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 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, there is little empirical evidence on the magnitude of the distortion. This paper compares appliance ownership patterns between homeowners and renters using household-level data from the Residential Energy Consumption Survey. The results show that, controlling for household income and other household characteristics, renters are significantly less likely to have energy-efficient refrigerators, clothes washers and dishwashers.

Key Words: Landlord-Tenant Problem; Principal-Agent Problem; Efficiency Gap;
JEL: D13, L68, Q41, Q54

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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 consumer appliances. Appliance standards have been used in the United States since the 1970s and currently standards are in place for dozens of different appliance types. 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. Many studies have pointed out that 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 have an incentive to inform tenants about energy-efficient appliances. However, it may be difficult for tenants to evaluate these claims because most tenants are not experienced in 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. Understanding the mechanisms that explain this behavior and the magnitude of the distortion is important for determining how to most effectively target policies.

This paper compares appliance ownership patterns between homeowners and renters using household-level data from a nationally-representative survey, the Residential Energy Consumption Survey. The results show that renters are significantly less likely to report having energy-efficient refrigerators, clothes washers, and dishwashers. Differences are large in magnitude and remain after controlling for household income, demographics, energy prices, weather, and other controls. The results imply nationwide an annual increase in energy consumption of 9 trillion btus, equivalent to 165,000 tons of carbon emissions annually.

The paper focuses on a set of appliances which together represent about one-fourth of energy consumption in rental housing units.[1] There is reason to believe, however, that the other three-

[1] U.S. Department of Energy (DOE), 2005 Residential Energy Consumption Survey, "Total Energy Consumption, Expenditures, and Intensities", Table US12.

fourths (mostly heating and cooling) is also subject to the landlord-tenant problem. The agency issues with building energy efficiency may actually be worse than with appliances. Although it is relatively easy to verify that a dishwasher is energy-efficient, it requires considerably more expertise to verify investments in, e.g. roof insulation or heating and cooling ductwork. Given pending legislation aimed at this broader class of residential energy efficiency investments, an important priority for future work is to examine directly this broader class of energy-efficient investments.[2]

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.

2 Background and Data

Under the Energy Policy and Conservation Act of 1975 the U.S. Department of Energy (DOE) 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) include provisions regarding energy efficiency standards for residential appliances.[3]

Since 1992 the Department of Energy in cooperation with the Environmental Protection Agency has, in addition, maintained a set of more stringent standards called "Energy Star" standards. Appliances exceeding these standards are among the most energy-efficient in a particular class and receive an Energy Star label that is prominently displayed on the appliance at the time of purchase.[4] Participation in the Energy Star program is voluntary though in practice all appliance

[2]The DOE's Weatherization Assistance Program has distributed $5 billion under the American Recovery and Reinvestment Act of 2009. Recently dubbed "Cash for Caulkers" in most states the program will provide incentive payments, generally from $2000 to $4000 for weatherization projects with the homeowner typically paying at least 50% of the projects total costs. See Leonard, David "A Stimulus That Could Save Money," *New York Times*, November 17, 2009 for details.

[3]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 in the United States.

[4]The Energy Star program has been criticized for using out of date testing procedures and because the program relies on manufacturers to do their own testing. In November 2008 a group of refrigerators produced by LG had their Energy Star status revoked after a Consumer Reports investigation revealed that the reported energy savings did not hold up under independent testing. DOE procedures call for a refrigerator's icemaker to be off during testing, and Consumer Reports found that in regular use the icemaker on these units approximately doubled annual electricity

manufacturers choose to participate. Similar programs are used in Australia, Canada, Japan, New Zealand, Taiwan and the European Union. In addition, many utilities offer rebates for households that purchase Energy Star appliances and the DOE recently committed $300 million in funding for rebates for qualified Energy Star appliances.[5]

This 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 information about energy prices and energy consumption that is obtained from the households' residential energy suppliers. The RECS is a national area-probability sample survey and RECS sampling weights are used throughout the analysis.

