Evaluating the Slow Adoption of Energy Efficient Investments: Are Renters Less Likely to Have Energy Efficient Appliances?

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Abstract

While public discussion of HR 2454 (the "Waxman Markey" bill) has focused on the cap-and-trade program that would be established for carbon emissions, the bill also includes provisions that would tighten energy efficiency standards for a variety of consumer appliances. Supporters argue that appliance standards help address a number of market failures. In particular, many studies have pointed out that landlords may buy cheap inefficient appliances when their tenants pay the utility bill. Although this landlord-tenant problem has been widely discussed in the literature (see, e.g. Blumstein, Krieg, and Schipper, 1980; Fisher and Rothkopf, 1989; Jaffe and Stavins, 1994; Nadel, 2002; and Gillingham, Newell and Palmer, 2009), its practical importance has yet to be determined empirically. Using household-level data from the *Residential Energy Consumption Survey*, this paper compares appliance ownership patterns between homeowners and renters. The results show that, controlling for household income and other household covariates, renters are significantly less likely to have energy efficient refrigerators, clothes washers and dishwashers. The paper discusses possible mechanisms that could explain this behavior and the appropriate response for climate policy.

Key Words: Landlord-Tenant Problem; Energy Efficiency; Efficiency Gap;
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1 Introduction

While public discussion of HR 2454 (the "Waxman Markey" bill) has focused on the cap-and-trade program that would be established for carbon emissions, the bill also includes provisions that would tighten energy efficiency standards for a variety of consumer appliances. Supporters argue that appliance standards help address a number of market failures that would not be addressed by a cap-and-trade program alone.

One frequently discussed example is the landlord-tenant problem. Landlords may buy cheap inefficient appliances when their tenants pay the utility bill. Although investments in energy efficient appliances could, in theory, be passed on in the form of higher rents, it may be difficult for landlords to effectively convey information about the efficiency characteristics of appliances. Landlords certainly have an incentive to inform tenants about energy efficient appliances. However, it may be difficult for tenants to evaluate these claims because people move infrequently and most tenants do not have a great deal of experience evaluating the energy efficiency of appliances. Moreover, old energy bills are typically of limited value in evaluating claims from landlords because appliance utilization varies across households.

The landlord-tenant problem has been widely discussed in the literature (see, e.g. Blumstein, Krieg, and Schipper, 1980; Fisher and Rothkopf, 1989; Jaffe and Stavins, 1994; Nadel, 2002; and Gillingham, Newell and Palmer, 2009), but its practical importance has yet to be determined empirically. This paper compares appliance ownership patterns between homeowners and renters using household-level data from a nationally-representative survey, the *Residential Energy Consumption Survey* (RECS). The results show that renters are significantly less likely to have energy efficient refrigerators, clothes washers, and dishwashers. This pattern is apparent whether or not one controls for household income, demographics, energy prices, weather, and other controls. Conservatively, the results imply that nationwide the landlord-tenant problem increases annual energy consumption by 7 trillion btus and increases annual carbon emissions by 127,000 tons.

The paper proceeds as follows. Section 2 provides relevant background information about energy efficiency standards in the United States and describes the data. Section 3 describes the estimating equation used to test for differences in appliance ownership patterns between homeowners and renters. Results are presented and discussed. Section 4 calculates the total energy consumption, expenditure, and carbon emissions implied by the estimates and Section 5 concludes with a discussion of the appropriate response for climate policy.

2 Background and Data

Under the Energy Policy and Conservation Act of 1975, the U.S. Department of Energy is required to establish energy efficiency standards for refrigerators, room air conditioners, clothes washers, dishwashers, and a broad class of additional residential appliances. Standards are periodically revised as warranted by technological improvements. Most recently, the Energy Policy Act of 2005, the Energy Independence and Security Act of 2007, and HR 2454 (the "Waxman Markey" bill) all include provisions regarding energy efficiency standards for residential appliances.[1]

Since 1992 the Department of Energy in cooperation with the Environmental Protection Agency has, in addition, maintained a set of more stringent ("*Energy Star*") standards. Appliances exceeding these standards are among the most energy efficient in a particular class and receive an *Energy Star* label (see figure 1) that is prominently displayed on the appliance at the time of purchase. Participation in the Energy Star program is voluntary though in practice all appliance manufacturers choose to participate. Similar programs are used in Australia, Canada, Japan, New Zealand, Taiwan and the European Union.

