An Empirical Analysis of Residential Energy Efficiency Adoption by Housing Types and Occupancy

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Abstract

Uncertainties about future levels of energy availability and concern for climate change have raised public interest in energy efficiency and conservation. In particular, efficiency gains in the residential sector, which accounts for about 22% of energy end-use in the United States has the potential to yield large benefits for society. In this research we conduct an empirical analysis to investigate the likelihood of adoption of energy efficiency (EE) measures in the residential sector. We consider heterogeneity of occupants and homeowners based on their demographic characteristics, as well as the structural characteristics of housing units, weather parameters and geographical characteristics. Our empirical results shed light on (1) the drivers of EE adoption for households, (2) the extent to which EE adoption differs between homeowners and landlords, and (3) the extent to which EE adoption differs among types of housing (utility-included vs. utility-excluded rent, owner occupied).

1. Introduction

Concerns about climate change and energy security have prompted many initiatives to reduce energy consumption. The residential sector, which accounts for about 22% of energy end-use in the United States, is an area where reduction in energy consumption can have a significant impact on overall energy demand (EIA 2008, 2012). Energy efficiency (EE) has been called the "fifth fuel" and studies show that overall energy demand can be reduced by as much as 23% by 2020 by exploiting untapped energy efficiency improvements as well as encouraging energy conservation (McKinsey & Company 2009, Yergin 2011).

The potential payoff from energy efficiency improvements has led to interest in increasing adoption of energy efficiency measures. Regulatory instruments have been largely opposed by many (i.e., real estate sector), and are difficult to enforce. Voluntary-based environmental approaches are considered a more viable alternative because they offer greater flexibility to building and homeowners. However, studies have pointed out the existence of an "energy efficiency gap" in which there is a mismatch between the optimal level of efficiency adoption given potential monetary benefits and the level of observed (voluntary) adoption (Jaffe and Stavins 1994). Studies have offered a number of explanations for this gap including market and behavioral failures and the role of uncertainty (Gillingham et al. 2009, Hasset and Metcalf 2004). In this paper, we further investigate drivers and obstacles to adoption of energy efficiency. Specifically, we examine energy efficiency measures undertaken by different households in the United States to determine the effects of the type of occupant (owner vs tenant), the type of housing unit (owner-occupied vs utility included/excluded rental), and other housing characteristics and environmental parameters on the likelihood of adopting energy efficiency measures.

The results of this paper contribute to understanding factors that affect residential EE adoption. The empirical findings of this paper could help policy makers design more targeted EE incentives and inform those in the energy sector (e.g. utility companies) about better strategies to encourage adoption of energy efficiency measures. Furthermore, the results of this study would be useful in identifying groups that are lagging in energy efficiency adoption and targeting incentives toward this group. For this analysis we use data from the Residential Energy Consumption Survey (RECS), a nationally-representative in-home survey conducted approximately every four years by the Department of Energy, which contains information on energy use and efficiency characteristics of housing units. The RECS data provide 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. We match this data with energy price data from the US Energy Information Administration (EIA). In addition, the RECS reports state of residence and Census division for all households. The RECS identifies apartments where heat and electricity are included in the rent; it details the demographic characteristics of occupants and the structural characteristics of houses, and it contains information about fuel use for every household.

We develop a model of adoption of updated EE standards that considers heterogeneity of owners and occupants based on their demographic characteristics, as well as the structural characteristics of housing units, weather parameters and geographical characteristics to investigate the likelihood of EE adoption.

Our empirical results shed light on (1) the drivers of EE adoption for households, (2) the extent to which EE adoption differs between homeowners and landlords, and (3) the extent to which EE adoption differs among types of housing (utility-included vs. utility-excluded rent, owner occupied).

While previous literature has examined energy consumption and efficiency adoption among tenants in utility included/excluded contracts, (Levinson and Niemann 2004, Maruejols and Young 2011), to the best of our knowledge this is the first research that analyzes the adoption of EE measures in different housing types, occupant characteristics and occupancy status. Our results identify factors that drive adoption of EE measures by landlords and owners. In particular, our model highlights that residents of urban areas are more likely to implement EE measures relative to the ones living in rural areas, and households in the New England, Mountain North, Mountain South, and Pacific census divisions live in more energy efficient dwellings than residents of other geographic divisions. Additionally, our model indicates that married householders, those with more education, and higher incomes invest in more energy efficient measures.

