Label it and they will buy? The case of energy efficient class-A appliances

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Abstract

The EU appliance energy consumption labelling scheme is a key component of efforts to increase the diffusion of energy-efficient household appliances. In this paper, the determinants of consumer knowledge of the energy label for house-hold appliances and the choice of class-A energy-efficient appliances are jointly estimated using data from a large survey of more than 20,235 German households. The results for five major appliances suggest that lack of knowledge of the energy label can generate considerable bias in both estimates of rates of uptake of class-A appliances and in estimates of the underlying determinants of choice of class-A appliance. Simulations of the choice to purchase a class-A appliance, given knowledge of the labelling framework, reveal that residence characteristics and, in several cases, regional electricity prices strongly increase the propensity to purchase a class-A appliance, but socio-economic characteristics have surprisingly little impact on appliance energy-class choice.

Introduction

Major household appliances account for 35 percent of total EU 15 residential end-use electricity consumption (Bertoldi and Atanasiu, 2007). Refrigerators and freezers alone account for 15 percent of residential electricity end-use, with washing machines accounting for 4 percent and dishwashers, electric ovens, and clothes dryers accounting for approximately 2 percent of total residential end-use, apiece. The remainder mostly goes into residential electric heating (22 percent), lighting (12 percent), storage water heating (9 percent) and consumer electronics (9 percent). Increasing the energy efficiency of appliances is crucial for realizing the European Council Action Plan for Energy Efficiency target of 27 percent residential energy-savings compared to expected baseline growth by 2020 using cost-effective technologies (European Council, 2006). The EU appliance energy consumption labelling scheme has been a key component of past efforts to increase the diffusion of energy-efficient appliances (Bertoldi and Atanasiu, 2007). Labelling schemes are often promoted as a cost-effective measure to over-come barriers related to information and search costs, or to bounded rationality on the part of appliance purchasers (e.g. Sutherland, 1991). In this case, the labelling scheme is designed to make consumers aware of the relative energy-efficiency of appliances and associated potential cost savings through the provision of observable, uniform, and credible standards (e.g. Truffer et al., 2001). Evaluation studies based on aggregate observed data typically find that the existing energy labelling programs for household appliances in the EU, the US or Australia are effective in terms of energy and carbon reductions (e.g. Sanchez et al., 2008; Lane et al., 2007, Banerjee and Solomon, 2003; Schiellerup, 2002; Bertoldi, 1999; Waide, 2001; Waide, 1998). Conducting survey-based conjoint analyses to explore consumers' stated choices for washing machines in Switzerland, Sammer and Wüstenhagen (2006) also find that eco-labelling affects consumers' purchasing decisions. However, existing studies based on observed behaviour do not explore the socio-economic or technology-related factors behind consumers' choices.

The effectiveness of the energy labelling scheme in terms of affecting consumer's technology choice depends on two outcomes. First, consumers have to be aware of the classification system. Second, the labelling scheme has to influence consumer purchase decisions. In this paper we empirically explore both the determinants influencing consumer knowledge of the EU energy labels for major kitchen and clothes washing appliances and the factors that affect consumer choice of class-A appliances. Hence, while the data set available does not allow to address the effectiveness of the labelling scheme, it provides an important snap-shot of factors associated with knowledge of the labelling scheme and purchase of class-A appliances. The econometric analyses of household appliance choices account for a possible selection bias which results from the fact that only households who are aware of the energy labelling scheme may respond to survey questions on the energy class of the appliance.

Study framework

The econometric analyses are based on a unique data set of more than 20,000 households in Germany. In the survey we use, many respondents did not report the energy class of their appliances. One possible "solution" would be to confine the analyses of adoption of energy-efficient appliances to those households which reported the appliance energy class. However, positive responders may have different observed and unobserved attributes, particularly with respect to awareness of energy use and concerns about environmental impacts. Hence, the analysis of determinants of consumer choice of energy-efficient appliances is potentially subject to serious knowledge-based selection bias when it is based on only households who respond to survey questions on the energy class of the appliance. Specifically, parameter estimates of the determinants of class-A energy efficient appliances may be biased. One way to control for this knowledge-based sample selection bias is to jointly estimate the determinants of class-A appliance choice and the determinants of knowledge of the energy class of the appliance (e.g. van de Ven and van Praag, 1981).