RECS also provides detailed information on who pays for utilities. The main results exclude households whose utilities are included in the rent. In the 2005 RECS sample, this includes 13.4% of all renters (4.2% of all households). These households do not pay directly for energy and thus tend to use their appliances more intensively.[6] In addition, the incentives for the adoption of energy-efficient technologies are very different. Paying utilities themselves, landlords in these housing units have an incentive to invest in energy-efficient appliances and one would not expect to see the typical landlord-tenant problem. This group is examined separately later in the paper.

Beginning in 2005 households in the RECS were asked whether or not their major appliances were Energy Star.[7] These questions are somewhat unusual. Although many surveys ask about appliance ownership (e.g. American Community Survey), nationally-representative surveys typically do not elicit information about energy efficiency. The question was asked for refrigerators, dishwashers, room air conditioners, and clothes washers and households were shown an Energy Star label when answering the question. Households with appliances more than 10 years old were

consumption. See Consumer Reports, "Energy Star Has Lost Some Luster," October 2008, 73 (10), pages 24-26 and Consumer Reports, "Fridges Lose Their Energy Star," February 2009, 74 (2), pages 40-40 for details.

[5]Department of Energy, "Secretary Chu Announces Nearly $300 Million Rebate Program to Encourage Purchases of energy-efficient Appliances," Press Release, July 14, 2009.

[6]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 (Fahrenheit) warmer during winter months when they are not at home.

[7]Earlier RECS waves do not ask about appliance energy efficiency. The 2001 RECS does include a question about whether your clothes washer is front loading or top loading. However, in 2001 front loading clothes washers were still relatively unusual in the United States, representing only 3.0% of all clothes washers in the RECS sample. See DOE, "2001 Residential Energy Consumption Survey: Housing Characteristics Tables", Table HC5-4a.

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. 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". In the main results, "don't know" responses are treated as if the appliance is not Energy Star. Results are also reported from a specification in which these responses are excluded and results are similar.

The Energy Star program has existed since 1992 and Energy Star labels are prominently displayed on most Energy Star appliances. Still, with any self-reported information there is reason to be concerned about accuracy.[8] Perhaps most problematic for this analysis, it would seem reasonable to believe that homeowners may be better informed than renters about whether or not their appliances are Energy Star. This could provide an alternative explanation for the finding that homeowners are more likely to report having Energy Star appliances. In light of these concerns, the following analysis also examines two alternative measures of energy efficiency. Results are generally similar for these alternative measures, suggesting that the results are not entirely driven by misreporting.

First, in addition to asking whether or not a household's clothes washer is Energy Star, RECS asks if the clothes washer is "front loading" or "top 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, using about 50% less energy per cycle than conventional washers. Thus "front loading" is an excellent proxy for energy efficiency and, importantly, whether the clothes washer is front loading is likely to be salient to both homeowners and renters.

Second, results are reported for energy-efficient lighting. After asking how many lights the household typically uses the survey asks, "How many of these lights use energy-efficient bulbs? An energy-efficient bulb is a fluorescent tube or a compact fluorescent bulb that costs more than a regular bulb but is one that lasts much longer." The measure used in the analysis is whether or not the household reports having *any* energy-efficient light bulbs though results are similar for the

[8]The fraction Energy Star in RECS corresponds poorly to fraction Energy Star in appliance sales data from DOE. For example, in the RECS among households with appliances less than four years old the percentage of households who report owning an Energy Star appliance is 58% for refrigerators, 63% for dishwashers, 30% for room air-conditioners, and 59% for clothes washers. In contrast, the DOE reports that the percentage Energy Star among appliances sold in 2005 was 33% for refrigerators, 82% for dishwashers, 52% for room air-conditioners, 36% for clothes washers. These percentages are based on sales data reported to DOE by retail partners. DOE warns users that the set of retail partners changes from year to year, and urges caution in using these data, particularly for making comparisons across years.

percentage of light bulbs that are energy-efficient. The survey also distinguishes between lighting that is used 1-4, 4-12, and 12+ hours per day. Specifications have also been examined separately for different levels of usage and the pattern is similar for the different categories.