The findings of this study also contribute to the literature on split-incentives between tenants and landlords. Previous literature has suggested that renters that do not pay their utility bills, and landlords that rent out apartment buildings or homes are less likely to invest in EE measures due to the fact that they cannot capture the full return on their investment (Davis 2010). Part of the gain from EE measures implemented by renters accrues to the landlord, and part of the gain from a landlord's investment may accrue to the tenant. As a consequence, landlords may buy inexpensive and inefficient appliances when their tenants pay the utility bill, and vice versa, tenants who do not directly pay the utility bills have no incentive to save energy. Levinson and Neimann (2004) find that tenants in utility included contracts are less inclined to conserve energy; for example, they set their thermostats between one and three degrees warmer during winter when they are not at home (Levinson and Niemann 2004). Although we do not observe energy use of tenants, we find that rental units with heat-inclusive rent are less likely to be updated with energy efficiency improvements. This result confirms previous findings that split-incentives between landlords and tenants in utility-included contracts are a cause of energy (and economic) inefficiency.

Finally, our results indicate that homes that are older and use less efficient heating fuel compared to natural gas adopt less EE measures, likely because the occupants have less financial means to adopt EE improvements. This finding implies that significant gains can be achieved by targeting EE incentives toward low-income groups.

2. Model for Household Energy Efficiency Adoption

2.1 Data description

We investigate the adoption of energy efficiency measures by household type and characteristics using data from the EIA's RECS, which provides a nationally-representative sample of household energy information and characteristics approximately every four years. Our analysis uses the most recently available data from 2009 and includes only households whose main space heating fuel is natural gas, liquefied propane gas (LPG), fuel oil or electricity. Additionally, we restrict our analysis to include only those households for which it is known that either the owner or renter pays the heating bills. These observations comprise 92% of households in the 2009 survey, while the remaining do not include information on who pays the household's heating bills.

Using data from the RECS survey we approximate the number of energy efficient measures adopted by each individual household using the variables defined in Table 1, in which the observations are weighted to represent all US households. The survey indicates if a household has updated their most-used refrigerator, dishwasher, clothes washer, main space heating equipment, and most-used window/wall air conditioning unit in the last four years. We assume that since the replacement occurred within the last four years, it is an energy efficiency improvement. We also consider window replacement, added insulation, the use of a programmable thermostat to adjust the heating or cooling temperature during the day or night, installation of energy-efficient bulbs, triple or double pane windows, and installation of caulking or weather stripping as household energy efficient adoptions. Every household is given a one for each of the above activities adopted. A zero indicates that household has not engaged in any energy efficient upgrades while a household with a count of 14 has adopted all of the identified measures.

Table 2 presents the description and weight-corrected descriptive statistics for the data. The variable *Heat_price* indicates the price a household pays for its main space heating fuel depending on the state or region in which the householder lives. These data are not included in the 2009 RECS, but average annual prices for each state or region is provided by the EIA. For 2009 the EIA provides average annual residential prices for electricity and natural gas by state, average annual residential fuel oil prices for most states and all regions, and for consumer grade propane only by region. For the missing states in the fuel oil data and all states in the propane data, state price was imputed using the given regional prices. We normalized prices for each fuel type by converting all units to dollars per one million Btu using standard conversion rates provided by the EIA.

Dummy variables for census divisions and urban or rural setting along with the numerical variables, heating degree-days (HDD) and cooling degree-days (CDD), account for local, regional and weather differences in household geographical location. Various regional differences, such as political affiliation, wealth and demographic composition impact energy efficiency adoption measures; however, according to the American Council for an Energy-Efficient Economy (ACEEE), the northeast, pacific coast and the eastern mid-west appear to lead in energy efficient policies in the US.
Structural characteristics of the housing units are the type of housing and number of apartments if it is an apartment building with five or more units, the year built, the number of windows, and whether the housing unit is shaded from the sun by large trees. Interior structural characteristics include type of the main space heating fuel used by the household, the age of the main space heating equipment used, the ratio of rooms heated to total number of rooms, whether the household uses air conditioning equipment, and the ratio of rooms cooled to total number of rooms in the house. The types of housing identified by the RECS include mobile homes, single-family detached homes, single-family attached homes, apartment buildings with two to four units, and apartment buildings with five or more units. Lastly, the demographic variables include the marital status of the householders, highest level of education achieved by the household, gross household income for 2009, number of household members, and other variables discussed below.

