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Why are rented dwellings less energy-efficient? Evidence from a representative sample of the U.S. housing stock

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ABSTRACT

This paper compares energy-efficient appliance adoption rates across U.S. residential markets. The focus is to explore variation across tenure modes (rented or owner-occupied residences). Bivariate probits are used to correct for endogenous determination of tenure mode and energy efficiency outcomes. Results suggest that, when compared to renters, homeowners are significantly more likely to have energy-efficient appliances. The mechanisms that could be driving those differences are also investigated. Heterogeneity analyses reveal that rented dwellings are more likely to have efficient appliances when landlords incur utility payments. Adoption rate differences are also shown to be inversely related to energy prices. Those findings are consistent with a problem of asymmetric information in the housing market, typically referred to as the "landlord-tenant problem." This paper is also the first to assess how tenancy duration influences efficiency investments in this context. Results suggest that investments in rented homes are more likely to occur at later periods of tenancy, when relations between landlords and tenants might be better established.

1. Introduction

The Energy Information Agency (EIA) estimates that approximately 20.6% of U.S. energy-related carbon emissions can be attributed to the residential sector (EIA, 2015). Space heating, water heating, and air conditioning collectively account for almost 65% of the energy consumption in U.S. homes. Other appliances, electronics and lighting account for the remaining 35% (EIA, 2009). Many engineering estimates from the late 2000 s (Chandler and Brown, 2009; EPRI, 2009; McKinsey, 2009) suggest that improving fuel and energy efficiency in homes may be cost-effective for carbon abatement, since future energy savings may exceed the upfront installation costs of new, more efficient technologies. However, recent environmental economics literature provides evidence that those technologies are being adopted at low or even sub-optimal rates (for reviews, see: Allcott and Greenstone, 2012; Gillingham and Palmer, 2014). This disconnect between an optimal and the current level of energy efficiency investments is often referred to as the energy efficiency "gap" or "paradox"

Jaffe and Stavins (1994) recognize that the extent of that gap depends on the definition of optimality being considered by the researcher. For example, if the social optimum takes into account environmental externalities, then the gap is likely to be wider. A discussion of optimality is omitted from this paper, which rather focuses on identifying mechanisms that might be causing energy efficiency investments to vary across U.S residences. Adoption rates of a broad set of Energy Star[1] (ES) rated appliances are compared, exploiting variations in tenure mode (rented or owner-occupied residences). First, with data from the 2011 American Housing Survey,[2] linear probability models (LPM) are estimated for ES appliance adoption, controlling for degree of urbanization, climate, household demographics, and housing amenities and structure. Second, alternative specifications are used to identify mechanisms that could be driving heterogeneity in technology adoption rates. Finally, bivariate probits are estimated, in order to correct for the endogenous determination of energy efficiency outcomes and tenure mode.

Initial LPM estimates show that rented homes are less likely to have efficient room air-conditioners (− 6.73%), central air conditioners (− 8.08%), dishwashers (− 14.85%), clothes washers (− 6.23%), refrigerators (− 12.96%), electric central heating (− 5.16%), gas central heating (− 7.41%), and oil central heating (− 7.56%). When compared to estimates from previous literature (Davis, 2012), these results suggest that the gap between rented and owner-occupied units became significantly wider between 2005 and 2011. The linear estimates, however, might be biased due to classic endogeneity: there might be unobserved household preferences that simultaneously affect both tenure

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[1] Energy Star is a voluntary program established in 1992 by the U.S. Environmental Protection Agency (EPA). To earn a label that attests high energy efficiency, a product must be certified by EPA-recognized third-party laboratories (EPA, 2016).

[2] The AHS is conducted every 2 years by the Department of Housing and Urban Development (HUD) and the U.S. Census Bureau. It comprises a nationally representative sample of the U.S. housing stock.

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mode and energy efficiency outcomes.

To attenuate that type of endogeneity, bivariate probit (or biprobit) models are estimated. Han and Vytlacil (2017) demonstrate that the nonlinear nature of biprobits allows identification of systems in which a binary variable (e.g. ownership of Energy Star appliances) is regressed on another endogenous binary variable (e.g. tenure mode). Estimation for each appliance consists of a system of two-equations: one which describes the adoption of ES appliances, and another which describes tenure mode. The endogeneity-corrected estimates reveal that linear models overestimate the effects of tenure mode on energy efficiency. For example, biprobit estimates suggest that renters are 8.98% less likely than homeowners to have Energy Star refrigerators. That estimate was closer to 13% with a linear model.

It was also possible to identify a few mechanisms that lead to ES appliance adoption heterogenenity across tenure modes. By exploiting variation in who pays (landlord or tenant) for the utility bills of rented dwellings, it is possible to test for the effects of split incentives ("landlord-tenant problem"), which previous literature has explored in similar contexts (see, for example: Myers, 2015; Gillingham et al., 2012; Levinson and Niemann, 2004). Since landlords often do not pay for utility bills, they have less incentives to invest in energy efficiency. Biprobit estimates are consistent with that scenario, indicating that, for some appliances, the adoption gap between homeowners and renters becomes significantly narrower when landlords do pay utility bills. For example, point estimates of the gap drop from 8.98% to 3.69% for refrigerators, and from 10.09% to 3.73% for dishwashers.