3 Results

3.1 Descriptive Statistics

Table 1 presents descriptive statistics. The first two columns report mean household characteristics for homeowners and renters. The final column reports p-values from tests that the means in the subsamples are equal. The table reveals pronounced differences between homeowners and renters. Household economic and demographic characteristics are very different. Homeowners have higher annual household income, are less likely to receive welfare benefits, are older, are less likely to be non-white, and are more likely to live in suburban and rural areas. In addition, appliance saturation levels differ substantially with homeowners more likely to have clothes washers and dishwashers but less likely to have room air conditioners.

The bottom of Table 1 describes patterns for energy-efficient technologies. Homeowners are significantly more likely to report having energy-efficient refrigerators, dishwashers, clothes washers, and lighting. Differences range from 7 percentage points for refrigerators to 11 percentage points for clothes washers. Particularly striking are the means for front loading clothes washers. Nine percent of homeowners report having a front loading washer compared to only two percent for renters. For air conditioners the pattern is reversed, with more renters reporting Energy Star units. This reflects the higher saturation levels for room air conditioners among renters. Moreover, room air conditioners are somewhat different because they are often owned by the renter. 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.

Comparison of means provides an important baseline for comparison. However, it is difficult to draw strong conclusions on the basis of the evidence in Table 1. Although these differences are consistent with the landlord-tenant problem, this pattern 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 this analysis, comparing ownership patterns across homeowners and renters while controlling for household income and other household characteristics.

3.2 Regression Results

Tables 2a-f present results corresponding to regressions of the following form,

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

The dependent variable y_i is an indicator variable equal to one if the household reports having a particular energy-efficient technology. For example, in Table 2a the dependent variable is an indicator variable for households with an Energy Star refrigerator. Tables report 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 with a negative coefficient indicating that renters are less likely to have an energy-efficient model. Households who do not have a particular technology type are excluded from the sample so the sample size varies across tables from 4,198 (all households) for lighting, to 1,184 for room air conditioners.

Households with high utilization levels have more to gain from adoption of energy-efficient technologies (Hausman and Joskow, 1982) and in making comparisons it is important to control for these differences. The complete specification controls for a vector of covariates X_i that includes household income, household demographics, electricity prices (cubic), heating and cooling degree days (cubics), Census division indicators and available state indicators. RECS reports state of residence only for households living in New York, California, Florida and Texas. Household demographics include indicators for whether the household head is employed and whether the household receives welfare benefits, 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.

Table 2a reports results for refrigerators. Renters are significantly less likely to report having energy-efficient refrigerators. In column (1) without controls, the difference is 6.7 percentage points, identical to the difference in sample means in Table 1. This difference is large compared to the sample mean of 22 percent. Controlling for income decreases the point estimate corresponding to $1(renter)$, consistent with high-income households being both more likely to be homeowners and more likely to own energy-efficient refrigerators. After adding additional controls the point estimate increases to 7.0 percentage points. Homeowners tend to be older, face lower electricity prices, and live in rural and suburban areas; all characteristics that tend to decrease the prob-

ability that a household reports having Energy Star. Tables 2b-f report results for dishwashers, room air-conditioners, clothes washers, and lighting. The magnitude of the estimates varies across technologies, but the overall pattern is generally similar, with renters significantly less likely have energy efficient technologies in most specifications.

Table 3 reports results for alternative specifications. Most of these specifications add additional controls, and, for the most part, the basic pattern of renters being less likely to have energy-efficient technologies is robust to the addition of these controls. Although it is impossible to rule out concerns about omitted variables, the fact that the results are similar with and without control variables lends support to the interpretation of these estimates as evidence of the landlord-tenant problem.

3.3 Discussion of Alternative Possible Explanations

These results demonstrate a consistent pattern of renters being less likely to have energy-efficient technologies. These results are consistent with the landlord-tenant problem. It is important to consider, however, a number of alternative explanations.

First, the differences could reflect landlords choosing not to invest in energy-efficient technologies because of appliances may have shorter lifespans in renter occupied units. Because they do not own the appliances, renters may treat appliances more roughly (e.g. slamming doors, breaking refrigerator shelves) increasing the wear and tear on appliances eventually leading to them needing to be replaced. If this behavior is prevalent, landlords would then efficiently choose less expensive appliances. Similarly, landlords may be concerned about possible theft of appliances. This might be particularly problematic for lighting, with expensive light bulbs likely to disappear when renters move out.

