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Residential Electricity Demand, Split Incentives, and Refrigerator Efficiency

Dan Werner
Department of Agricultural and Resource Economics
University of Maryland, College Park
dwerner@arec.umd.edu

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Motivation

Contemporary policymakers regularly discuss energy efficiency as a key component within policy responses that aim to mitigate emissions, curb climate change, and enhance energy security. Understanding the implications of such policies requires a rigorous understanding of electricity demand in conjunction with appliance ownership patterns. Previous demand estimations have not considered appliance efficiency in combination with home ownership status.

The "split incentives" issue: Typically, renters are responsible for paying electricity bills, while landlords are responsible for major appliances and structural improvements that influence electricity use via efficiency. Thus, a landlord has no incentive to invest in energy efficiency except when such investments can be recovered through higher rents. This potentially creates an efficiency gap between owner-occupied households and renter-occupied households, where renter-occupied households end up using less efficient appliances. This project seeks to further understand and quantify this issue, using an empirical approach.

Research Questions

(1) What is the net effect of an efficient refrigerator on residential electricity demand?
(2) How does the refrigerator efficiency and electricity demand of owner-occupied households compare to renter-occupied households?
(3) What are the price and income elasticities of demand when these additional considerations are included?

Methods

I estimate a log-log residential electricity demand model which controls for electricity price, income, refrigerator efficiency, home-ownership, housing characteristics, demographic information, and weather. Since household refrigerator choice is endogenous to electricity demand, I use a two-stage least squares approach with instrumental variables to improve consistency. In the first stage, I estimate a linear probability model of owning an "Energy Star" efficient refrigerator.

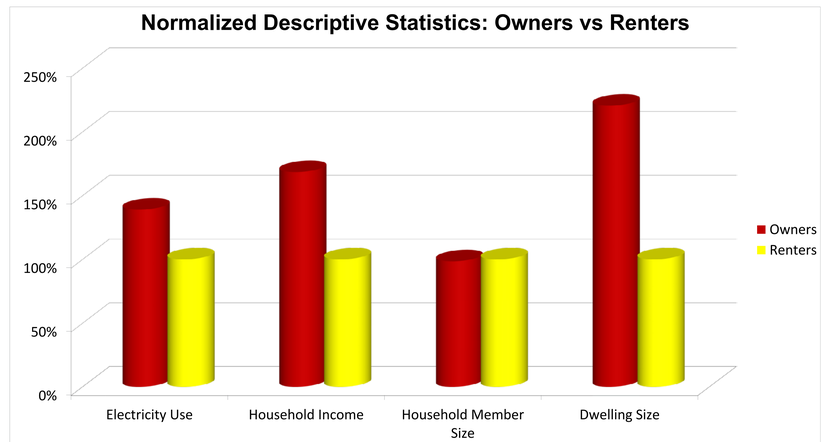
Summary Statistics

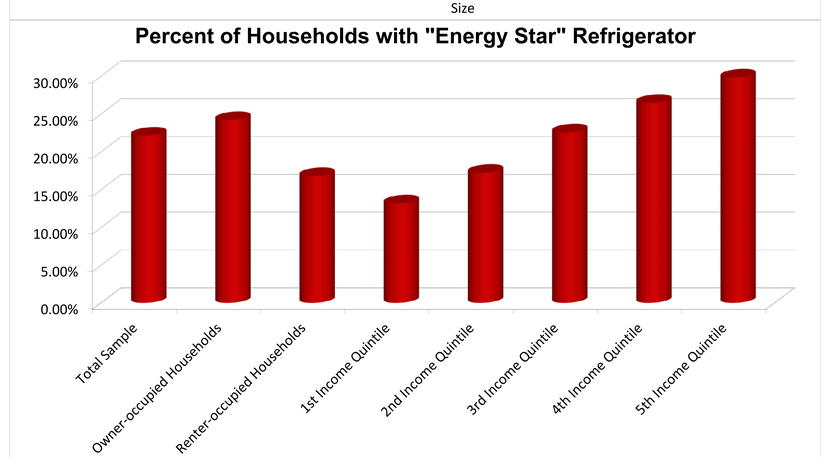
	Owners	Renters
Annual Electricity Use (kWh)	12,494	8,988
	(7,568)	(6,327)
Household Income ($USD)	55,393	32,874
	(35,450)	(26,412)
Household Members	2.69	2.73
	(1.43)	(1.61)
Total Rooms	6.41	4.38
	(1.78)	(1.46)
Household Sq Ft	2,785	1,263
	(1,644)	(931)
Energy Star Refrigerator	24.2%	16.8%
Single-family Dwelling	95.5%	43.5%
Multi-family Dwelling	4.5%	56.5%
Total Sample Size	2950	1146
Sample Proportion	72.0%	28.0%