2.2 Model description

The number of energy efficiency measures adopted by each household, or energy efficiency index (EE index), is the dependent variable in a count model used to estimate the number of energy efficient measures assuming that the count is a function of energy prices, various geographic and structural characteristics of households, and demographic characteristics of household members. Since the dependent variable displays overdispersion the model is estimated using a negative binomial regression with the following form:

$$p(\boldsymbol{Y} = y_i|\mu, \alpha) = \frac{\Gamma\left(y_i + \frac{1}{\alpha}\right)}{\Gamma(y_i + 1)\Gamma\left(\frac{1}{\alpha}\right)}\left(\frac{1}{1 + \alpha\mu_i}\right)^{1/\alpha}\left(\frac{\alpha\mu_i}{1 + \alpha\mu_i}\right)^{y_i}$$

With $y_i = 0, \dots, 14$ and $i = 1, \dots, n$.

Where:

$$\mu = E(\boldsymbol{Y}) = e^{\boldsymbol{x'\beta}}$$

The variance of **Y** is:

$$Var(y|\mu, \alpha) = \mu(1 + \alpha\mu).$$

The estimated coefficients from this model can be interpreted as follows: for a one unit change in the predictor variable the difference in the logs of expected counts of the response variable is expected to change by the respective regression coefficient, all other variables held constant.

We expect a positive sign on the regressor indicating the price paid by the household for the fuel heat source they use. In fact, householders should adopt energy efficient measures to incur cost savings when the cost of their main space heating fuel increases. For the regional variables, assuming urban areas have better and cheaper access to energy efficient technologies, we expect more energy efficient adoption in urban relative to rural areas. Also, households in geographic areas with more HDD and CDD should have higher EE indices to save on heating and cooling costs.

We expect single-family detached homes to have the most flexibility in choice and ease of energy efficiency installations; therefore we expect a negative sign on the other housing types. Similarly, householders in apartment buildings with fewer apartment units may have more opportunity to update their homes relative to larger apartment complexes. The anticipated sign for year built is negative as newer homes should already be updated, while the sign for the number of windows should be positive as the presence of more windows increases the need to heat or cool. Tree shade could increase the amount of heating needed in the winter or decrease the amount of cooling required in the summer, and hence the sign should depend on which effect is stronger.

For fuel type, since natural gas is the least expensive heating fuel according to the EIA (2014), we expect relative to natural gas, the other fuel types to have positive signs. We also anticipate the older the heating equipment and higher ratio of rooms heated or cooled, the higher the EE index for the household. Additionally, the RECS reports householder indicated efficacy of insulation and reported winter draftiness, which should, respectively, be negatively and positively correlated to the EE index.

While the anticipated affect of marital status remains ambiguous, we expect a positive relationship between the EE index and higher educational achievement, increased wealth and larger households. Additionally, we investigate other householder characteristics such as whether the householder runs a home business, has installed Energy Star appliances, whether the householder owns or rents, and if he is renter, is heat included in his rent. Seemingly, a home-run business would require more residential energy expenditure, and thus, we expect adopting energy efficiency measures would be financially beneficial. Since Energy Star appliances are potentially a signal of energy efficiency to consumers, the variable *Es_app* indicates the household uses an Energy Star refrigerator, dishwater, clothes washer, or window/wall air conditioning unit and is a proxy for environmental-consciousness. We assume some households have a preference for environmental conservation, and if so, would be more inclined to adopt energy efficient measures as a utility-enhancing effort. Finally, we assume renters are less likely to have high EE indices as they have less discretion over structural changes to their home, and Levinson and Niemann (2004)'s analysis empirically supports a negative relationship between energy efficient activities and households with heat included in the rent.

3. Results and discussion

Results from the negative binomial model are reported in Table 4, which presents the coefficients and corrected standard errors using Fay's method of balanced repeated replication. [1] The signs of the estimated parameters are mostly consistent with our expectations. Specifically, the price variable, while statistically insignificant is positive as expected. Among the census region dummies, compared to households located in the East North Central Census division, households in the New England, Mountain North, Mountain South, and Pacific divisions are predicted to have higher EE indices. The coefficients on the remaining divisions indicate that households in these divisions have lower EE indices relative to the East North Central division. There results are mostly consistent with state energy efficiency rankings by the ACEEE. However, the regional differences are only statistically significant between the East North Central division and the East South Central, West South Central, Mountain North and Pacific divisions. The geographic variables indicating urban or rural location of the household, HDD, and CDD, have the anticipated positive signs, though CDD is statistically insignificant.