STATISTICAL MODEL

Formally, the implicit relationship between household attributes and choice of a class-A appliance is:

$$y_i^* = x_i B + u_{1i} \tag{1}$$

where y_i^* is a latent measure of household preferences for the class-A appliance, x_i is a row vector of household i characteristics, B is the parameter vector to be estimated, and u_{1i} is a residual term. The observed outcome is:

$$\begin{aligned} y_i &= 1 \quad \text{if} \quad y_i^* > 0 \\ y_i &= 0 \quad \text{if} \quad y_i^* \le 0 \end{aligned} \tag{2}$$

However information on the purchase decision is only available if the energy-class of the appliance is reported by the respondent. Respondent latent knowledge of appliance energy class is modelled as:

$$s_i^* = z_i \Gamma + u_{2i} \tag{3}$$

where s_i^* is a latent measure of household knowledge of the appliance classification, z_i is a row vector of household i characteristics, Γ is the parameter vector to be estimated, and is u_{2i} a residual. Observed response to the survey question on energy-class on the appliance is:

$$\begin{aligned} s_i &= 1 \quad \text{if} \quad s_i^* > 0 \\ s_i &= 0 \quad \text{if} \quad s_i^* \le 0 \end{aligned} \tag{4}$$

Estimation of class-A energy-efficient appliance choice with the sub-sample of respondents who provide a response on appliance energy class is equivalent to:

$$E(y_i^*) = x_i B + E(u_{1i} \mid x_i, s^* \ge 0) \tag{5}$$

Assume $u_1 \sim N(0,1),\ u_2 \sim N(0,1),$ and $\rho = \text{corr}(u_1, u_2)$, then

$$\begin{aligned} &E(u_{1i} \mid x_i, s^* \ge 0) = \rho \lambda_i \\ &\text{where } \lambda_i = \theta(z_i\Gamma) / \Theta(z_i\Gamma) \end{aligned} \tag{6}$$

λ_i is the inverse of the Mills ratio, i.e. the ratio of the normal density function $\theta(.)$ over the cumulative distribution function $\Theta(.)$.

If the error terms of the energy-class choice equation and the energy-class knowledge equation are correlated then $E(u_1) \ne 0$ and the regression results will be biased. Maximum likelihood estimations are applied to estimate the product of the bivariate normal distribution $F_2(u_1, u_2)$ and the probability of sample exclusion $F(u_2)$:

$$\prod_{i=1}^{N_1} F_2(x_i B, z_i\Gamma; \rho) \prod_{i=N_1+1}^{N} F_2(-x_i B, z_i\Gamma; \rho) \prod_{i=N+1}^{M} F(-z_i\Gamma) \tag{7}$$

where 1 to N_1 are observations for which the energy-class of the appliance is known and a class-A appliance is chosen, N_1+1 to N are observations for which the energy-class of the appliance is known and a class-A appliance is not chosen, and N_1+1 to M are observations for which the energy class of the appliance is not known.

MODEL SPECIFICATION AND DATA

Knowledge of the energy labelling scheme is measured by household responses on the question of the energy-efficiency class of their household appliance. However, there is no way to verify, that responses were actually correct. Respondents who indicate that they own a certain type of appliance but do not provide a labelling scheme classification of between A and G on the questionnaire are categorized as unaware of the energy-rating of the appliance.

Residence characteristics

Residence characteristics may influence both the knowledge of labelling scheme and the choice of class-A appliances. In the empirical model, particular attention is paid to the age of the residence. For example, households living in residences built after 1997 are much more likely to have purchased an appliance after the official implementation of the energy-labelling scheme in the beginning of January 1998 in Germany and, thus, to have been exposed to the labelling scheme when purchasing the appliance. Discrete indicators for residences built in 2002, 2001, 2000, 1998-1999, 1996-1997, 1993-1995, 1990-1992, and 1985-1989 are included in the knowledge of energy-class specification. New detached residences may be especially likely to be equipped with new kitchen and laundry appliances, therefore a separate indicator for detached residences built after 1997 is also included in the knowledge of energy-class specification. Age of the appliance could not be included, because the survey did not ask for it.

