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# Determinants of Household Use of Selected Energy Star Appliances

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## 1. Introduction

According to the 2009 Residential Energy Consumption Survey (RECS), household appliances[1] accounted for 35% of U.S. household energy consumption, up from 24% in 1993. Thus, improvements in the energy performance of residential appliances as well as increases in the use of more efficient appliances can be effective in reducing household energy consumption and greenhouse gas emissions.

In 1992, the U.S. Environmental Protection Agency and the U.S. Department of Energy established the ENERGY STAR® voluntary labeling program to promote energy efficiency and reduce greenhouse gas emissions. Usually ENERGY STAR appliances use 20% to 30% less energy than required by federal standards in place at the time of purchase (Tugend 2008). Computers and monitors were the first products with the ENERGY STAR labels. In 1997, the program expanded to include other appliances such as refrigerators, dishwashers, and clothes washers. Currently the ENERGY STAR label covers major appliances, lighting, home electronics, office equipment, and new buildings (U.S. EPA 2014).

The main objective of this paper is to test a series of hypotheses regarding the influences of household characteristics (such as education, age, sex, race, income, and size of household), building characteristics (such as age, ownership, and type), and electricity prices on the use of ENERGY STAR appliances. First, the paper provides a brief description of the data and an overview of the model specification and estimation method. Second, the paper examines factors influencing a household's decision to adopt ENERGY STAR for selected appliances and presents conclusions.

## 2. Data

The U.S. Energy Information Administration (EIA) 2009 RECS, a survey of occupied housing units used as primary residences (excluding vacation homes), is the main source of this analysis. RECS data are developed from an area probability statistical sample designed to provide national and regional data.[2] The RECS includes information about household and building characteristics, appliances in the home, and estimates of energy consumption and expenditures.

In the 2009 RECS, respondents who had a refrigerator, dishwasher, or clothes washer less than nine years old were asked if any of these units were ENERGY STAR products.[3] The analyses in this paper are focused on these sub-samples. The publicly available replicate weights were used to account for the complex sample design in the RECS.

[1] Appliances exclude space heating, space cooling, and water heating units, but include computers, household electronics, and all other appliances.

[2] The 2009 RECS also includes data for 16 individual states.

[3] These are the only appliances for which ENERGY STAR data are available. Heads of household were also asked to identify their ENERGY STAR wall unit air conditioners, which are not included in this analysis.

## 3. Theoretical framework and model

Among the respondents, some households did not respond or did not know whether or not they had an ENERGY STAR appliance. Because households who responded either yes or no may have different observed and unobserved attributes than those that didn't know or did not respond, selection of only the households that responded yes or no could lead to sample selectivity bias.[4] If bias exists, the exclusion of households who did not respond will influence the estimated results (Heckman 1979).

Following the conventional sample selection model, a household's decision to purchase ENERGY STAR appliances can be expressed as

$$D_i^* = C_i\beta + u_i, \qquad (1)$$

where

$D_i^*$ = a latent (i.e., unobserved) measure of propensity of household to use ENERGY STAR appliances;

$C_i$ = a vector of household characteristics;

$\beta$ = a vector of unknown parameters; and

$u_i$ = an error term.

However, $D_i^*$ is not observed. What is observed is

$D_i = 1$ if household $i$ purchases an ENERGY STAR appliance ($D_i^* > 0$); and

$D_i = 0$ otherwise ($D_i^* \leq 0$).

Equation (1) applies only to households that responded either yes or no to the ENERGY STAR question. It is hypothesized that households who knew whether they had an ENERGY STAR appliance had knowledge of the ENERGY STAR program. It is further postulated that those who did not respond or did not know had no knowledge about this program (Bernisky 2004, Mills and Schleich, 2010, Murray and Mills 2011). Thus, the household's knowledge of the ENERGY STAR appliance program can be expressed as

$$A_i^* = X_i\alpha + \boldsymbol{\varepsilon}_{i,} \qquad (2)$$

[4]Another possible bias results from a non-randomly selected sample, because only households who purchased appliances after 2000 were selected for questions about ENERGY STAR (refrigerators, dishwashers, and clothes washers). These ENERGY STAR appliances were on the market about three years earlier, but because data on the exact age of appliances are not available (RECS asks only for age ranges), this type of bias could not be considered in the analyses.

where

$A_i^*$ = a latent measure of household knowledge of ENERGY STAR;

$X_i$ = a vector of household characteristics;

$\alpha$ = a vector of unknown parameters; and

$\boldsymbol{\varepsilon_i}$ = an error term.

However, we observe the following:

$A_i = 1$ if household had knowledge ($A_i^*$>0); and

$A_i = 0$ otherwise ($A_i^* \leq 0$).