Second, the differences could reflect unobserved differences between homeowners and renters in taste for green products. Suppose that, controlling for observables, homeowners receive a warm glow from using an energy-efficient technology but renters do not. This could lead landlords to efficiently invest less in energy-efficient technologies. For this to explain these findings, this preference for "green" would need to not be perfectly correlated with household income and other control variables, and positively correlated with home ownership.

Third, the differences could reflect unobserved differences between homeowners and renters in taste for appliance characteristics that are correlated with energy efficiency. Energy-efficient appliances tend also to have other desirable features. In fact, in some cases the Energy Star

standards are actually a function of appliance characteristics. For example, minimum standards for refrigerators with through-the-door ice service are considerably less stringent than standards for refrigerators without this feature.[9] If, controlling for observables, homeowners have stronger tastes for these features, this could cause a spurious correlation between homeownership and energy efficiency even if homeowners do not have any particular preference for "green" products.

4 Evaluating the Implied Total Cost

An appealing feature of the estimates in Section 3 is that they provide some of the information necessary to evaluate the overall magnitude of the landlord-tenant problem for an important group of household technologies. This section illustrates how these estimates can be applied, under simplified assumptions, to infer the implied total energy consumption, expenditure, and carbon emissions from the landlord-tenant problem. This preliminary assessment indicates that the total cost of this market failure is not negligible, but that it is small relative to total energy consumption in rental housing units.

Table 4 reports the total cost of the landlord-tenant problem as implied by the estimates in the baseline specification. These results are calculated using average annual energy consumption and energy expenditure for Energy Star appliances from Sanchez, et. al (2008).[10] The thought experiment is to consider how many additional energy-efficient appliances there would be in the United States if renters were equally likely as homeowners to have these technologies. The baseline estimates control for household income, number of household members, and other household characteristics and these measures should also be viewed as being conditional on covariates.

The estimates imply that if renters were equally likely to have energy-efficient appliances, in the United States there would be 2.3 million more Energy Star refrigerators, 3.1 million more Energy Star dishwashers, and 6.3 million more energy-efficient lightbulbs.[11] The estimates imply

[9] See 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 details.

[10] Sanchez, et. al (2008, Table 5) reports annual energy savings per Energy Star unit of 0.85 Mbtu ($7.59) for refrigerators (15%), 1.17 Mbtu ($11.45) for dishwashers (29%), 0.68 Mbtu ($6.05) for room air conditioners (10%), and 1.32 Mbtu ($12.23) for clothes washers (20%). 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. energy-efficient lightbulbs are assumed to use 15 watts, compared to 60 watts for conventional incandescent bulbs.

[11] 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. They conclude that

smaller impacts for room air conditioners and clothes washers. Nationwide this would reduce annual energy consumption by 9.4 trillion btus, reduce annual energy expenditures by 93 million, and reduce annual carbon emissions by 166,000 tons.

To put this in perspective, this is about 1/2 of 1% of total energy consumption in rental housing units.[12] There are several reasons why this is not a larger fraction. First, in this thought experiment the saturation of energy-efficient technologies is increasing by only between 1 and 9 percentage points. Although not negligible, this is very different from assuming, for example, comprehensive replacement of all conventional appliances with energy-efficient appliances. Second, these end-uses represent only about one-fourth of total energy expenditure in rental housing units.[13] Third, these calculations assume that energy-efficient technologies use between 10% and 30% less energy than conventional technologies. The one exception is lighting, for which savings are larger.

5 Concluding Remarks

These results provide empirical evidence consistent with the landlord-tenant problem. Across specifications, the results indicate that renters are significantly less likely to have energy-efficient refrigerators, clothes washers, dishwashers, and lighting. Taken literally, the estimates imply 9 trillion btus of excess energy consumption annually in the United States. More research and better data are necessary if the landlord-tenant problem is to be understood. The new questions in the RECS that made this study possible are a step in the right direction, but more and better questions are needed to evaluate the full extent of the landlord-tenant problem and to assess potential problems about the accuracy of the self-reported measures of energy efficiency. In future work, it would also be valuable to extend the analysis to a broader class of residential energy efficiency investments such as building insulation, windows, and heating equipment.