The paper examines the saturation of *Energy Star* appliances using household-level data from the 2005 *Residential Energy Consumption Survey* (RECS), a nationally-representative in-home survey conducted approximately every five years by the Department of Energy. The RECS provides detailed information about the appliances used in the home as well as information about the demographic characteristics of the household, the housing unit itself, and weather characteristics. In addition, RECS provides detailed information about energy consumption that is obtained from the households' residential energy suppliers to ensure the reliability of energy prices and expenditures. The RECS is a national area-probability sample survey and RECS sampling weights are used throughout the analysis.

As in the 1997 and 2001 surveys, the 2005 RECS asked about the age of all major appliances. In addition, beginning in 2005 households were also asked whether or not appliances were *Energy Star*. These questions are somewhat unusual because although many surveys ask about appliance ownership (e.g. American Community Survey), it is unusual to have information from a nationally-representative survey about energy efficiency. The question was asked for refrigerators, dishwashers, room air conditioners, and clothes washers and households are shown an *Energy Star* label when

[1] See Nadel (2002) and U.S. Department of Energy (2009), "Code of Federal Regulations, Energy Conservation Program for Consumer Products, Energy and Water Conservation Standards and Their Effective Dates, 430.32" for more information about appliance efficiency standards.

answering the question. Households with appliances more than 10 years old were assumed not to have *Energy Star* appliances and were not asked the question. In addition to "Yes" and "No", households could respond that they "Don't Know" if their appliance is *Energy Star*. In the main results, we treat "Don't Know" responses as if the appliance is not *Energy Star*. Estimates are also reported in which these responses are excluded and results are similar.

Throughout the analysis we exclude households whose utilities are included in the rent. In the 2005 RECS sample, 13.4% of all renters (4.2% of all households) have their utilities included in the rent. These households do not face any marginal cost of using energy and thus tend to use their appliances more intensively.[2] It makes sense to exclude these households because the incentives are very different in this case. Paying utilities themselves, these landlords have an incentive to invest in high-efficiency appliances. It would have been interesting to specifically examine appliance ownership patterns among these housing units but there are too few observations for credible inference.

3 Results

3.1 Descriptive Statistics

Table 1 reports mean household characteristics for homeowners and renters. The final column reports p-values from tests that the means in the subsamples are equal. There are several pronounced differences between homeowners and renters. First, household economic and demographic characteristics are very different. Homeowners have higher annual household income, are less likely to receive welfare benefits, are older, less likely to be non-white, and more likely to live in suburban and rural areas. Second, appliance saturation levels differ – homeowners are more likely to have clothes washers and dishwashers but less likely to have room air conditioners, presumably because homeowners tend to have central air conditioners. Third, homeowners are considerably more likely to have *Energy Star* refrigerators, clothes washers, and dishwashers. Differences range from 8 percentage points for refrigerators to 12 percentage points for clothes washers. These three differences are statistically significant at the 1% level.

Comparison of subsample means provides an important baseline for comparison. However,

[2]Using RECS data from 1987, 1990, 1993 and 1997, Levinson and Niemann (2004) test whether energy use is higher by apartment tenants when landlords pay for utilities, finding that tenants in utility-included apartments set their thermostats between one and three degrees (Farenheit) warmer during winter months when they are not at home.

it is difficult to draw strong conclusions on the basis of the evidence in Table 1. Although these differences are consistent with a true difference in saturation rates between homeowners and renters, these patterns could also be driven by other factors such as household income that are correlated with homeownership. The analysis that follows adopts a regression framework to refine these comparisons, comparing *Energy Star* saturation across homeowners and renters while controlling for household income and other household characteristics.