Using expressions (1) and (2), characterization of the ENERGY STAR appliance purchase decision based on households who gave a yes or no response can be written as:

$$\text{E}\,(D_i^*) = C_i\beta + E(u_i|X_i\alpha + \boldsymbol{\varepsilon_i} > 0), \quad (3)$$

$$= C_i\beta + E(u_i|\boldsymbol{\varepsilon_i} > -X_i\alpha).$$

If $u_i$ and $\boldsymbol{\varepsilon_i}$ have the normal distribution with mean zero and variance equal to one, and $if\ u_i$ and $\boldsymbol{\varepsilon_i}$ are correlated (ρ), as Green (1993) has shown, expression (3) can be written as

$$\text{E}\,(D_i^*) = C_i\beta + \rho\left(\frac{\varphi(X_i\alpha)}{\Phi(X_i\alpha)}\right), \quad (4)$$

where

$\varphi$ = the standard normal density function; and

$\Phi$ = the cumulative distribution function of a normal distribution.

The ratio of the normal density function to the cumulative distribution function of a normal distribution is known as the Inverse Mill's ratio ($\lambda$). It takes account of sample selection bias. Thus, the expected value of the household decision to purchase ENERGY STAR appliances, given that they had knowledge of ENERGY STAR, can be written as

$$\text{E}\,(D_i^*) = C_i\beta + \rho\lambda_{i.}. \quad (5)$$

Sample selection bias arises when ρ is not equal to zero, that is, $E(u_i) \neq 0$. Over the years, different techniques have been proposed to handle this problem. Heckman (1974, 1979, and 1980) proposed a method that consists of two steps. First, probit estimation is applied to maximize the likelihood of expression (2) by using data from all households, including those who did not respond or did not know. From the probit estimation of expression (2), an estimate of $\lambda_i$ is obtained. Second, this estimate of $\lambda_i$ is included as an explanatory variable in the probit estimation of the decision to purchase ENERGY STAR appliances. According to Heckman, this technique eliminates the potential sample selection bias. When $\lambda_i$ is not statistically significant, there is no sample selection bias. Another more efficient method (Wynand et al., 1981, Schleich and Mills 2008, Mills and Schleich 2009, Murray and Mills 2011) is the joint maximum likelihood estimation of the determinants of the household's knowledge of ENERGY STAR with the determinants of adoption of ENERGY STAR appliances.

In subsequent analyses, both the joint maximum likelihood and Heckman maximum likelihood estimators are applied. This paper relies on the estimates from the joint maximum likelihood, although the estimates from the Heckman method are reported in Appendix A for comparison. The paper uses the QLIM procedure in SAS to estimate both methods.

## 4. Factors affecting use and knowledge of energy star appliances

It is hypothesized that the decision to use/purchase ENERGY STAR and household knowledge of ENERGY STAR are influenced by the following set of variables:

1. Household occupant characteristics: age, education, sex, race, family size
2. Buildings characteristics: ownership, age of buildings, building type
3. Economic factors: income, electricity price
4. Regional factors: Census region

Table 1 shows the variables that are used in this analysis with mean and standard deviation based on the number of observations for each of the three appliance types. Inclusion of the education variable EDHIGH reflects the expectation that access to information influences the choice to use ENERGY STAR appliances. Thus, a household's being headed by a person with a high school degree or lower level of education is expected to have a negative effect on the decision to use and the knowledge of ENERGY STAR. Also, households headed by older people are expected to be less likely to use ENERGY STAR, as older householders may be reluctant to adopt a new technology. The variable HHEAD is included to test for correlation between the householder's sex and the choice to use ENERGY STAR. More than 50% of the RECS sample households are headed by women. The study also attempts to test the link between the race of the head of household and adoption[5] and knowledge of ENERGY STAR appliances. To do so, two dummy variables for Hispanic (HISPANIC) and Black/ African (BLACK) were included in the decision to use and knowledge equations.

The economic status of households can influence their knowledge of and choice to use ENERGY STAR appliances. Two dummy variables are used to reflect the effects of household income. One represents households at or below the 100-percent of poverty line (POVERTY100), and the other represents

[5] The terms "adoption" and "use" are used interchangeably throughout the paper.

households with income more than $80,000 (HIGHINCOME). It is further hypothesized that households with higher income are more likely to purchase ENERGY STAR appliances.

Because energy consumption tends to be greater in larger families, a family size variable (NHSLDMEM) is included to capture the effect of household size. It is hypothesized that households with more members are more likely to be informed about ENERGY STAR appliances and to purchase them.