Renting, rather than owning, a residence has been found in a number of previous studies to inhibit the adoption of energy-saving technologies, as it is difficult for residence owners to appropriate the savings from investments in energy-saving technologies from tenants. Households with larger residences (as measured by floor space) have on average more appliances and higher levels of energy consumption and hence are likely to have greater interest in, and knowledge of, household energy consumption and consumption saving technologies.

Household characteristics

Characteristics of the household included in both the knowledge of energy class and class-A purchase equation specifications include family size and if children under six years of age are present. The intensity of use of major appliances increases with the number of persons in the household, making it more profitable to both acquire information on the energy class of appliances and to purchase class-A appliances. A quadratic specification of age of the main household income earner is also included in both equation specifications. Older household heads may find it more difficult to process information on new technologies, or they may be less likely to have recently purchased a new appliance. On the other hand older household heads may have lower level of knowledge of energy efficient technologies, weaker preferences for state-of-the-art technologies, weaker preferences for environmental preservation, and lower propensities to carry out energy efficiency improvements. An indicator for retired heads of households is also included in both specifications. Retirees may have more freetime for shopping and, therefore, potentially greater awareness of the attributes of appliances after controlling for age (Aguiar and Hurst, 2007). The level of education is included because it may affect the costs of information acquisition, the ability to trade off investment costs versus energy-costs over an appliance's life cycle. Likewise, attitudes towards the environment and association in social groups disposed to environmentally friendly behaviour also tend to be positively related with education (e.g. Lutzenhiser, 1993; Weber and Perrels, 2000). The impact of a household head's management position on consumer knowledge of appliance energy classes is unclear a priori. On the one hand, senior managers and skilled professional may better understand information on appliance energy classes. On the other hand, the higher opportunity cost of time of this group of workers may reduce their willingness to invest in information. Class-A appliance choice may also be influenced by job type if senior managers and skilled professional are better able to calculate the potential profitability class-A appliances. Household income is expected to have positive impact on energy-saving investments because richer households are less likely to face income or credit constraints and because environmental concerns and awareness may increase with income (Fransson and Garling, 1999). Similarly, the propensity to purchase class-A appliances may increase with income levels because the income elasticity of willingness to pay for environmental benefits is positive (Kriström and Riera, 1996). An indicator of whether the household resides in East Germany is also included in the specification. Regional power prices are included in both the knowledge of class and class-A choice specifications, as higher electricity prices may in-crease energy awareness and the value of investing in information on energy-saving technologies and also generate greater incentives for the purchase of class-A appliances. Owning more than one of the same type of appliance may also be an indicator for more recent purchase of that appliance type and, thus, positively associated with knowledge of energy class. Similarly, the market in Germany has trended away from the purchase of separate refrigerators and freezers toward combination units, implying refrigerators and freezers in households that also own a combination unit may be older. For refrigerators and freezers an indicator is included for concurrent ownership of a combination unit, while for combination refrigerator-freezer units, an indicator is included for concurrent ownership of a refrigerator or freezer. An indicator of household personal computer ownership is included in both the knowledge of energy class and class-A choice specifications, serving as a proxy for ease of information access and receptivity to new technology. Also, an indicator of ownership of a class-A appliance of another type is included in the class-A choice equation specification, but not the knowledge of class specification, as the propensity to purchase class-A appliances may be strongly correlated across appliance types. Two variables with expected positive correlations with awareness of appliance energy class are included in the knowledge of class specification, but not in the class-A choice equation. The first variable is an indicator for household provision of information on annual electricity consumption that proxies for household awareness of energy use. The second variable is the share of other households in the same region with knowledge of the appliance energy class as a proxy for potential regional spill-overs in energy class awareness resulting, for example, from regional information campaigns by state energy agencies, retailers, or consumer groups.