3.2 Regression Results

Table 2 presents results corresponding to five separate regressions of the form,

$$y_i = \beta_0 + \beta_1 1(renter) + \beta_2 X_i + \epsilon_i.$$

The unit of obsevation is the household and all specifications are estimated using RECS sampling weights. The dependent variable y_i is indicated at the top of each column. For example, in column (1) the dependent variable is an indicator variable equal to one if the household has an *Energy Star* refrigerator. For each dependent variable the table reports the estimated coefficient and standard error corresponding to $1(renter)$, an indicator variable for renters. The coefficient of interest β_1 is the difference in *Energy Star* appliance saturation between renters and homeowners. The sample includes all households with an appliance of a particular type. As indicated in Table 1, virtually all households have a refrigerator so the sample size is relatively large whereas saturation rates for other appliances are lower and the sample sizes are correspondingly smaller.

Renters are significantly less likely to have energy efficient refrigerators, dishwashers and clothes washers. For these three appliances the differences are large in magnitude ranging from 3.2 percentage points for clothes washers to 9.7 percentage points for dishwashers. The point estimate on room air conditioners is negative but the estimate is not statistically significant. Of the four appliances, room air conditioners are somewhat different because in many cases they are owned by the renter than the landlord. Whereas it would be unusual for a tenant to install his/her own refrigerator or clothes washer in a rental unit, room air conditioners are relatively portable and can be easily installed. To the extent that room air conditioners are owned by tenants themselves, we would not expect to see a landlord-tenant problem.

The stacked specification in column (5) uses all four appliance indicators as dependent variables (stacked), and allows all parameters except for β_1 to vary across appliances. Taken together, renters

are 5.5 percentage points less likely to own energy efficient appliances. The estimate in the stacked specification is statistically significant at any conventional significance level. For all specifications the table also reports p-values for one-sided tests where the null hypothesis is that renters and home-owners are equally likely to have energy efficient appliances.

The regressions control flexibly for all a wide-range of household characteristics. Electricity prices (cubic) are included to control for differences in the private benefits of energy efficiency across households. Household economic characteristics include a cubic in household income, as well as indicators for whether the household head is employed and whether the household receives welfare benefits. Household demographic characteristics include indicator variables for 1, 2, 3, 4, 5, and 6+ household members, the age of the household head, and indicators for whether the household has children and whether the household head is non-white. In addition, all specifications control for Census division indicators and available state indicators (RECS reports state of residence only for households living in New York, California, Florida and Texas). Finally, the regressions control for heating and cooling degree days to account for differences in appliance utilization that vary across households living in different climates. After including these covariates there remains large unexplained variation in *Energy Star* saturation, with low values of R^2 across specifications.

3.3 Alternative Specifications

Table 3 reports results from a number of alternative specifications. The table reports coefficients and standard errors corresponding to $1(renter)$ for 21 separate regressions, all estimated using RECS sampling weights. As in Table 2, for each regression the dependent variable is indicated in the top of the column and the stacked specification allows all parameters except for the coefficient on the renter indicator to vary across appliances.

Row (A) reports the baseline specification. Row (B) reports estimated coefficients from a specification that excludes all control variables. Results are very similar to the baseline specification, suggesting that the main result that renters are less likely to have energy efficient appliances appliance saturation is not unduly sensitive to selection of control variables. Row (C) reports results from estimating the model using a logit model rather than the linear probability model used elsewhere. Results are very similar to the baseline specification.

The estimates in row (D) exclude households that "don't know" if their appliance is *Energy Star*. In the baseline specification these households were treated as if they did not have *Energy Star* appliances, and it is reassuring that this does not seem to be driving the results. Relatively

few households answer "don't know" and the fraction is similar for homeowners and renters. For example, for refrigerators 4.0% of homeowners and 5.3% of renters answer "don't know". Row (E) restricts the sample to households that have purchased the appliance within the last ten years. Again results are similar to the baseline specification, suggestion that the results are not driven by differences in appliance age between homeowners and renters.