Regional differences are accounted for by using dummy variables for three of the four Census regions (South, Midwest, and West).[6] Since these variables reflect regional variations in energy prices as well as energy efficiency policies and marketing strategies, they were included in the estimation of the knowledge equation. Thus, the electricity price variable, ELPRICE, was included in the adoption equation only.

Also, it is hypothesized that the use of ENERGY STAR appliances is influenced by the age and type of homes. A dummy variable (BUILT2000), representing homes built in 2000 or after, was included in both the use and knowledge equations. Apartments and mobile homes are assumed to be less likely to use ENERGY STAR appliances. Two other variables (APT and MOBHOME) were included to reflect the influence of housing type. Finally, the variable OWN is used to test the hypothesis that home ownership encourages the use of ENERGY STAR. However, this variable is not truly independent or exogenous. Home ownership is also affected by some of the factors affecting the knowledge and propensity to use ENERGY STAR appliances (e.g., Jayantha 2012 and Hood 1999). Given the endogeneity of home ownership, the analysis first estimates the predicted value of home ownership using the probit method. In addition to the above factors, employment status of the head of household (EMPLOYED) is included in the estimation of home ownership. Then the predicted probability of home ownership is used as an explanatory variable in the joint maximum likelihood estimation of household knowledge and use of ENERGY STAR appliances.

[6] Intercept captures the effect of the forth Census region (i.e., Northeast).

## Table 1. Description of variables used in the regressions

| | | Refrigerator | | Dishwasher | | Clothes Washer | |
|---|---|---|---|---|---|---|---|
| Variables | Definition | Mean | Standard Error | Mean | Standard Error | Mean | Standard Error |
| Use of ENERGY STAR | | | | | | | |
| Refrigerator | use =1; nonuse=0 | 0.609 | 0.006 | | | | |
| Dishwasher | use =1; nonuse=0 | | | 0.644 | 0.008 | | |
| Clothes Washer | use =1; nonuse=0 | | | | | 0.666 | 0.008 |
| Knowledge of ENERGY STAR | | | | | | | |
| Refrigerator | yes=1; otherwise 0 | 0.893 | 0.005 | | | | |
| Dishwasher | yes=1; otherwise 0 | | | 0.88 | 0.005 | | |
| Clothes Washer | yes=1; otherwise 0 | | | | | 0.905 | 0.005 |
| NHSLDMEM | family size | 2.695 | 0.017 | 2.749 | 0.022 | 2.827 | 0.021 |
| HHEAD | Sex of head of household (female=1; male=0) | 0.533 | 0.005 | 0.517 | 0.007 | 0.529 | 0.006 |
| HHAGE | age of household head (years) | 48.583 | 0.213 | 48.505 | 0.282 | 49.136 | 0.231 |
| EDHIGH | high school or less years of schooling=1; otherwise 0 | 0.369 | 0.007 | 0.257 | 0.007 | 0.352 | 0.007 |
| HISPANIC | Hispanic households | 0.138 | 0.004 | 0.075 | 0.004 | 0.121 | 0.005 |
| BLACK | Black or African households | 0.141 | 0.006 | 0.094 | 0.005 | 0.117 | 0.006 |
| INCOMEGE80 | income at or above $80,000=1; otherwise 0 | 0.257 | 0.006 | 0.371 | 0.009 | 0.292 | 0.007 |
| POVERTY100 | income at or below the 100-percent of poverty line=1; otherwise 0 | 0.146 | 0.005 | 0.072 | 0.004 | 0.117 | 0.005 |
| OWN | ownership of home=1; rent=0 | 0.667 | 0.005 | 0.777 | 0.006 | 0.778 | 0.006 |
| BUILT2000 | homes built after 2000=1; otherwise 0 | 0.176 | 0.007 | 0.259 | 0.011 | 0.191 | 0.008 |
| Mobile | mobile homes=1; otherwise 0 | 0.057 | 0.002 | 0.032 | 0.003 | 0.065 | 0.002 |
| APT | apartments=1; otherwise 0 | 0.248 | 0.003 | 0.185 | 0.006 | 0.132 | 0.004 |
| ELPRICE | electricity price (Cents per kWh) | 12.627 | 0.058 | 12.375 | 0.072 | 12.360 | 0.064 |
| EMPLOYED | employment status, worked part time or fulltime=1; otherwise 0 | 0.627 | 0.007 | 0.675 | 0.008 | 0.64 | 0.007 |
| SOUTH | South =1; otherwise 0 | 0.385 | 0.004 | 0.389 | 0.007 | 0.408 | 0.004 |
| MIDWEST | Midwest =1; otherwise 0 | 0.217 | 0.004 | 0.22 | 0.007 | 0.219 | 0.004 |
| WEST | West =1; otherwise 0 | 0.223 | 0.002 | 0.226 | 0.005 | 0.22 | 0.003 |

Source: Computed from U.S. Energy Information Administration, 2009 RECS.