For the structural characteristics, many of the coefficients are statistically significant. The housing type coefficients indicate that single-family attached homes adopt more energy efficient measures than the other included housing types, and for apartment buildings, the presence of more apartment units results in lower EE indices. Additionally, housing units with more windows and large trees that shade the sun have adopted more energy efficient measures. The positive sign on the tree shade variable indicates that the effect of reduced natural heating from the sun in the winter appears to be more costly than the savings from reduced cooling needs in the summer.

Of the interior structural characteristics, only some are statistically significant and have the expected sign, such as whether the household uses air conditioning equipment and the ratio of rooms cooled to total number of rooms, which have positive signs. The ratio of rooms heated to total number of rooms is also positive, although not significant. The coefficients on the main space heating fuel type and reported winter draftiness are neither statistically significant nor as expected. The dummies for main space heating equipment age and reported efficacy of insulation are mostly statistically significant but negative, contrary to expectation. This result is probably due to the fact that those residing in these households are income constrained and may not have the means to invest in energy efficient measures. In fact, homes that use more expensive heating fuel, with older space heating equipment, poor insulation and experience winter draftiness are most likely older and less expensive. Thus, while these households could financially benefit from energy efficient updates in the long run, householders may be unable to devote financial resources to such updates.

Finally, the demographic variables indicate that married householders, those with more education, and higher incomes in a larger number of energy efficient measures. The signs on the education dummies are all positive but indicate that there is only a statistically significant difference between householders with no high school diploma or GED and householders with a Bachelor's, graduate or professional degree. As for income, the EE indices are significantly higher for households with a gross income of $70,000-$89,999 and over $100,000 than households with gross incomes of less than $20,000. Contrary to expectation, the estimated coefficients for householders with gross incomes $20,000-$29,999 and $30,000-$39,999 are negative, although only the latter is significant. A possible explanation for this result could be that receipt of rent or housing

[1] Correction methodology is described in the manual provided by the EIA for the 2009 RECS, available online at http://www.eia.gov/consumption/residential/data/2009/index.cfm?view=microdata.

assistance from the government could allow or force households to make more energy efficiency adoptions than they otherwise would at their income level. Since 75% of the recipients of rent or housing assistance in our sample make less than $20,000, perhaps this distorts the true income effect, which seemingly suggests that without financial assistance, households begin to invest in energy efficient measures at a gross income of at least $40,000. Finally, the sign on number of household members is also positive as expected, however statistically insignificant.

The additional householder characteristics are all statistically significant with the anticipated signs. Householders who run a home business, have installed Energy Star appliances, or are owners (as opposed to renters) are all more likely to have higher EE indices. If the householder is a renter and has heat included in his rent, he is less likely to adopt as many energy efficient measures as rents with heat payments separate from their rent.

4. Concluding Remarks

Our analysis is consistent with previous literature on split-incentives between tenants and landlords and indicates a number of policy implications in regard to residential energy efficiency adoption. Preliminary results suggest specific regional and demographic household characteristics for which residential EE adoption could be incentivized to increase energy conservation efforts. One important area in need of efficiency improvement is homes/apartments with older structural characteristics such as poor insulation, winter draftiness, older space heating equipment, and use less efficient space heating fuel types.

Future work will focus on investigating the further differences in EE adoption by owners vs. renters, and for those that rent, renters whose utilities are included in their rent and those whose rent payments do not include utilities. While characteristics of owner or renter and heat included or excluded in rent payment are currently estimated as dummy variables in our model, we will explore different specifications of our model to account for potential endogeneity that results from selection. The issue of self-selectivity concerning the decision to own or rent has been examined by Lee and Trost (1978) in application to the problem of housing demand. Additionally, Levinson and Niemann (2004) suggest that selection into heat-included contracts is not exogenous of heat-using characteristics of renters. Future work will explore switching regressions with endogenous switching for count models as specified by Deb, Munkin and Trivedi (2006). We will also explore endogenous switching regressions in which there are multiple criteria for selectivity (Maddala 1983). Since the RECS includes observation of both decisions, and the decision of whether to enter into a heat-included rental contract is defined for only a subset of our observations (those who choose rent), a sequential decision model with full observability should be specified.