DATA

The dataset comes from a mail survey of private sector household energy consumption conducted in December of 2002 as part of a multi-topic survey of an existing representative panel of German households (Schlomann et al., 2004). Overall, 20,235 households (75 percent) responded to the mailed questionnaire. The sample sizes for households that own the appliance being analyzed and supply information on all covariates are 15,526 households for refrigerators, 12,943 households for freezers, 6,993 households for refrigerator – freezer combination units, 12,814 households for dishwashers, and 19,014 households with washing machines. Knowledge of appliance energy class is low for all appliance types, ranging from 24 percent for households with a washing machine to 16 percent for households with a dishwasher. By comparison, among those households who know the energy class of the appliance, washing machines show the highest rate of class-A purchases at 65 percent, while refrigerators have the lowest rate of class-A purchases at about 54 percent. As discussed, observed and unobserved heterogeneity between those who know and those who do not know the appliance energy class suggests that these rates of class-A purchase may not be representative of expected rates of purchase for the whole sample. It is worth noting that the level of knowledge generally increases with the length of time since the EU implementation directive on the energy-efficiency classification scheme for the appliance, with the implementation directive for washing machines put in place in Germany in 1995 and the directive for dish washers implemented in 1999. Lack of purchase of an appliance after the implementation of the energy classification scheme is obviously an important factor in the observed low-levels of knowledge of the energy-class of household appliances. Given the typical lifespan of appliances of around ten to twelve years approximately one-third to one-half of households can be expected to have replaced an appliance due to the end of its lifespan in the period from the beginning of 1998 when energy-efficiency classification schemes were officially implemented for most appliances in German and the time of the survey at the end of 2002. Descriptive statistics further reveal that combination refrigerator-freezer units tend to be more prevalent in recently built residences than are separate refrigerator and freezer units, confirming the recent market trend towards combination units. However, residences with combination units also tend to be smaller than those with separate refrigerator and freezer units, suggesting combination unit purchase decisions may be partly motivated by space considerations. Finally, dishwashers appear to be luxury items, as they are disproportionately present in more educated and higher income households relative to other appliances in the study.

Results

ESTIMATION RESULTS FOR KNOWLEDGE OF ENERGY CLASS AND CLASS-A CHOICE EQUATIONS

Parameter estimates for the knowledge of energy class equation and class-A choice equation are presented in table 1. While the results cannot be discussed in detail, a couple of general points are worth mentioning. Overall, there are fewer statistically significant associations in the class-A choice equations than in the knowledge of energy class equations. In general, the statistically significant parameter estimates tend to exhibit the expected signs. Further, knowledge of energy class is typically higher in newer residences, in richer households, in retiree households, in rental residences and if power consumption is known. As expected, knowledge of energy class also increases with higher regional power prices. The finding that younger houses tend to be associated with higher probability of knowing the energy class and of purchasing class-A appliances is consistent with the observation that the market for high efficiency products in the EU has grown significantly since the labelling program. Finally, the correlation coefficient for the knowledge of energy class and class-A appliance choice equations (rho) is statistically significant in two of the five cases. Hence, failing to ac-count for the selection bias caused by the lacking knowledge of the labelling scheme would result in biased estimates for the washing machines and refrigerators equations.

RESULTS FOR SIMULATIONS

The economic impacts of major statistically significant factors are highlighted through the series of simulations that are presented in table 2. The first row of the table shows descriptive statistics from the data on the probability that households know the energy class of the appliance and the probability of choosing a class-A appliance, given that the energy class is known. The second row then presents the results of a benchmark simulation, where the averages of the probability of knowing the energy class and the probability of choosing a class-A appliance, given that the energy class is known, are calculated for each observation based on all parameter estimates. The average calculated probabilities of knowing the energy class of the appliance are, as expected, the same as in the data descriptive statistics. However, the simulated conditional probabilities of class-A appliance choice represent the expected rate of class-A appliance choice across the whole sample, not just those who are observed to know the energy class of the appliance. These simulated conditional probabilities are lower than those found in the baseline data for all appliances. This difference stems from the fact that sample households which do not know the appliance energy class have differences in characteristics which make them less likely to choose class-A appliances than those households which know the energy class of the appliance. Thus, inference of rates of class-A energy appliance adoption from the sample of survey responders provides upwardly biased estimates of expected rates of class-A appliance purchase for the general population. The rest of the simulations focus on the impacts that changes in individual variables have on the expected probabilities of knowing the appliance class and choosing a class-A appliance for the general population. Thus, the correct reference point for each of these changes is the benchmark simulation. The first case considers the impact of new housing stock, with all residences simulated as being built in 2002. For all appliances the probability of knowing the energy class increases when residences are built in 2002. As new housing is a rough proxy for new appliance purchase, the results highlight the fact that responses to the EU labelling scheme will only occur slowly as the stock of appliances is gradually renewed as older appliances reach the end of their lifecycle. The impact of new residences on the conditional probability of choosing class-A appliances is mixed, but in all cases the unconditional probability of observing a class-A appliance (based on the product of the probability of knowing the appliance energy class and the conditional choice of a class-A appliance) increases in the new housing stock simulations.