# 5. Model estimates: joint maximum likelihood

## *5.1 Refrigerators*

Based on RECS data, in 2009 about 89% of the respondents who used refrigerators that were purchased between 2000 and 2009 had knowledge about ENERGY STAR refrigerators. Among the households who had knowledge, nearly 61% used an ENERGY STAR refrigerator.[7]

Table 2 shows the joint maximum likelihood estimation results for refrigerators. The estimated coefficients of probit models show the effect of one unit change in an explanatory variable on the log-odds of the dependent variable. For ease of interpretation, marginal probability effects for the significant variables of the use equation are also reported. This statistic reflects the effects of a one-unit change in an explanatory variable (for dichotomous variables in this study, changes are from zero to one) on the probability that the dependent variable is one.[8] The results indicate that use of ENERGY STAR refrigerators is positively influenced by a household's family size. The age of head of household shows a significant positive relationship with the likelihood of using Energy STAR refrigerators[9], but the gender of the head of household does not seem to matter. The education level is important, and high school degree or lower level of schooling negatively affects the decision to use ENERGY STAR. Among household characteristics, the ethnic background of the household also affects the likelihood of adoption. Heads of households who are Hispanic are less likely to adopt ENERGY STAR refrigerators; the coefficient for Hispanics is significantly negative. Household income at or above $80,000 has a significantly positive effect on the likelihood of adoption of ENERGY STAR refrigerators, while income at or below the poverty level has a significantly negative effect.

Home ownership seems to be a significant factor explaining the decision to use ENERGY STAR refrigerators. Also, both the age and type of home influence the likelihood of adoption. Homes built after 2000 have a significantly higher probability of having ENERGY STAR refrigerators than homes built earlier. Apartments and mobile homes have significantly lower likelihoods of adoption of ENERGY STAR refrigerators, relative to single- family homes. As expected, there is a direct relationship between electricity price and the likelihood of adoption. The coefficient of this variable is positive and highly significant.

With respect to high income level and housing unit type, the results of the regression analysis for the knowledge of ENERGY STAR equation are similar to those for the adoption equation. The coefficient for Hispanic householder, however, is significantly negative in the adoption equation and significantly positive in the knowledge equation.

[7] The household is considered to use an ENERGY STAR refrigerator if the respondent said yes to any of the following: a) the most-used refrigerator was an ENERGY STAR or b) the second most-used refrigerator was an ENERGY STAR, or c) the third most-used refrigerator was an ENERGY STAR.
[8] The estimated results may be affected by the correlation that may exist between some of the explanatory variables.
[9] The 1998 Department of Energy study of 500 appliance purchasers also found that 44% of the purchasers of the ENERGY STAR appliances were 50 or older.

Finally, there are regional differences with respect to the likelihood of knowledge equation. Households in the South and Midwest are less likely to be informed than those in the other Census regions. The correlation between the error terms from the two equations is negative and highly significant, which indicates that unobservable factors that are positively related to the decision to use ENERGY STAR are negatively related to households' knowledge of the ENERGY STAR program.

### Table 2. Joint maximum likelihood estimates for refrigerators

| Explanatory Variables | Estimation of Home Ownership | | Knowledge of ENERGY STAR | | Use of ENERGY STAR | | |
|---|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | Coefficient | Standard Error | Coefficient | Standard Error | Marginal Effects |
| Constant | -0.236* | 0.142 | 1.452*** | 0.200 | -0.447*** | 0.118 | |
| NHSLDMEM | 0.029** | 0.014 | 0.010 | 0.014 | 0.051*** | 0.011 | 0.018 |
| HHEAD | -0.051 | 0.037 | -0.067 | 0.044 | -0.020 | 0.033 | |
| HHAGE | 0.026*** | 0.002 | -0.001 | 0.002 | 0.007*** | 0.001 | 0.003 |
| EDHIGH | -0.241*** | 0.046 | -0.028 | 0.046 | -0.069* | 0.038 | -0.026 |
| HISPANIC | -0.174*** | 0.055 | 0.186*** | 0.060 | -0.129** | 0.055 | -0.050 |
| BLACK | -0.426*** | 0.060 | 0.139** | 0.068 | 0.035 | 0.051 | |
| HIGHINCOME | 0.529*** | 0.044 | 0.098* | 0.054 | 0.220*** | 0.041 | 0.080 |
| POVERTY100 | -0.436*** | 0.060 | -0.028 | 0.068 | -0.181*** | 0.052 | -0.070 |
| OWNHAT[a] | | | 0.045 | 0.156 | 0.273*** | 0.105 | 0.082 |
| BUILT2000 | 0.326*** | 0.061 | -0.022 | 0.059 | 0.124*** | 0.040 | 0.045 |
| MOBHOME | 0.070 | 0.110 | 0.009 | 0.111 | -0.348*** | 0.081 | -0.134 |
| APT | -2.006*** | 0.063 | -0.293* | 0.152 | -0.190* | | -0.090 |
| ELPRICE | | | | | 0.018*** | 0.004 | 0.006 |
| EMPLOYED | 0.130** | 0.053 | | | | | |
| SOUTH | -0.043 | 0.061 | -0.192*** | 0.067 | | | |
| MIDWEST | 0.067 | 0.081 | -0.227*** | 0.077 | | | |
| WEST | -0.283*** | 0.069 | 0.015 | 0.073 | | | |
| ρ[b] | | | | | -0.860*** | | |
| Log Likelihood | -3,202 | | | | -7,867 | | |
| Number of observations | 8,889 | | | | | | |

