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What's Driving Energy Efficient Appliance Label Awareness and Purchase Propensity?

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Abstract

The EU appliance energy consumption labeling 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 household appliances and the choice of class-A energy-efficient appliances are jointly estimated using data from a large survey of more than 20,000 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 labeling 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.

Table of Contents

Page

Tables

1 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 are responsible 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. Increasing the energy efficiency of these appliances is crucial for realizing energy efficiency policy objectives. For example, as part of the climate and energy package the EU is committed to curtail energy consumption by 20 percent compared to expected baseline growth by 2020 (European Commission, 2008). To achieve this target, the European Council Action Plan for Energy Efficiency foresees residential energy-savings of 27 percent using cost-effective technologies (European Council, 2006). Since its implementation in the 1990s the EU appliance energy consumption labeling scheme has been viewed as a key component of past efforts to increase the diffusion of energy-efficient appliances and is expected to contribute to the achievement of future targets (Bertoldi and Atanasiu, 2007).

Labeling schemes are often promoted as a cost-effective measure to overcome barriers related to information and search costs, or to bounded rationality on the part of appliance purchasers (Sutherland, 1991; Howarth et al., 2000). In this case, the labeling 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 labeling 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-labeling affects consumers' purchasing decisions. However, existing studies based on observed behavior do not explore the socio-economic or technology-related factors behind consumers' choices.

The generation of consumer information on appliance energy efficiency is, in turn, expected to create market incentives for appliance manufactures to design more energy-efficient products, and may reinforce price-induced technological innovation. For example, Newell et al. (1998) find that the mean energy efficiency of water heaters and air conditioners sold in the US rose significantly once a labeling scheme was introduced in 1975.

The effectiveness of the energy labeling 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 labeling 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. The econometric analyses are based on a unique data set of more than 20,000 households in Germany. Since only households who are aware of the energy labeling scheme may respond to survey questions on the energy class of the appliance, the analysis of determinants of consumer choice of energy-efficient appliances may suffer from knowledge-based selection bias. Thus, we jointly estimate the determinants of knowledge of the energy labeling scheme with the determinants of class-A appliance choice.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of the EU Energy Labeling Framework and its implementation in Germany. Section 3 presents the statistical model and the specification of factors potentially associated with both knowledge of appliance energy class and choice of class-A appliances. Study data are outlined in Section 4 and estimation results are presented and discussed in Section 5. Section 6 highlights the economic impacts of important factors through simulations. The paper then concludes by distilling implications for enhancing the adoption of energy-efficient appliances.

2 The Energy Labeling Framework

According to the EU Directive on Energy Labeling of Household Appliances ("Labeling Directive") (CEC, 1992) retail stores are obliged to provide certain household appliances with energy labels at the point of sale. The label includes standardized information on electricity consumption. Originally, the seven efficiency classes ranged from the green class-A label for the best performance to the red Class-G label for the worst performance. Implementing directives were published by the EU in 1994 for refrigerators, freezers and their combinations, in 1995 for washing machines, and in 1997 for dishwashers. After September 1999 new refrigerators with classes D to G and freezers with classes E to G were no longer allowed.

In Germany the Directive became national law effective in January 1998 for refrigerators, freezers, refrigerator – freezer combinations, and washing machines. The Directive became national law in March 1999 for dishwashers. While Germany was one of the last EU Member States where the "Labeling Directive" became national law, appliances with EU labels were present in the German market prior to 1998, largely because appliance manufacturers had to comply with the provisions of the directives in other EU Member States. However, even in Member States where the EU appliance scheme became national law early on, evaluations for refrigerators and freezers suggest that compliance with the labeling laws in the retail sector was rather poor, i.e. a large share of refrigerators and freezers were not correctly labeled (Winward et al., 1998). For Germany, Schlomann et al. (2001) find that the highest share of completely and correctly labeled large household appliances was found in large scale specialist stores or hypermarkets, while the level of compliance was generally poor in retail stores specializing in kitchen or furniture items.

EU-wide early evaluations on the effectiveness of the labeling scheme for refrigerators and freezers (Waide, 1998) and also for washing machines and wash-driers (Waide, 2001) conclude that the scheme was successful based on an observed increase in the market share of energy-efficient appliances. However, some portion of efficient appliance uptake almost certainly occurred independent of the incentives created by the labeling scheme. Since this counterfactual level of adoption cannot be determined, it is difficult to quantify the actual contribution of the scheme to the diffusion of energy-efficient appliance. The current data set also does not allow us to directly address the effectiveness of the labeling scheme, but the data does provide an important snap-shot of factors associated with knowledge of the labeling scheme and purchase of class-A appliances at the end of 2002, four years after official implementation of the labeling directive for most major appliances in Germany. To the best of our knowledge, the importance of such factors has not been previously documented with a large sample survey in any country.

3 Study Framework

Survey-based analyses often have to deal with missing data. 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).

3.1 Statistical model

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

$$y_i^* = x_i B + u_{1i} \qquad (1)$$

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:

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

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 modeled as:

$$s_i^* = z_i \Gamma + u_{2i} \qquad (3)$$

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 u_{2i} is a residual. Observed response to the survey question on energy-class on the appliance is:

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

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:

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

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

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

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 $E(u_1) \neq 0$ and the regression results will be biased. Unbiased parameter estimates can be recovered either by including $\hat{\lambda}_i$ as a predicted variable in the Probit energy-class choice equation as suggested by Heckman (1976) or more efficiently by maximum likelihood estimation of the bivariate normal distribution $F_2(u_1, u_2)$ and the probability of sample exclusion $F(u_2)$ underlying the data generating process as:

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

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. This maximum likelihood estimator is employed in the current application.