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Appendix

Table 1. Summary of variables used to calculate energy efficiency index for households.

Variable	Description	Mean[a]	Std.Dev.[a]
Replcfri	Most-used refridgerator replaced by this household in the last 4 years (=1 if yes, =0 if no)	0.2443	0.4297
Replcdw	Dishwasher replaced by this household in the last 4 years (=1 if yes, =0 if no)	0.1526	0.3596
Replccw	Clothes washer replaced by this household in the last 4 years (=1 if yes, =0 if no)	0.2620	0.4397
Replcht	Main space heating equipment replaced by this household in the last 4 years (=1 if yes, =0 if no)	0.1514	0.3584
Replcwwac	Most-used window/wall AC unit replaced by this household in the last 4 years (=1 if yes, =0 if no)	0.0757	0.2645
Newglass	Windows replaced by this household (=1 if all or some, =0 if none)	0.3069	0.4612
Instlins	Insulation added by this household (=1 if yes, =0 if no)	0.2260	0.4182
Autoheatnite	Programmable thermostat lowers temperature at night (=1 if yes, =0 if no)	0.2414	0.4279
Autoheatday	Programmable thermostat lowers temperature during the day (=1 if yes, =0 if no)	0.2080	0.4059
Autocoolnite	Programmable thermostat adjusts temperature at night (=1 if yes, =0 if no)	0.1776	0.3822
Autocoolday	Programmable thermostat adjusts temperature during the day (=1 if yes, =0 if no)	0.1759	0.3808
Instlcfl	Energy-efficient bulbs installed by this household (=1 if yes, =0 if else)	0.5293	0.4992
Typeglass	Type of glass in most windows (=1 if triple or double pane, =0 if single pane or other)	0.5897	0.4919
Instlws	Caulking or weather stripping by this household (=1 if yes, 0 if else)	0.3612	0.4804

[a]Weighted observations to represent all US households.

Table 2. Summary of independent variables.

Variable	Description	Mean[a]	Std.Dev.[a]
Eeindex	Numer of energy efficieny measure adopted (see Table 2)	3.702	2.545
Heat_price	Average annual fuel cost by fuel type and geographic region in $/MMBtu	20.07	11.18
New England	Census division (=1 if CT, MA, ME, NH. RI, VT, =0 if else)	0.0483	0.2145
East North Central	Census division (=1 if IL, IN, MI, OH. WI, =0 if else)	0.1631	0.3695
West North Central	Census division (=1 if IA, KS, MN, MO, ND, NE, SD, =0 if else)	0.0731	0.2603
East South Central	Census division (=1 if AL, KY, MS, TN, =0 if else)	0.0634	0.2436
West South Central	Census division (=1 if AR, LA, OK, TX, =0 if else)	0.1157	0.3198
Mid Atlantic	Census division (=1 if NJ, NY, PA, =0 if else)	0.1369	0.3438
South Atlantic	Census division (=1 if DC, DE, FL, GA, MD, NC, SC, VA, WV, =0 if else)	0.1960	0.3970
Mountain North	Census division (=1 if CO, ID, MT, UT, WY, =0 if else)	0.0385	0.1857
Moutain South	Census division (=1 if AZ, NM, NV, =0 if else)	0.0353	0.1845
Pacific	Census division (=1 if AK, CA, HI, OR, WA, =0 if else)	0.1325	0.3391
Urban	Housing unit classified as urban or rural (=1 if urban, =0 if rural)	0.7876	0.409
HDD65	Heating degree days (base 65)	4255	2144
CDD65	Cooling degree days (base 65)	1367	1068
SingleFamDetach	Type of housing unit (=1 if single-family detached, =0 if else)	0.6358	0.4812
Mobile	Type of housing unit (=1 if mobile home, =0 if else)	0.0572	0.2322
SingleFamAtt	Type of housing unit (=1 if single-family attached, =0 if else)	0.0609	0.2391
Apt2_4	Type of housing unit (=1 if apartment building with 2-4 units, =0 if else)	0.0815	0.2736
Apt5_more	Type of housing unit (=1 if apartment building with 5+ units, =0 if else)	0.1646	0.3709
Numapts	Number of apertment units in a 5+ unit apartment building (=0 if housing unit is not a 5+ unit building)	6.480	40.38
Yearmade	Year housing unit was built	1971	25.03
Window0_5	Number of windows in heated area (=1 if 0-5 windows, =0 if else)	0.1560	0.3629
Window6_9	Number of windows in heated area (=1 if 6-9 windows, =0 if else)	0.2580	0.4375
Window10_15	Number of windows in heated area (=1 if 10-15 windows, =0 if else)	0.3374	0.4729
Window16_19	Number of windows in heated area (=1 if 16-19 windows, =0 if else)	0.1076	0.3099
Window20_more	Number of windows in heated area (=1 if 20 or more windows, =0 if else)	0.1411	0.3482
Treeshad	Housing unit shaded from sun by large trees (=1 if yes, =0 if no)	0.4424	0.4967
NaturalGas	Main space heating fuel (=1 if natural gas, =0 if else)	0.5232	0.4995
Propane	Main space heating fuel (=1 if propane, =0 if else)	0.0520	0.2221
FuelOil	Main space heating fuel (=1 if fuel oil, =0 if else)	0.0650	0.2466
Electricity	Main space heating fuel (=1 if electricity, =0 if else)	0.3598	0.4800