Notes: The Northeast region is omitted from the models and serves as a baseline.
[a] Predicted value of ownership (OWN).
[b] Correlation between the error terms.
* **Significant at the 1% level.
**Significant at the 5% level.
* Significant at the 10% level.
Source: U.S. Energy Information Administration, RECS 2009.

### *5.2 Dishwashers*

The RECS data show that an estimated 88% of the respondents who used dishwashers purchased between 2000 and 2009 had knowledge about ENERGY STAR dishwashers. Among the households who had knowledge, about 64% used an ENERGY STAR dishwasher. Table 3 gives the estimated parameters for households' decisions to use and their knowledge of ENERGY STAR dishwashers. The likelihood of adopting ENERGY STAR dishwashers with respect to family size, age of head of household, income above $80,000, home ownership, type of home, and electricity price are similar to those for refrigerators. Education of head of household, race, and age of homes are not statistically significant determinants of adoption for ENERGY STAR dishwashers.

Among the household and building characteristics, only female head of household (HHEAD) and education (EDHIGH) are statistically significant in the knowledge equation. The negative estimated effect of HHEAD indicates that female headed households are less likely to have knowledge about ENERGY STAR dishwashers. Similarly, households with a lower level of education and households residing in apartments are less likely to have knowledge of ENERGY STAR. Geographical location of homes does not appear to be a significant determinant in the knowledge equation. Also, the correlation between error terms is not statistically significant, which suggests that sample selection bias is not a problem in this case.

### Table 3. Joint maximum likelihood estimates for dishwashers

| Explanatory Variables | Estimation of Home Ownership | | Knowledge of ENERGY STAR | | Use of ENERGY STAR | | |
|---|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | Coefficient | Standard Error | Coefficient | Standard Error | Marginal Effects |
| Constant | 0.043 | 0.199 | 1.599*** | 0.229 | -0.490** | 0.216 | |
| NHSLDMEM | 0.008 | 0.019 | 0.002 | 0.023 | 0.044** | 0.020 | 0.015 |
| HHEAD | 0.024 | 0.050 | -0.144*** | 0.050 | -0.053 | 0.057 | |
| HHAGE | 0.028*** | 0.002 | -0.002 | 0.002 | 0.008*** | 0.002 | 0.003 |
| EDHIGH | -0.203*** | 0.060 | -0.170*** | 0.066 | -0.066 | 0.073 | |
| HISPANIC | -0.200** | 0.088 | 0.121 | 0.107 | -0.119 | 0.082 | -0.043 |
| BLACK | -0.461*** | 0.090 | 0.004 | 0.089 | 0.008 | 0.076 | |
| HIGHINCOME | 0.462*** | 0.069 | 0.006 | 0.053 | 0.299*** | 0.048 | 0.102 |
| POVERTY100 | -0.452*** | 0.093 | -0.053 | 0.099 | -0.136 | 0.104 | |
| OWNHAT | | | -0.078 | 0.218 | 0.269* | 0.158 | 0.098 |
| BUILT2000 | 0.201*** | 0.076 | -0.072 | 0.059 | 0.053 | 0.050 | |
| MOBHOME | 0.389*** | 0.197 | 0.001 | 0.171 | -0.316** | 0.133 | -0.117 |
| APT | -1.925*** | 0.092 | -0.284 | 0.196 | -0.319* | 0.181 | -0.118 |
| ELPRICE | | | | | 0.021*** | 0.007 | 0.007 |
| EMPLOYED | 0.098 | 0.072 | | | | | |
| SOUTH | -0.194** | 0.100 | -0.086 | 0.111 | | | |
| MIDWEST | -0.013 | 0.129 | -0.132 | 0.081 | | | |
| WEST | -0.463*** | 0.106 | -0.028 | 0.078 | | | |
| ρ[b] | | | | | -0.839 | | |
| Log Likelihood | -1,603 | | | | -4,705 | | |
| Number of observations | 5,315 | | | | | | |

Notes: The Northeast region is omitted from the models and serves as a baseline.

