven to provide heat?

Continued....

	Mean	St. Error
Total Sq. Ft.	2,915.54	(31.20)
Bedrooms	3.18	(0.02)
Bathrooms	1.74	(0.01)
Income	56,000.74	(678.76)
Ownership Status	0.89	(0.01)
SNAP Benefits	0.06	(0.00)
LIHEAP Eligible	0.28	(0.01)
Employment Status	0.90	(0.01)
Number of Household Members	2.82	(0.03)
<i>N</i>	2,698	

Standard Errors in Parentheses