Row (F) uses an alternative dependent variable for clothes washers. In addition to asking whether or not a household's clothes washer is *Energy Star*, RECS asks if the clothes washer is front-loading. As described in detail in Davis (2008), front-loading clothes washers tumble clothes on a horizontal axis through a pool of water at the bottom of the tub, thereby using up to 60% less energy per cycle than conventional washers. During this period all front-loading clothes washers met *Energy Star* requirements so this represents an alternative and potentially less error-prone measure of energy efficiency. This specification addresses concerns, for example, about whether or not households actually know whether or not they have an *Energy Star* appliance. Overall in the sample 7.2% of households report having a front-loading clothes washer. Among homeowners the rate is 9.0% compared to only 2.3% among renters. In the regression the point estimate on $1(renter)$ indicates a 6.7 percentage point difference in ownership between renters and homeowners. Finally, row (G) reports the results from estimating the sample using only households from California. Results are similar to the baseline estimates though the standard errors are considerably larger.

4 Evaluating the Implied Total Cost

An appealing feature of the estimates in the previous section is that they provide some of the information necessary to evaluate the overall magnitude of the landlord-tenant problem for an important group of residential appliances. This section illustrates how the estimates from Table 2 can be applied, under simplified assumptions about the energy consumption characteristics of appliances, to measure the implied total energy consumption, expenditure, and carbon emissions from the landlord-tenant problem. This preliminary assessment indicates that the social cost of this market failure is large in magnitude.

Table 4 reports the total cost of the landlord-tenant problem as implied by the estimated coefficients in Table 2. These results are calculated using average annual energy consumption for *Energy Star* appliances from Sanchez, et. al (2008).[3] Nationally, if renters were equally likely

[3]Sanchez, et. al (2008, Table 5) reports annual energy savings per *Energy Star* unit of 0.85 Mbtu ($7.59) for refrigerators, 1.17 Mbtu ($11.45) for dishwashers, 0.68 Mbtu ($6.05) for room air conditioners, and 1.32 Mbtu

as homeowners to have energy efficient appliances there would be 2.2 million more *Energy Star* refrigerators, 3.2 million more *Energy Star* dishwashers, 0.3 million more *Energy Star* room air conditioners, and 1.1 million more *Enery Star* clothes washers.[4] Nationwide these appliances would reduce annual energy consumption by 7.2 trillion Btus, reduce annual energy expenditures by 73 million, and reduce annual carbon emissions by 127,000 tons.

These results provide a valuable preliminary assessment of the overall magnitude of the landlord-tenant problem, though it is important to emphasize that these calculations are based on several assumptions that are difficult to verify empirically. First, basing the results on average energy consumption is likely to be conservative, biasing down the estimates of energy consumption, expenditure, and carbon emissions if in practice landlords tend systematically to choose relatively inefficient appliances within the class of non-*Energy Star* appliances. Second, basing expenditures on average energy prices. Although the regressions in Section 3 control for energy prices, the regressions implicitly assume that the landlord-tenant problem is equally prevalent in places with different levels of energy prices. In practice, the effect is presumably larger in places where energy prices are high and the gains from energy efficiency are the largest. This would imply larger measures of implied annual energy expenditures than the numbers reported in Table 4.

5 Implications for Policy

These results confirm conventional wisdom about the landlord-tenant problem, finding that renters are significantly less likely to have energy efficient refrigerators, clothes washers and dishwashers. The effect if large in magnitude, implying annual excess energy consumption of 7.2 trillion Btus and excess annual carbon emissions of more than 100,000 tons. While these effects are not small, the total cost of the landlord-tenant problem is likely to be considerably larger than the magnitudes reported here, given that our analysis has been restricted to four major appliances and the landlord-tenant problem extends to a broader class of appliances as well as to the energy-efficiency characteristics of the housing units themselves (e.g. windows, doors, and insulation).

($12.23) for clothes washers. Sanchez, et. al (2008, Table 6) reports that these appliances generate between .015 and .018 tons of carbon per Mbtu depending on the types of energy (electricity, natural gas, etc) used by each appliance.

[4] In related work Murtishaw and Sathaye (2006) use data from the American Housing Survey to evaluate the scope for principal-agent problems in residential refrigeration, water heating, space heating and lighting. For each end use they count the number of (i) owner-occupied residences older than 15 years, (ii) owner-occupied residences less than 15 years old, and thus potentially subject to a principal-agent problem between the builder and the owner, (iii) rental units where household pays utilities and (iv) rental units where household does not pay utilities. This study was part of an international project whose results are described in IEA (2007).