[a] Predicted value of ownership (OWN).

[b] Correlation between the error terms.

* **Significant at the 1% level.

**Significant at the 5% level.

* Significant at the 10% level.

Source: U.S. Energy Information Administration, RECS 2009.

## *5.3 Clothes washers*

The RECS data show that an estimated 90% of the respondents who used clothes washers purchased between 2000 and 2009 had knowledge about ENERGY STAR clothes washers. Among the households who had knowledge, nearly 67% of households had ENERGY STAR units. Table 4 shows the regression results for clothes washers. There are some similarities between the results for the decision to use ENERGY STAR clothes washers and the estimated results for the two appliances previously discussed. The coefficients for family size, household age, income variables, home ownership, mobile homes, and electricity price are statistically significant in the equation for adoption of ENERGY STAR. Once again, income and home ownership are important determinants of adoption. Also, households in mobile homes are less likely to use ENERGY STAR clothes washers. As in the case of dishwashers, the positive link between the likelihood of adoption of ENERGY STAR clothes washers and homes built after 2000 is not statistically significant.

Unlike in the refrigerator case, the negative association between the Hispanic head of household and the likelihood of adoption is not significant. Also, ownership is an important determinant in the knowledge equation, and the link between the knowledge of ENERGY STAR and this explanatory variable is significantly positive, suggesting that households who own their homes are more likely to have knowledge about ENERGY STAR clothes washers.

As in the case of dishwashers, the negative association between the likelihood of knowledge and householders' high school or lower level of education is statistically significant. Race does not appear to be a significant determinant in the knowledge equation. Households in the South or West Census regions are more likely to be informed of ENERGY STAR clothes washers. Also, the correlation between error terms is highly significant, which suggests that important differences exist between households who do and those who do not adopt ENERGY STAR clothes washers.

### Table 4. Joint maximum likelihood estimates for clothes washers

| Explanatory Variables | Estimation of Home Ownership | | Knowledge of ENERGY STAR | | Use of ENERGY STAR | | |
|---|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | Coefficient | Standard Error | Coefficient | Standard Error | Marginal Effects |
| Constant | -0.195 | 0.166 | 1.143*** | 0.195 | -0.404*** | 0.155 | |
| NHSLDMEM | 0.020 | 0.015 | 0.004 | 0.016 | 0.059*** | 0.012 | 0.022 |
| HHEAD | -0.009 | 0.044 | 0.004 | 0.041 | -0.043 | 0.033 | |
| HHAGE | 0.029*** | 0.002 | -0.003** | 0.002 | 0.002** | 0.001 | 0.001 |
| EDHIGH | -0.193*** | 0.045 | -0.111** | 0.051 | -0.093** | 0.043 | |
| HISPANIC | -0.167*** | 0.057 | 0.121 | 0.075 | -0.075 | 0.054 | |
| BLACK | -0.395*** | 0.067 | -0.023 | 0.073 | -0.005 | 0.058 | |
| HIGHINCOME | 0.455*** | 0.049 | 0.013 | 0.055 | 0.162*** | 0.040 | 0.062 |
| POVERTY100 | -0.451*** | 0.079 | -0.024 | 0.099 | -0.236*** | 0.071 | -0.092 |
| OWNHAT | | | 0.264* | 0.157 | 0.341*** | 0.116 | 0.134 |
| BUILT2000 | 0.284*** | 0.062 | -0.103 | 0.067 | 0.01 | 0.044 | |
| MOBHOME | 0.089 | 0.090 | -0.167* | 0.097 | -0.299*** | 0.090 | 0.004 |
| APT | -1.740*** | 0.070 | 0.076 | 0.156 | -0.082 | 0.110 | |
| ELPRICE | | | | | 0.014*** | 0.005 | 0.005 |
| EMPLOYED | 0.138*** | 0.053 | | | | | |
| SOUTH | -0.167*** | 0.063 | 0.240*** | 0.080 | | | |
| MIDWEST | -0.011 | 0.079 | 0.0001 | 0.076 | | | |
| WEST | -0.393*** | 0.072 | 0.261*** | 0.076 | | | |
| ρ[b] | | | | | 0.942*** | | |
| Log Likelihood | -2,638 | | | | -6,347 | | |
| Number of observations | 7,365 | | | | | | |

Notes: The Northeast region is omitted from the models and serves as a baseline.

[a] Predicted value of ownership (OWN).

[b] Correlation between the error terms.

* **Significant at the 1% level.