The impact of the 15.4 percent increases in real electricity prices that occurred in Germany between 2002 and 2007 is simulated by increasing regional electricity prices. In all cases, except combination units where parameter estimates are not statistically significant, increases in regional electricity prices generate a strong increase in the probability of knowing the energy class of the appliance in response to economic incentive.

For appliances with significant income parameter estimates, increasing incomes of every household by one income class, equivalent to 250 Euro per month, has little impact on either the probability of knowing the energy class of the appliance or the conditional probability of choosing a class-A appliance. Thus, rates of adoption of energy-efficient appliances are unlikely to be greatly enhanced by widespread increases in levels

Table 1: Estimates of Choice of Energy-Saving with Knowledge-Based Selection

		Refrigerator				Freezer				Refrigerator - Freezer Combination				Dishwasher				Washing Machine			
		Know Class		Class-A		Know Class		Class-A		Know Class		Class-A		Know Class		Class-A		Know Class		Class-A	
		Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
Rent residence	yes = 1	0.053 *	0.030	0.087 *	0.053	0.020	0.032	-0.101	0.064	0.086 **	0.043	0.099	0.086	0.145 **	0.033	0.191 **	0.068	0.059 **	0.025	-0.028	0.047
Floor space	residence m^2	0.001 *	0.000	0.001 *	0.001	0.000	0.000	0.002 **	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.002 *	0.001	0.000	0.000	0.001	0.001
Residence built:	(base = built pre-1985)																				
2002	yes = 1	0.494 **	0.186	0.309	0.281	0.620 **	0.198	0.011	0.340	0.293	0.244	0.990 *	0.553	0.593 **	0.166	0.367	0.308	0.449 **	0.152	0.122	0.232
2001	yes = 1	0.352 **	0.149	0.247	0.229	0.202	0.160	0.000	0.292	0.354 *	0.182	0.332	0.312	0.242 *	0.139	-0.189	0.271	0.282 **	0.124	0.023	0.193
2000	yes = 1	0.398 **	0.125	0.500 **	0.193	0.372 **	0.133	0.030	0.243	0.370 **	0.166	0.027	0.298	0.335 **	0.120	0.264	0.227	0.258 **	0.107	-0.037	0.172
1998-1999	yes = 1	0.088	0.089	-0.053	0.147	0.200 **	0.095	0.004	0.174	-0.072	0.121	0.144	0.231	0.149 *	0.088	0.102	0.167	0.080	0.074	-0.062	0.118
1996-1997	yes = 1	0.002	0.084	-0.053	0.141	0.030	0.090	-0.096	0.166	-0.065	0.107	0.150	0.204	0.027	0.083	-0.185	0.159	0.021	0.067	-0.013	0.108
1993-1995	yes = 1	-0.051	0.056	-0.054	0.096	0.020	0.059	0.156	0.113	-0.097	0.081	-0.019	0.162	-0.178 **	0.061	-0.148	0.130	-0.002	0.047	0.074	0.080
1990-1992	yes = 1	-0.186 **	0.068	-0.010	0.129	-0.146 **	0.071	0.011	0.147	-0.408 **	0.111	0.225	0.325	-0.189 **	0.072	-0.192	0.154	-0.173 **	0.057	0.002	0.110
1985-1989	yes = 1	-0.057	0.053	-0.145	0.094	-0.066	0.057	-0.023	0.114	-0.055	0.079	-0.036	0.148	0.011	0.057	0.111	0.115	-0.022	0.045	0.126	0.081
Post-1997 detached house	yes = 1	0.015	0.088	0.027	0.140	0.019	0.093	0.142	0.163	-0.028	0.120	-0.050	0.216	-0.045	0.086	0.033	0.160	0.003	0.073	0.035	0.114