24% of residential energy consumption in the United States is potentially subject to principal-agent problems. This study was part of an international project whose results are described in IEA (2007).

[12] According to DOE, "2005 Residential Energy Consumption Survey, Total Energy Consumption, Expenditures, and Intensities", Table US1, rental housing units in the United States used 2.39 quadrillion btus of energy in 2005.

[13] From DOE, "2005 Residential Energy Consumption Survey, Total Energy Consumption, Expenditures, and Intensities", Table US12, air-conditioners, refrigerators, lighting, and other appliances together represent 36% of total energy consumption in rental housing units. Space and water heating represent the other 64%.

References

[1] Blumstein, Carl and Betsy Krieg and Lee Schipper. "Overcoming Social and Institutional Barriers to Energy Conservation." *Energy*, 1980, 5, 355-371.

[2] Brueckner, Jan and Stuart Rosenthal. "Gentrification and Neighborhood Housing Cycles: Will America's Future Downtowns Be Rich?" *Review of Economics and Statistics*, 2008.

[3] Davis, Lucas W. "Durable Goods and Residential Demand for Energy and Water: Evidence from a Field Trial." *RAND Journal of Economics*, 2008, 39(2), 530-546.

[4] Gillingham, Kenneth, Richard Newell, and Karen Palmer. "Energy Efficiency Policies: A Retrospective Examination." *Annual Review of Environment and Resources*, 2006, 31, 161-192.

[5] Gillingham, Kenneth, Richard Newell, and Karen Palmer. "Energy Efficiency Economics and Policy." *Annual Review of Resource Economics*, 2009, 1, 597-619.

[6] Hausman, Jerry A. and Paul L. Joskow. "Evaluating the Costs and Benefits of Appliance Efficiency Standards." *American Economic Review*, 1982, 72(2), 220-225.

[7] International Energy Agency (IEA). *Mind the Gap: Quantifying Principal-Agent Problems in Energy Efficiency*, Paris: OECD Publishing, 2007.

[8] Fisher, Anthony C. and Michael H. Rothkopf. "Market Failure and Energy Policy: A Rationale for Selective Conservation." *Energy Policy*, 1989, 397-406.

[9] Jaffe, Adam B. and Robert N. Stavins. "The Energy Paradox and the Diffusion of Conservation Technology." *Resource and Energy Economics*, 1994, 16, 91-122.

[10] Levinson, Arik and Scott Niemann. "Energy Use By Apartment Tenants When Landlords Pay for Utilities." *Resource and Energy Economics*, 2004, 26, 51-75.

[11] Murtishaw, Scott and Jayant Sathaye. "Quantifying the Effect of the Principal-Agent Problem on U.S. Residential Energy Use." Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory Working Paper 59773, 2006.

[12] Nadel, Steven. "Appliance and Equipment Efficiency Standards." *Annual Review of Energy and the Environment*, 2002, 27, 159-192.

[13] Sanchez, Marla, Richard E. Brown, Gregory K. Homan, and Carrie A. Webber. "2008 Status Report: Savings Estimates for the Energy Star Voluntary Labeling Program." Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory Working Paper 56380, 2008.

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 and Electricity Prices			
Annual Cooling Degree Days (1000s)	1.58	1.61	.64
Annual Heating Degree Days (1000s)	4.15	3.82	.09
Electricity Prices (cents per kwh)	10.3	11.1	.09
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 Efficient Technologies			
Energy Star Refrigerator	0.24	0.17	.00
Energy Star Dishwasher	0.18	0.07	.00
Energy Star Room Air Conditioner	0.04	0.05	.01
Energy Star Clothes Washer	0.23	0.12	.00
Front Loading Clothes Washer	0.09	0.02	.00
Energy-efficient Lighting (any)	0.41	0.33	.01
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. Some households have more than one refrigerator or room air conditioner, and the table reports whether or not the most used unit is Energy Star. The survey questions about clothes washers are careful to exclude community clothes washers located in, for example, the basement or laundry room of an apartment building.