**Significant at the 5% level.

* Significant at the 10% level.

Source: U.S. Energy Information Administration, RECS 2009.

## 6. Summary

The main objective of this study is to examine the determinants for use of ENERGY STAR refrigerators, clothes washers, and dishwashers. The estimated results reveal that there are differences between households who choose and those who do not choose ENERGY STAR appliances for the cases of refrigerators and clothes washers, as indicated by the statistically significant coefficients of λ. The estimated equations reveal several interesting relationships. Income and electricity prices are positively related to the decision to use ENERGY STAR for all appliances in the study. The likelihood of use is higher among older and wealthier households and those with higher energy prices. Lower level of education significantly negatively influences the decision to use ENERGY STAR refrigerators and clothes washers. The effects of differences in race are significant for adoption in the equation for refrigerators but not in those for use of clothes washers or dishwashers. Mobile home residence is negatively related to the propensity to use ENERGY STAR in all three cases. The most consistent indicators of the probability of adopting any of the ENEGY STAR appliances studied are family size, age of head of household, income, owner-occupancy, and mobile home residence.

Comparison of the joint maximum likelihood estimates with the Heckman estimates (presented in Appendix A) reveals differences in the estimated coefficients. Both methods of estimation show strong evidence of sample selection bias for the estimated propensity to use refrigerators and clothes washers. In general, the absolute values of coefficients are different and standard errors are higher for these cases in the Heckman method.

# 7. Appendix A. Estimation results for Heckman Method

## Table A1. Probit maximum likelihood estimates, Heckman method for refrigerators

| Explanatory Variables | Estimation of Home Ownership | | Knowledge of ENERGY STAR | | Use of ENERGY STAR | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | Coefficient | Standard Error | Coefficient | Standard Error |
| CONSTANT | -0.236* | 0.142 | 1.475*** | 0.185 | -0.198 | 0.167 |
| NHSLDMEM | 0.029** | 0.014 | 0.009 | 0.014 | 0.050*** | 0.012 |
| HHEAD | -0.051 | 0.037 | -0.066 | 0.044 | 0.007 | 0.037 |
| HHAGE | 0.026*** | 0.002 | -0.002 | 0.001 | 0.009*** | 0.001 |
| EDHIGH | -0.241*** | 0.046 | -0.026 | 0.046 | -0.059 | 0.040 |
| HISPANIC | -0.174 | 0.055 | 0.177*** | 0.061 | -0.223** | 0.065 |
| BLACK | -0.426 | 0.060 | 0.115* | 0.066 | -0.003 | 0.060 |
| HIGHINCOME | 0.529*** | 0.044 | 0.099* | 0.053 | 0.184*** | 0.048 |
| POVERTY100 | -0.436*** | 0.060 | -0.059 | 0.060 | -0.185*** | 0.055 |
| OWNHAT[a] | | | 0.021 | 0.148 | 0.298*** | 0.109 |
| BUILT2000 | 0.326*** | 0.061 | -0.022 | 0.059 | 0.146*** | 0.044 |
| MOBHOME | 0.070 | 0.110 | 0.014 | 0.111 | -0.379*** | 0.082 |
| APT | -2.006*** | 0.063 | -0.309** | 0.145 | -0.087 | 0.130 |
| ELPRICE | | | | | 0.017*** | 0.004 |
| EMPLOYED | 0.130** | 0.053 | | | | |
| SOUTH | -0.043 | 0.061 | -0.143 | 0.074 | | |
| MIDWEST | 0.067 | 0.081 | -0.210* | 0.080 | | |
| WEST | -0.283*** | 0.069 | 0.022 | 0.077 | | |
| λ[b] | | | | | -2.207*** | |
| Log Likelihood | -3,202 | | -2,965 | | -4,913 | |
| Number of Observations | 8,889 | | | | | |

Notes: The Northeast region is omitted from the models and serves as a baseline.

[a] Predicted value of ownership (OWN).

[b] Correlation between the error terms.

* **Significant at the 1% level.

**Significant at the 5% level.

* Significant at the 10% level.

Source: U.S. Energy Information Administration, RECS 2009.