Table 2. (Continued)

Variable	Description	Mean[a]	Std.Dev.[a]
Equip0_1yrs	Age of main space heating equipment (=1 if less than 2 years, =0 if else)	0.0970	0.2960
Equip2_4yrs	Age of main space heating equipment (=1 if 2-4 years, =0 if else)	0.1420	0.3490
Equip5_9yrs	Age of main space heating equipment (=1 if 5-9 years, =0 if else)	0.2408	0.4276
Equip10_14yrs	Age of main space heating equipment (=1 if 10-14 years, =0 if else)	0.2304	0.4211
Equip15_19yrs	Age of main space heating equipment (=1 if 15-19 years, =0 if else)	0.1878	0.3906
Equip20_moreyrs	Age of main space heating equipment (=1 if 20 or more years, =0 if else)	0.1020	0.3027
Ratiohtrm	Total number of rooms heated to total number of rooms in housing unit	0.9360	0.1610
Aircond	Air conditioning equipment used (=1 if yes, =0 if no)	0.8415	0.3653
Ratioacrm	Total number of rooms cooled to total number of rooms in housing unit	0.6055	0.4690
Insul_well	Level of insulation (=1 if well insulated, =0 if else)	0.3598	0.4800
Insul_adqu	Level of insulation (=1 if adequately insulated, =0 if else)	0.4369	0.4960
Insul_poor	Level of insulation (=1 if poorly insulated, =0 if else)	0.1969	0.3977
Insul_none	Level of insulation (=1 if no insulation, =0 if else)	0.0064	0.0798
Drafty_all	Reported draftiness of home in winter (=1 if always drafty, =0 if else)	0.0744	0.2624
Drafty_most	Reported draftiness of home in winter (=1 if mostly drafty, =0 if else)	0.0788	0.2694
Drafty_some	Reported draftiness of home in winter (=1 if sometimes drafty, =0 if else)	0.3194	0.4662
Drafty_never	Reported draftiness of home in winter (=1 if never drafty, =0 if else)	0.5275	0.4993
Spouse	Householder lives with spouse or partner (=1 if yes, =0 if no)	0.5630	0.4960
Edu_none	Highest education completed by householder (=1 if no HS or GED, =0 if else)	0.1017	0.3022
Edu_HS	Highest education completed by householder (=1 if HS diploma or GED, =0 if else)	0.2693	0.4436
Edu_somecol	Highest education completed by householder (=1 if some college with no degree, =0 if else)	0.2274	0.4192
Edu_Assoc	Highest education completed by householder (=1 if Associate's degree, =0 if else)	0.0948	0.2930
Edu_Bach	Highest education completed by householder (=1 if Bachelor's degree, =0 if else)	0.1982	0.3987
Edu_Grad	Highest education completed by householder (=1 if graduate or professional degree, =0 if else)	0.1085	0.3110

Table 2. (Continued)