Retiree	yes = 1	0.221 **	0.045	0.157 *	0.086	0.236 **	0.047	-0.050	0.119	0.216 **	0.066	0.019	0.163	0.272 **	0.053	-0.045	0.142	0.181 **	0.038	0.111	0.077
Number of persons	truncated at 5 persons	0.047 **	0.015	0.008	0.028	0.029 *	0.016	-0.023	0.032	0.025	0.022	-0.052	0.047	0.034 *	0.016	0.044	0.033	0.076 **	0.012	0.044 *	0.024
Children in household	under 6 years = 1	0.053	0.046	0.045	0.076	0.054	0.048	0.092	0.088	-0.005	0.066	0.145	0.119	0.027	0.047	-0.070	0.091	-0.019	0.039	-0.002	0.062
Age	age of main income earner	0.007	0.007	0.029 **	0.012	-0.002	0.008	0.019	0.015	0.001	0.009	-0.021	0.019	0.012	0.009	0.005	0.018	-0.004	0.006	0.003	0.010
Age^2		0.000 **	0.000	0.000 **	0.000	0.000 **	0.000	0.000	0.000	0.000 *	0.000	0.000	0.000	0.000 **	0.000	0.000	0.000	0.000 **	0.000	0.000	0.000
Secondary school	main income earner, yes=1	0.057 *	0.033	0.128 **	0.060	0.078 **	0.035	0.089	0.074	0.113 **	0.050	0.009	0.112	0.052	0.039	0.045	0.082	0.096 **	0.028	0.064	0.054
Management position	senior official, executive, skilled profession=1	-0.071 *	0.041	0.038	0.074	-0.073 *	0.044	-0.032	0.087	-0.065	0.061	-0.091	0.115	-0.032	0.043	0.081	0.088	-0.043	0.035	0.002	0.060
Income class	lowest = 1 and highest = 16	0.012 **	0.004	0.004	0.008	0.007 *	0.004	-0.009	0.009	0.006	0.006	-0.002	0.012	0.003	0.004	-0.001	0.009	0.009 **	0.003	0.012 **	0.006
East Germany	yes = 1	0.068	0.063	0.116	0.093	-0.025	0.074	0.060	0.123	0.226 **	0.076	-0.083	0.161	0.101 *	0.060	-0.154	0.125	0.063	0.055	-0.156 *	0.088
Regional power price	average electric price in Federal State (€cents/kWh)	17.307 **	4.257	3.757	7.900	23.912 **	5.525	-12.795	10.828	9.437	7.486	1.464	9.845	15.797 **	4.731	17.872 *	9.189	10.564 **	3.775	11.710 **	5.823
Own a PC	yes = 1	0.099 **	0.031	0.005	0.060	0.089 **	0.034	-0.100	0.075	0.104 **	0.045	0.052	0.093	0.080 **	0.037	-0.048	0.083	0.061 **	0.026	-0.059	0.051
Own more than one	appliance type	-0.039	0.033	-0.029	0.058	-0.003	0.041	0.016	0.083	0.087	0.092	0.539 **	0.181	0.016	0.140	0.004	0.288	-0.021	0.078	0.012	0.136
Also own Combination	for Refrigerators and Freezers	-0.075 **	0.032	-0.222 **	0.059	0.032	0.033	-0.006	0.065												
Also own Refrigerator or Freezer	for Combination									-0.147 **	0.039	-0.177 **	0.083								
Know power consumption	annual, yes=1	0.193 **	0.027			0.197 **	0.030			0.192 **	0.039			0.213 **	0.031			0.167 **	0.023		
Region class knowledge	share of households in Federal State	2.405 **	1.007			3.145 **	0.971			0.095	1.612			2.260 *	1.308			1.291 *	0.664		
Own other Class-A appliances	yes=1			0.606 **	0.109			0.629 **	0.071			0.580 **	0.110			0.754 **	0.111			0.567 **	0.082
Constant		-4.289 **	0.697	-2.777 **	1.333	-4.917 **	0.924	0.748	1.940	-2.391 **	1.109	-0.523	1.953	-4.032 **	0.724	-4.179 **	1.713	-2.550 **	0.543	-2.674 **	1.035
Rho		0.662 **	0.197			0.237	0.339			0.362	0.464			0.401	0.320			0.557 *	0.223		
Log-likelihood		-8550.1				-7597.3				-4288.4				-6687.8				-12742.5			
No. Observations		15,526				12,943				6,993				12,814				19,014			
No. Uncensored Observations		2,676				2,447				1,428				2,043				4,596			