Data

Residential Energy Consumption Survey
- -2005 household survey microdata
- -Electricity use, average price, appliance characteristics, detailed housing characteristics, and demographic information
- -Source: Energy Information Administration

Instrumental Variables
- -Historical state average electricity price
- -Source: Energy Information Administration
- -Survey of Energy Star "awareness"
- -Source: Consortium for Energy Efficiency / Environmental Protection Agency





Two-stage Least Squares Model

$$lnY_i = \beta_0 + \beta_1 lnP_i + \beta_2 lnI_i + \beta_3 H_i + \beta_4 A_i + \varepsilon_i$$

Y_i: annual electricity consumption
P_i: average electricity price
I_i: annual household income
H_i: housing attributes and demographic controls
A_i: appliance attributes (instrumented)
ε_i : random error term

Regression Results

Second Stage: Dependent variable is log Electricity Use (kWh).

Variables	(A)	(B)
log Electricity Price	-0.658***	-0.667***
	(0.047)	(0.047)
log Household Income	0.111***	0.094***
	(0.015)	(0.015)
Energy Star Refrigerator	-0.049*	-0.050*
	(0.026)	(0.026)
Renter-occupied Household	-0.017	-0.031
	(0.022)	(0.022)
Basic Housing Controls	Yes	Yes
Regional & State Controls	Yes	Yes
Additional Housing & Demographic Controls	No	Yes
Total Observations	4096	4096
R^2	0.645	0.656

Note: ***, **, & * denote statistical significance at the 1%, 5%, and 10% levels respectively. Standard errors are reported in parenthesis. Results are robust to heteroscedasticity. Additional robustness checks (not shown here) include subsample estimations by region and income groups.

First Stage: Dependent variable is a binary indicator Energy Star refrigerator.

Variables	(A)	(B)
log Historical Price	0.081***	0.080***
	(0.021)	(0.021)
Energy Star Awareness	0.025***	0.025***
	(0.001)	(0.001)
Renter	-0.041**	-0.040**
	(0.016)	(0.017)
Basic Housing Controls	Yes	Yes
Regional & State Controls	Yes	Yes
Additional Housing & Demographic Controls	No	Yes
Total Observations	4096	4096
R^2	0.495	0.509

Note: ***, **, & * denote statistical significance at the 1%, 5%, and 10% levels respectively. Standard errors are reported in parenthesis. Results are robust to heteroscedasticity. Additional robustness checks (not shown here) include subsample estimations by region and income groups.

Conclusion

Empirical results confirm that appliance efficiency plays a significant role in electricity demand, with an "Energy Star" refrigerator reducing annual electricity consumption by an average of 4.9%. Additionally, renter-occupied households are 4.1% less likely to contain an Energy Star refrigerator because of the split incentives issue. Regardless, there is no evidence that renters use significantly more electricity after proper controls. This suggests that gains from closing the efficiency gap between renters and owners may be smaller than previously thought. After considering appliance efficiency and the split incentives issue, the demand estimation still yields price and income elasticities consistent with the previous literature.