As described by Charles (2009), principal-agent problems such as this one, "occur when someone gets to spend another person's money." The principal (the tenant) is hiring the agent (the landlord) to provide housing services. Problems arise, however, because the two parties have different incentives. In particular, the principal values high-quality services such as energy efficient appliances, but these services are costly for the agent to provide. Similar situations arise, for example, between builders and home buyers and between hotels and hotel guests. The agents in these problems do not face the marginal cost of energy, so Pigouvian approaches will not address these market failures.

Although the evidence for principal-agent problems is clear, the policy implications are not. Appliance standards address these problems by eliminating non energy-efficient appliances from the market. This "solves" the landlord-tenant problem by obligating all landlords to purchase energy efficient appliances. Hausman and Joskow (1982) point out, however, that there is heterogeneity among households in utilization levels, energy prices, and preferences for energy efficiency. Some households (and in particular, some tenants) would indeed be made better off with more stringent standards but for other households the more expensive energy efficient models do not make sense. For example, Davis (2008) finds that while 83% of households are better off buying a clothes washer than meets the 2007 minimum efficiency standards, 17% of households would have better off buying a cheaper model.

Appliance standards also may slow the rate at which households replace their appliances. As articulated by Gruenspecht (1982), standards increase the cost of new durable goods, potentially causing households to delay new purchases. One way to address this concern is to use publicly-funded rebates or even a "cost for clunkers" program for appliances. The Department of Energy recently committed nearly $300 million in funding for rebates for qualified *Energy Star* appliances (see U.S. Department of Energy, 2009 for details). Such rebates bring the purchase price of energy efficient appliances close to that of non energy efficient models and thus will encourage some landlords to adopt energy efficient models. Rebates also, however, will be enjoyed by a potentially large number of inframarginal households who would have purchased energy efficient appliances anyway.

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Figure 1: *Energy Star* Label

Table 1
Comparing Mean Household Characteristics of Homeowners and Renters

	Homeowners	Renters	p-value
Household Economic Characteristics			
Household Income (1000s)	55.7	34.2	.00
Proportion Household Head Employed	0.90	0.88	.08
Proportion Welfare	0.06	0.24	.00
Household Demographics			
Household Size (persons)	2.60	2.57	.69
Age of Household Head	52.7	42.2	.00
Proportion with Children	0.34	0.38	.10
Proportion Household Head Non-White	0.21	0.44	.00
Type of Neighborhood			
Urban	0.36	0.57	.00
Town	0.16	0.19	.14
Suburban	0.23	0.14	.00
Rural	0.25	0.10	.00
Climate			
Annual Cooling Degree Days (1000s)	1.58	1.61	.64
Annual Heating Degree Days (1000s)	4.15	3.82	.09
Energy Prices (dollars per BTU)			
Electricity	30.5	32.7	.15
Natural Gas	11.6	12.5	.30
Fuel Oil	10.4	10.3	.06
Liquefied Petroleum Gas	28.0	24.6	.11
Appliance Saturation			
Refrigerator	1.00	1.00	.95
Dishwasher	0.67	0.39	.00
Room Air Conditioner	0.21	0.38	.01
Clothes Washer	0.95	0.57	.00
Energy Star Appliance Saturation			
Refrigerator	0.24	0.17	.00
Dishwasher	0.18	0.07	.00
Room Air Conditioner	0.04	0.05	.01
Clothes Washer	0.23	0.12	.00
Sample Size	2979	1219	
Implied Number of Households (millions)	77.8	28.6	

Note: This table describes households in the 2005 Residential Energy Consumption Survey. Means are computed using RECS sampling weights. The final column reports p-values (clustering by Census division) from tests that the means in the subsamples are equal. The table refers to the household's primary refrigerator.

Table 2
Are Renters Less Likely to Have Energy Efficient Appliances?