Note: ** indicates significance at the p=0.05 level and * indicates significance at the p=0.10 level in a two-tailed t-test

Table 2: Simulations of Probability of Knowing Energy Class and Conditional Probability of Class-A Selection

	Refrigerators		Freezers		Combination Units		Dishwasher		Washing Machine	
	Prob. Know	Cond. Prob. Class-A	Prob. Know	Cond. Prob. Class-A	Prob. Know	Cond. Prob. Class-A	Prob. Know	Cond. Prob. Class-A	Prob. Know	Cond. Prob. Class-A
Descriptive statistic	0.172	0.543	0.189	0.551	0.204	0.562	0.159	0.596	0.242	0.649
Benchmark simulation	0.172	0.406	0.189	0.445	0.204	0.481	0.159	0.431	0.242	0.571
All new housing stock	0.321	0.439	0.388	0.429	0.294	0.797	0.329	0.516	0.391	0.545
15.4 percent electricity price increase	0.292	0.354	0.370	0.297			0.264	0.555	0.323	0.645
Income class increase	0.175	0.405	0.191	0.442					0.244	0.575
Universal secondary school	0.175	0.417	0.193	0.453	0.210	0.479			0.247	0.573
Universal knowledge of electricity bill	0.187	0.392	0.203	0.441	0.220	0.474	0.174	0.423	0.257	0.562
Universal ownership other class-A appliance		0.638		0.639		0.663		0.665		0.764

of economic well-being. Similarly, increased education, simulated by giving each household at least secondary school education, has little impact.

Increasing household energy awareness, simulated by assuming all house-holds know their annual electric bill, appears to generate limited increases in the probability of knowing the energy class of appliances. Since this variable is not included in the class-A energy choice equation, it only has an indirect negative impact on the conditional probability of class-A choice by increasing the weight given to households with relative low probabilities of class-A appliance purchase during the calculation of conditional probabilities of class-A purchase. Similarly, the indicator for ownership of other class-A appliances is only included in the class-A appliance choice equation. This simulation highlights the fact that the conditional probability of purchase of a class-A appliance increases strongly when households own other appliances with a class-A energy rating. The result, again, likely stem from the fact that there are unobserved factors that influence class-A appliance purchase common to all appliance types.

Discussion and conclusion

The results generate a number of implications for the refinement of energy-efficiency labelling schemes and other policies to promote the take up of energy efficient household appliances. Perhaps most obvious, given the relatively long average life of most major household appliance, the information provided in energy labels will diffuse very slowly into consumer purchase decisions. While proxies for recent appliance purchase are arguably noisy, the data provide evidence that for most appliances that conditional propensities to purchase class-A appliances increased rapidly between mandatory implementation for most appliances in the beginning of 1998 and the survey at the end of 2002. The portion of this shift motivated by increased supply of class-A appliance due to energy efficiency technology advances on the part of manufactures can not be separated from the portion due to increased demand for class-A appliances due to the EU labelling scheme with the current cross-sectional dataset. The results do suggest that consumers respond to economic incentives, as knowledge of energy classes increases with regional energy prices for most appliances. This finding suggests that policies that internalize the social costs of energy consumption will spur awareness and, therefore, adoption of energy efficient appliances. The finding also suggests that provision of economic information on the likely economic benefits of energy efficient appliances as currently discussed in the context of the revision of the labelling Directive can further influence purchase decisions. Increased awareness of household energy use and access to information through personal computers are also likely to influence consumer purchase decisions and should be incorporated into future energy classification scheme information awareness campaigns. Greater awareness of the potential contributions of energy-efficient appliances to household energy conservation will also increase the efficiency of tax and other policies to align marginal energy consumption decisions with marginal social costs. On the other hand, simulations based on model results suggest that household characteristics in the current dataset have surprisingly little impact on the purchase of energy efficient appliances. Yet, within households, the propensity to purchase class-A appliances is strongly correlated across appliance types. Further research is needed to identify the currently unobserved factors underlying these common purchase propensities, with particular attention paid to environ-mental attitudes, psychological factors and social norms. Incorporating these aspects would delineate the role of perceived environmental benefits in household energy-efficient appliance purchase decisions, and thus complement the economics-based approach presented in this paper.

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