Table 2a
Are Renters Less Likely to Have Energy Star Refrigerators? [Sample Mean = .22]

	(1)	(2)	(3)	(4)
1(*renter*)	-.067	-.037	-.059	-.070
	(.014)	(.017)	(.015)	(.015)
Household Income ($10,000)	-	.014	.010	.009
		(.002)	(.003)	(.003)
Household Demographics	no	no	yes	yes
Electricity Prices (Cubic)	no	no	no	yes
Heating and Cooling Degree Days (Cubics)	no	no	no	yes
Census Division and Available State Indicators	no	no	no	yes
Number of Observations	4,194	4,194	4,194	4,194
R^2	.01	.02	.03	.05

Note: Tables 2a-f report estimated coefficients and standard errors corresponding to 4 separate regressions, all estimated using least squares with RECS sampling weights. For each regression the dependent variable is an indicator variable equal to one if the household has the energy efficient technology indicated in the table title. Standard errors (in parentheses) are robust to heteroskedasticity and arbitrary correlation within Census divisions.

Table 2b
Are Renters Less Likely to Have Energy Star Dishwashers? [Sample Mean = .25]

	(1)	(2)	(3)	(4)
1(*renter*)	-.100	-.074	-.084	-.092
	(.024)	(.026)	(.036)	(.038)
Household Income ($10,000)	-	.012	.008	.007
		(.004)	(.003)	(.003)
Household Demographics	no	no	yes	yes
Electricity Prices (Cubic)	no	no	no	yes
Heating and Cooling Degree Days (Cubics)	no	no	no	yes
Census Division and Available State Indicators	no	no	no	yes
Number of Observations	2,433	2,433	2,433	2,433
R^2	.01	.02	.03	.05

Table 2c
Are Renters Less Likely to Have Energy Star Room Air Conditioners? [Sample Mean = .16]

	(1)	(2)	(3)	(4)
1(*renter*)	-.032	-.019	-.021	-.012
	(.011)	(.014)	(.014)	(.021)
Household Income ($10,000)	-	.009	.007	.006
		(.004)	(.005)	(.006)
Household Demographics	no	no	yes	yes
Electricity Prices (Cubic)	no	no	no	yes
Heating and Cooling Degree Days (Cubics)	no	no	no	yes
Census Division and Available State Indicators	no	no	no	yes
Number of Observations	1,184	1,184	1,184	1,184
R^2	<.01	.01	.02	.04

Table 2d
Are Renters Less Likely to Have Energy Star Clothes Washers? [Sample Mean = .23]

	(1)	(2)	(3)	(4)
1(*renter*)	-.030	-.004	-.028	-.033
	(.014)	(.016)	(.017)	(.014)
Household Income ($10,000)	-	.015	.010	.008
		(.002)	(.002)	(.002)
Household Demographics	no	no	yes	yes
Electricity Prices (Cubic)	no	no	no	yes
Heating and Cooling Degree Days (Cubics)	no	no	no	yes
Census Division and Available State Indicators	no	no	no	yes
Number of Observations	3,546	3,546	3,546	3,546
R^2	<.01	.02	.03	.05

Table 2e
Are Renters Less Likely to Have Front Loading Clothes Washers? [Sample Mean = .08]

	(1)	(2)	(3)	(4)
1(*renter*)	-.054	-.032	-.028	-.030
	(.007)	(.004)	(.005)	(.005)
Household Income ($10,000)	-	.012	.012	.010
		(.002)	(.003)	(.003)
Household Demographics	no	no	yes	yes
Electricity Prices (Cubic)	no	no	no	yes
Heating and Cooling Degree Days (Cubics)	no	no	no	yes
Census Division and Available State Indicators	no	no	no	yes
Number of Observations	3,546	3,546	3,546	4,198
R^2	<.01	.03	.03	.05

Table 2f
Are Renters Less Likely to Have Energy Efficient Lighting? [Sample Mean = .39]

	(1)	(2)	(3)	(4)
1(*renter*)	-.075	-.045	-.052	-.055
	(.023)	(.025)	(.031)	(.024)
Household Income ($10,000)	-	.014	.014	.013
		(.003)	(.002)	(.002)
Household Demographics	no	no	yes	yes
Electricity Prices (Cubic)	no	no	no	yes
Heating and Cooling Degree Days (Cubics)	no	no	no	yes
Census Division and Available State Indicators	no	no	no	yes
Number of Observations	4,198	4,198	4,198	4,198
R^2	<.01	.01	.02	.04