## Table A2. Probit maximum likelihood estimates, Heckman method for dishwashers

| Explanatory Variables | Estimation of Home Ownership | | Knowledge of ENERGY STAR | | Use of ENERGY STAR | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | Coefficient | Standard Error | Coefficient | Standard Error |
| Constant | 0.043 | 0.199 | 1.564*** | 0.220 | -0.461 | 0.283 |
| NHSLDMEM | 0.008 | 0.019 | 0.007 | 0.021 | 0.047** | 0.020 |
| HEAD | 0.024 | 0.050 | -0.143*** | 0.050 | -0.024 | 0.089 |
| HHAGE | 0.028*** | 0.002 | -0.002 | 0.002 | 0.010*** | 0.002 |
| EDHIGH | -0.203*** | 0.060 | -0.170** | 0.067 | -0.032 | 0.114 |
| HISPANIC | -0.200*** | 0.088 | 0.118 | 0.106 | -0.158 | 0.103 |
| BLACK | -0.461*** | 0.090 | -0.008 | 0.087 | 0.009 | 0.079 |
| INCOMEGE80 | 0.462*** | 0.069 | 0.002 | 0.053 | 0.315*** | 0.048 |
| POVERTY100 | -0.452*** | 0.093 | -0.077 | 0.096 | -0.149 | 0.104 |
| OWNHAT[a] | | | -0.079 | 0.211 | 0.347** | 0.179 |
| BUILT2000 | 0.201*** | 0.076 | -0.083 | 0.056 | 0.075 | 0.071 |
| MOBILE | 0.389*** | 0.197 | 0.001 | 0.173 | -0.345*** | 0.139 |
| APT | -1.925*** | 0.092 | -0.279 | 0.189 | -0.278 | 0.236 |
| ELPRICE | | | | | 0.022*** | 0.008 |
| EMPLOYED | 0.098 | 0.072 | | | | |
| SOUTH | -0.194** | 0.100 | -0.031 | 0.073 | | |
| MIDWEST | -0.013 | 0.129 | -0.108 | 0.074 | | |
| WEST | -0.463*** | 0.106 | -0.006 | 0.070 | | |
| λ[b] | | | | | -1.473 | |
| Log Likelihood | -1,603 | | -1,929 | | -2,780 | |
| Number of Observations | 5,315 | | | | | |

Notes: The Northeast region is omitted from the models and serves as a baseline.

[a] Predicted value of ownership (OWN).

[b] Correlation between the error terms.

* ** Significant at the 1% level.

**Significant at the 5% level.

* Significant at the 10% level.

Source: U.S. Energy Information Administration, RECS 2009.

## Table A3. Probit maximum likelihood estimates, Heckman method for clothes washers

| Explanatory Variables | Estimation of Home Ownership | | Knowledge of ENERGY STAR | | Use of ENERGY STAR | |
|---|---|---|---|---|---|---|
| | Coefficient | Standard Error | Coefficient | Standard Error | Coefficient | Standard Error |
| Constant | -0.195 | 0.166 | 1.29*** | 0.208 | -0.833*** | 0.214 |
| NHSLDMEM | 0.020 | 0.015 | 0.002 | 0.017 | 0.071*** | 0.012 |
| HHEAD | -0.009 | 0.044 | -0.003 | 0.042 | -0.054 | 0.037 |
| HHAGE | 0.029*** | 0.002 | -0.004** | 0.002 | 0.001 | 0.001 |
| EDHIGH | -0.193*** | 0.045 | -0.108** | 0.050 | -0.157*** | 0.052 |
| HISPANIC | -0.167*** | 0.057 | 0.115 | 0.075 | -0.024 | 0.067 |
| BLACK | -0.395*** | 0.067 | -0.014 | 0.073 | -0.005 | 0.064 |
| HIGHINCOME | 0.455*** | 0.049 | 0.005 | 0.056 | 0.195*** | 0.043 |
| POVERTY100 | -0.451*** | 0.079 | -0.031 | 0.100 | -0.283*** | 0.077 |
| OWNHAT | | | 0.265* | 0.162 | 0.490*** | 0.132 |
| BUILT2000 | 0.284*** | 0.062 | -0.086 | 0.068 | -0.011 | 0.051 |
| MOBHOME | 0.089 | 0.090 | -0.163* | 0.097 | -0.409*** | 0.108 |
| APT | -1.740*** | 0.070 | 0.070 | 0.162 | -0.077 | 0.117 |
| ELPRICE | | | | | 0.016*** | 0.005 |
| EMPLOYED | 0.138*** | 0.053 | | | | |
| SOUTH | -0.167*** | 0.063 | 0.182** | 0.084 | | |
| MIDWEST | -0.011 | 0.079 | -0.016 | 0.081 | | |
| WEST | -0.393*** | 0.072 | 0.209** | 0.084 | | |
| λ [b] | | | | | 2.688*** | |
| Log Likelihood | -2,638 | | -2,290 | | -4,059 | |
| Number of Observations | 7,365 | | | | | |

Notes: The Northeast region is omitted from the models and serves as a baseline.
[a] Predicted value of ownership (OWN).
[b] Correlation between the error terms.
* **Significant at the 1% level.
**Significant at the 5% level.
* Significant at the 10% level.
Source: U.S. Energy Information Administration, RECS 2009.

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