	Energy Star Refrigerator [mean=.22]	*Energy Star* Dishwasher [mean=.25]	*Energy Star* Room Air Conditioner [mean=.16]	*Energy Star* Clothes Washer [mean=.23]	Stacked Specification [mean=.23]
	(1)	(2)	(3)	(4)	(5)
1(Renter)	-.067	-.097	-.009	-.032	-.055
	(.015)	(.036)	(.021)	(.014)	(.010)
p-value	.00	.01	.34	.02	.00
Electricity Prices (Cubic)	yes	yes	yes	yes	yes
Household Economic Characteristics	yes	yes	yes	yes	yes
Demographics and Neighborhood Type	yes	yes	yes	yes	yes
Census Division and Available State Indicators	yes	yes	yes	yes	yes
Heating and Cooling Degree Days (Cubics)	yes	yes	yes	yes	yes
Number of Observations	4,194	2,433	1,184	3,564	11,375
R^2	.05	.05	.04	.05	.05

Note: This table reports estimated coefficients and standard errors corresponding to 5 separate regressions, all estimated using RECS sampling weights. For each regression the dependent variable is indicated in the top of the column. For example, in column (1) the dependent variable is an indicator variable equal to one if the household has an *Energy Star* refrigerator. The variable of interest is an indicator variable for renters. The table also reports p-values for one-sided tests where the null hypothesis is that renters and home-owners are equally likely to have energy efficient appliances. The stacked specification allows all parameters except for the coefficient on the renter indicator to vary across appliances. Standard errors (in parentheses) are robust to heteroskedasticity and arbitrary correlation within Census divisions.

Table 3
Are Renters Less Likely to Have Energy Efficient Appliances? Alternative Specifications

	Energy Star Refrigerator [mean=.22]	*Energy Star* Dishwasher [mean=.25]	*Energy Star* Room Air Conditioner [mean=.16]	*Energy Star* Clothes Washer [mean=.23]	Stacked Specification [mean=.23]
	(1)	(2)	(3)	(4)	(5)
(A) Baseline Specification	-.067	-.097	-.009	-.032	-.055
	(.015)	(.036)	(.021)	(.014)	(.010)
(B) No Controls	-.067	-.100	-.032	-.030	-.067
	(.014)	(.024)	(.011)	(.014)	(.008)
(C) Logit Model	-.072	-.106	-.010	-.033	-.062
	(.015)	(.037)	(.020)	(.015)	(.009)
(D) Excluding "don't know"	-.071	-.108	-.013	-.039	-.062
	(.015)	(.036)	(.025)	(.016)	(.011)
(E) Among Households with Newer Appliances	-.082	-.096	-.011	-.021	-.056
	(.020)	(.036)	(.035)	(.017)	(.014)
(F) Front-Loading Washer [mean=.07]	-	-	-	-.067	-
				(.015)	
(G) California Only	-.082	-.157	.111	-.023	-.068
	(.053)	(.076)	(.099)	(.065)	(.035)

Note: The table reports coefficients and standard errors corresponding to 1(*renter*) for 31 separate regressions, all estimated using RECS sampling weights. As in Table 2, for each regression the dependent variable is indicated in the top of the column. In row (B) the model is estimated using a logit model rather than the linear probability model used elsewhere. This row reports marginal effects with standard errors estimated using the delta method. In row (D) observations are dropped for which households do not know if their appliance is *Energy Star*. In row (F) the dependent variable is an indicator equal to one if the household has a front-loading clothes washer.

Table 4
The Implied Total Cost of the Landlord-Tenant Problem

	Refrigerators	Dishwashers	Room Air Conditioners	Clothes Washers	All Appliances Combined
Total Units in millions	2.2	3.2	0.3	1.1	6.8
	(0.5)	(1.2)	(0.7)	(0.5)	(1.6)
Annual Energy Consumption	1.9	3.7	0.2	1.4	7.2
in Btus, trillions	(0.4)	(1.3)	(0.5)	(0.6)	(1.6)
Annual Expenditure on Energy	18	39	1.9	14	73
in 2009 dollars, millions	(4.0)	(14)	(4.4)	(5.9)	(16)
Annual Carbon Emissions	35	67	3.6	21	127
in metric tons, thousands	(7.7)	(25)	(8.4)	(9.1)	(29)

Note: This table reports the total cost of the landlord-tenant problem as implied by the estimated coefficients in Table 2. Standard errors are reported in parentheses. RECS sampling weights are used in all calculations.