Table 3
Are Renters Less Likely to Have energy-efficient Technologies? 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]	Front Loading Clothes Washer [mean=.08]	Energy Efficient Lighting [mean=.39]
	(1)	(2)	(3)	(4)	(5)	(6)
(A) Baseline Specification	-.071	-.093	-.013	-.033	-.030	-.056
	(.015)	(.038)	(.020)	(.014)	(.005)	(.024)
(B) Logit Model	-.075	-.103	-.013	-.034	-.044	-.056
	(.014)	(.039)	(.020)	(.015)	(.006)	(.026)
(C) Controlling Flexibly for Income (cubic)	-.067	-.095	-.009	-.033	-.031	-.049
	(.015)	(.036)	(.023)	(.014)	(.005)	(.024)
(D) Excluding "don't know"	-.073	-.105	-.018	-.040	NA	NA
	(.015)	(.038)	(.023)	(.016)		
(E) Among Households with Appliances < 10 years old	-.085	-.092	-.014	-.021	-.037	NA
	(.020)	(.039)	(.034)	(.017)	(.011)	
(F) Among Households with Appliances < 5 years old	-.148	-.119	-.035	-.071	-.062	NA
	(.030)	(.055)	(.048)	(.031)	(.017)	
(G) Among Households with Appliances < 2 years old	-.131	-.099	-.014	-.019	-.073	NA
	(.035)	(.071)	(.015)	(.055)	(.034)	
(H) Renters with Utilities Included	-.073	.007	-.110	-.152	-.046	-.015
	(.018)	(.045)	(.036)	(.045)	(.012)	(.034)
(I) Among Households Living in Multi-Unit Buildings	-.069	-.035	-.021	-.078	-.041	-.011
	(.033)	(.086)	(.037)	(.099)	(.018)	(.069)
(J) Including Housing Characteristics	-.040	-.069	.001	-.032	-.030	-.043
	(.015)	(.043)	(.014)	(.011)	(.008)	(.027)
(K) Including Self-Reported Utilization	NA	-.093	-.013	-.032	-.030	-.052
		(.038)	(.021)	(.014)	(.005)	(.024)
(L) Excluding Households Who Receive Energy Assistance	-.079	-.098	-.020	-.031	-.032	-.053
	(.017)	(.037)	(.021)	(.015)	(.005)	(.020)
(M) Excluding Cities With Rent Control (NY, CA)	-.067	-.084	-.028	-.032	-.026	-.065
	(.016)	(.036)	(.031)	(.014)	(.005)	(.016)

Note: This table reports coefficients and standard errors corresponding to 1(*renter*) for 73 separate regressions, all estimated using least squares with 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. All specifications control for household income and other household demographics, as well as electricity prices (cubic), heating and cooling degrees (cubics), and Census division and available state indicators, as in column (4) of Tables 2a-2f. Standard errors (in parentheses) are robust to heteroskedasticity and arbitrary correlation within Census divisions.

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

	Refrigerators	Dishwashers	Room Air Conditioners	Clothes Washers	Light Bulbs	All Technologies Combined
Total Units in millions	2.3	3.1	0.4	1.1	6.3	13.1
	(0.5)	(1.2)	(0.7)	(0.5)	(3.2)	(3.6)
Annual Energy Consumption	2.0	3.6	0.3	1.4	2.1	9.4
in btus, trillions	(0.4)	(1.5)	(0.5)	(0.6)	(1.1)	(2.1)
Annual Expenditure on Energy	18.7	37.2	2.7	14.1	20.2	92.9
in 2009 dollars, millions	(3.9)	(15.1)	(4.2)	(5.9)	(10.3)	(20.0)
Annual Carbon Emissions	35.6	64.8	5.2	21.6	38.6	165.8
in metric tons, thousands	(7.4)	(26.3)	(8.0)	(9.1)	(19.6)	(35.7)

Note: This table reports the total cost of the landlord-tenant problem as implied by the estimated coefficients in column (4) of Tables 2a-f. Standard errors are reported in parentheses. RECS sampling weights are used in all calculations.