To explore further heterogeneity, the effects of tenancy duration[3] on ES appliance adoption are tested for, by estimating alternative LPM specifications. Even though data on ownership of Energy Star appliances are only available for the survey year of 2011, the panel structure of the AHS allows the construction of variables that identify how long a given household has resided in the same unit. Results from regressions with those variables suggest that tenancy duration does not significantly affect homeowners' decisions to adopt small ES appliances. This is expected, since homeownership implies no asymmetric information problem. On the other hand, saturations of small ES appliances are significantly lower for short-duration renters, when compared to long-duration renters (which have been in the dwelling for more than 10 years). For large appliances (central AC and heating), the effects are reversed: renters are unaffected by tenancy duration, but homeowners are. It could be that homeowners choose to postpone investments in large appliances due to liquidity constraints right after the purchase of their homes.

Finally, it was possible to assess if ES appliance adoption is heterogeneous across U.S. census divisions. That is implicitly a test for heterogeneity across energy prices. It can be shown that saturation differences between renters and homeowners are smaller in areas with higher energy prices (especially New England and Middle Atlantic). This suggests that renters in those areas are more attentive to energy costs, thus demanding dwellings with more energy-efficient appliances.

Overall, the gap between rented and owner-occupied units is evident. Incentives for investments in energy efficiency are misaligned especially in the rental markets. Therefore, it may be more cost-effective to provide energy efficiency subsidies to renters or landlords, rather than to owner-occupants. Policies that encourage homeownership might simultaneously address this issue. Those findings also reinforce the importance of policies, such as appliance labeling, energy consumption audits, and disclosure requirements that address information asymmetries in rental markets.

The remainder of the paper is organized as follows: Section 2 presents the data and descriptive statistics; in Section 3, empirical strategy and results are presented; concluding remarks and policy recommendations are in Section 4.

[3] Throughout this paper, "tenancy duration" or "household duration" refers to how long a given household has been occupying the same residential unit.

2. Data and descriptive statistics

The American Housing Survey (AHS) comprises a nationally representative sample of the U.S. housing stock. It includes several variables which were used as controls in the regression specifications: number of bathrooms, half bathrooms, bedrooms, and overall rooms in the residence; year or decade that the unit was built; age of householder; education level; householder's works status; household income; number of family members; indicator for who pays for the utility bills; year in which the household moved into the dwelling. Available geographic information includes: broad climate classifications, based on heating degree days (HDD) and cooling degree days (CDD)[4]; degree of urbanization (city, suburb, small town, and rural); census division and state (when available).[5]

In survey year 2011, a supplemental module of the AHS included questions to identify if the appliances in the dwellings are rated as Energy Star.[6] For this study, the following appliances were considered: room air conditioner, dishwasher, clothes washer, clothes dryer, refrigerator, central air conditioning, central electric heating, central gas heating, and central oil heating.[7] That is a comprehensive list of appliances for which it is possible to identify Energy Star rating.[8] The full survey collected data for 186, 448 residences. However, this study restricts the sample to residences that were not vacant during the survey year of 2011, and for which it is possible to identify tenancy (otherwise, crucial variables of interest would be lacking). The final sample for this study therefore consists of 132, 995 housing units.

Descriptive statistics of the control variables were computed using the 2011 AHS data. Table 1 presents differences in means of the demographic variables for owner-occupied units, tenant-pay and landlord-pay rented units. The p-values indicate if the differences in means are statistically significant (based on Welch *t*-tests). It is clear that the groups are unbalanced in terms of demographics. For example, compared to renters, homeowners on average have higher income, are older, and are more likely to be white. Furthermore, tenant-pay dwellings are in general occupied by lower income families than landlord-pay dwellings. Table 2 also reveals significant imbalance, by comparing means for geographic and climactic variables. Owner-occupied homes tend to be in suburban areas, while rented homes are more likely to be closer to city centers, especially when under a tenant-pay regime.

Table 3 presents mean comparisons for variables related to housing amenities and structure. It can be noted that homeowners are more likely to live in single-unit buildings (houses), with large square footage. Renters, on the other hand, are more likely to live in smaller apartments that have less rooms. The variables for decade built provide evidence that older constructions are more likely to be put up for rental.

Fig. 1 illustrates densities for the years in which tenants moved into their dwellings. The graph suggests that homeowners tend to stay in the

[4] Climates are identified as: Coldest (more than 7001 HDD and less than 2000 CDD), Cold (5500–7000 HDD and less than 2000 CDD), Cool (4000–5499 HDD and less than 2000 CDD), Mild (less than 4000 HDD and less than 2000 CDD), Mixed (2000–3999 HDD and more than 2000 CDD), and Hot (less than 2000 HDD and more than 2000 CDD).

[5] Due to confidentiality, states are not identified for some housing units in the dataset.

[6] Householders are first asked if the unit has a particular appliance. Then they are asked if the appliance is Energy Star rated. Responses include 'Yes', 'No' and 'Do not know'.

[7] "Central heating" refers to large appliances intended to heat all the rooms of a dwelling. Over 96% of the survey respondents reported using those as their main heating equipment. The remaining 4% reported using portable or single-room heaters. Also, less than 0.5% of the sample reported using any supplemental (secondary) heating equipment. Water heaters (although widespread) have been omitted from this study, since the survey does not identify the efficiency rating for those appliances.

[8] Almost all the appliances for which it is possible to identify Energy Star rating were used. Due to sparsity of the data, the only omitted appliances were built-in trash compactors (less than 4% of sample), and heating equipment that do not use gas, electricity or oil (less than 2% of sample).

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