Variable	Description	Mean[a]	Std.Dev.[a]
Income_20	2009 gross household income (=1 if less than $20,000, =0 if else)	0.2028	0.4021
Income_30	2009 gross household income (=1 if $20,000-$29,999, =0 if else)	0.1281	0.3342
Income_40	2009 gross household income (=1 if less than $30,000-$39,999 =0 if else)	0.1200	0.3129
Income_50	2009 gross household income (=1 if less than $40,000-$49,999 =0 if else)	0.1149	0.3189
Income_60	2009 gross household income (=1 if less than $50,000-$59,999 =0 if else)	0.0732	0.2605
Income_70	2009 gross household income (=1 if less than $60,000-$69,999 =0 if else)	0.0691	0.2537
Income_80	2009 gross household income (=1 if less than $70,000-$79,999 =0 if else)	0.0562	0.2304
Income_90	2009 gross household income (=1 if less than $80,000-$89,999 =0 if else)	0.0469	0.2114
Income_100	2009 gross household income (=1 if less than $90,000-$99,999 =0 if else)	0.0375	0.1901
Income_plus100	2009 gross household income (=1 if more than $100,000 =0 if else)	0.1613	0.3678
Nhsldmem	Number of household members	2.556	1.500
Hbusness	Home-based business or service (=1 if yes, =0 if no)	0.0797	0.2709
Es_app	Energy star refridgerator, dishwater, clothes washer, or window/wall AC unit installed in household	0.3526	0.4778
Owner	Housing unit is owned or rented (=1 if owned, =0 if rented)	0.6854	0.4644
Heat_inc	Who pays heating bills (=1 if household, =0 if else)	0.0887	0.2844

[a]Weighted observations to represent all US households.

Table 3. Negative binomial estimates.

Variable	Coefficient	S.E.
Heat_price	0.0003	0.0022
New England	0.0466	0.0371
West North Central	-0.0103	0.0288
East South Central	-0.1663***	0.0456
West South Central	-0.0720**	0.0348
Mid Atlantic	-0.0069	0.0276
South Atlantic	-0.0129	0.0314
Mountaun North	0.0768*	0.0398
Mountain South	0.0732	0.0484
Pacific	0.1738***	0.0357
Urban	0.0502***	0.0181
HDD65	0.00003***	0.000008
CDD65	0.000009	0.00002
Mobile	-0.1483***	0.0367
SingleFamAtt	-0.0607**	0.0278
Apt2_4	-0.1434***	0.0378
Apt5_more	-0.1940***	0.0357
Numapts	-0.0008***	0.0003
Yearmade	-0.0030***	0.0003
Window6_9	0.0456	0.0276
Window10_15	0.1117***	0.0270
Window16_19	0.1134***	0.0314
Window20_more	0.1397***	0.0303
Treeshad	0.0604***	0.0124
Propane	-0.0375	0.0407
FuelOil	-0.0402	0.0322
Electricity	-0.0651	0.0504
Equip2_4yrs	-0.0593***	0.0211
Equip5_9yrs	-0.2302***	0.0211
Equip10_14yrs	-0.2721***	0.0234
Equip15_19yrs	-0.2468***	0.0217
Equip20_moreyrs	-0.2368***	0.0245

Table 3. (Continued)

Variable	Coefficient	S.E.
Ratiohtrm	0.0263	0.0363
Aircond	0.1499***	0.0206
Ratioacrm	0.1133***	0.0124
Insul_adq	-0.0159	0.0147
Insul_poor	-0.0685***	0.0212
Insul_none	-0.3008***	0.0904
Drafty_most	-0.0245	0.0317
Drafty_some	0.0429	0.0264
Drafty_all	0.0384	0.0286
Spouse	0.0953***	0.0160
Edu_HS	0.0152	0.0262
Edu_somecol	0.0306	0.0260
Edu_Assoc	0.0425	0.0301
Edu_Bach	0.0636**	0.0281
Edu_Grad	0.0746**	0.0304
Income_30	-0.0282	0.0239
Income_40	-0.0652**	0.0261
Income_50	0.0174	0.0268
Income_60	0.0220	0.0260
Income_70	0.0202	0.0277
Income_80	0.0676**	0.0290
Income_90	0.0729**	0.0299
Income_100	0.0484	0.0340
Income_plus100	0.1023***	0.0255
Nhsldmem	0.0033	0.0044
Hbusness	0.0377**	0.0186
Es_app	0.2930***	0.0155
Owner	0.4200***	0.0212
Heat_inc	-0.0516*	0.0297
Constant	6.3382***	0.5867
Number of Observations	11,115	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1