3.2 Model specification

Knowledge of the energy labeling scheme is measured by household responses on the question of the energy-efficiency class of their refrigerators, freezers, refrigerator and freezer combination units, dishwashers, and washing machines. Specifically, respondents who indicate that they own a certain type of appliance but do not provide a labeling 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 the labeling scheme and the choice of class-A appliances. In the empirical model, particular attention is paid to the age of the residence. Households living in residences built after 1997 are much more likely to have purchased a refrigerator, freezer, refrigerator-freezer combination unit, or a washing machine after the official implementation of the energy-labeling scheme for these appliances in the beginning of January 1998 and, thus, to have been exposed to the labeling scheme when purchasing the appliance. Similarly, households in residences built after 1998 are much more likely to have purchased a dishwasher after the official implementation of the energy-labeling scheme in March 1999. 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. The same set of indicators on the year of residence construction is also included in the class-A appliance choice specification. Households in more recently constructed residences may be more likely to purchase class-A appliances, as the share of appliances sold that are class-A has trended upward over time at the market level (Europe Economics, 2007).

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 (Jaffe and Stavins, 1994; Sutherland, 1996). This user-investor dilemma is likely to be particularly strong for energy saving measures requiring large capital investments (Black, Stern, and Elworth, 1985). However, in Germany the vast majority of tenants supply their own appliances and pay for electricity usage. Thus, the influence of tenancy on benefit appropriation may be rather limited for class-A appliances. Further, renters change residence more frequently than owners and may have purchased appliances more recently as a result. This increased propensity to have made a recent purchase would increase the likelihood of tenants knowing the energy class of appliances relative to residence owners.

Households with larger residences have on average more appliances and higher levels of energy consumption. As a result, larger residences are likely to have greater interest in, and knowledge of, household energy consumption and consumption saving technologies, particularly if the cost of information gathering is relatively fixed. Larger residences may also have greater incentives to invest in energy-saving technologies if appliance use is greater (Mills and Schleich, 2008; Walsh 1989). Thus residence size, as measured by floor space in square meters, is included as a variable in both the knowledge of energy class and choice of class-A appliance equation specifications.

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. However, existing empirical studies addressing the impact of household size on energy-saving investments provide mixed results. Curtis, Simpson-Housley, and Drever (1984) find that households with two to four members exhibit higher energy saving activity than other households, while Long (1993) finds a negative impact of household size on energy saving expenditures. In general, parents with children may be more concerned about short and long run local and global environmental effects (Dupont 2004). However, Torgler et al. (2008) find that the presence of children has no significant impact on parental environmental preferences. Children may also have a differential impact on appliance usage. The use of washing machines may be especially high in households with children under six years of age because they have disproportionately high laundry needs.

A quadratic specification of age of the main household income earner is also included in both equation specifications. Previous research suggests that older household heads have lower level of knowledge of energy efficient technologies, weaker preferences for state-of-the-art technologies, weaker preferences for environmental preservation, and generally lower propensities to carry out energy efficiency improvements (Linden, Carlsson-Kanyama, and Eriksson, 2006; Carlsson-Kanyama, Linden, and Eriksson, 2005; Torgler et al., 2008; Walsh, 1989). Elderly households may also be less likely to have recently purchased a new appliance, especially when compared to younger newly established families. An indicator for retired heads of households is also included in both specifications. Retirees may have more free-time for shopping and, therefore, potentially greater awareness of the attributes of appliances after controlling for age (Aguiar and Hurst, 2007). Whether retirees are more or less likely to purchase class-A appliances after controlling for other factors is left as an empirical question.

Higher education reduces the costs of information acquisition (Schultz, 1979), making it more likely that a person understands the class of an appliance when exposed to sticker information. Education may also be positively related to the purchase of energy-saving technologies (Hirst and Goeltz, 1982; Brechling and Smith, 1994; Scott, 1997), perhaps because education, as a long term investment, is correlated with a low household discount rate. Finally, attitudes towards the environment and association in social groups disposed to environmentally friendly behavior also tend to be positively related with education (e.g. Lutzenhiser, 1993; Weber and Perrels, 2000). Potential impacts of education are captured through a discrete indicator for secondary school attainment of the highest household income earner.

An indicator for households headed by senior officials, senior managers, or highly skilled professionals is also included in both the knowledge of class and class-A purchase equations. The influence of job type 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 typically found to have positive impact on energy-saving investments (Dillman, Rosa, and Dillman, 1983; Long, 1993; Walsh, 1989; Sardianou, 2007; Mills and Schleich, 2008). Further, environmental concerns and awareness may increase with income (Fransson and Garling, 1999), which would lead to greater knowledge of appliance energy classes. An indicator of whether the household resides in East Germany is also included in the specification, as that part of the country underwent rapid social change and residents may be disproportionately likely to have recently changed residence. East German residents have also been found to have generally lower levels of environmental awareness (BMU, 2004).

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, 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 spillovers in energy class awareness or regional differences in levels of awareness resulting from regional information campaigns by state energy agencies, retailers, or consumer groups. Finally, regional power prices are included in both the knowledge of class and class-A choice specifications, as higher electricity prices may increase 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.[1]

1 Regional power prices are based on the average prices for other survey households in the same Federal State. Calculations produced infeasible prices for a small share of households and Federal State averages are based on households with calculated prices in the Euro 0.10 to Euro 0.20 per kWh range.

4 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.

Table 1 provides figures on the share of households that were able to provide information on energy class for each appliance type, as well as the share of appliances which were of energy-class A. 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. 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 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. Specifically, the lifespan of appliances ranges from 9 years for dishwashers to 13 years for refrigerators (NAHB, 2007). Thus, 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.[2]

2 Formation of new households and purchases for reasons other than replacement of an existing unit will also increase the share of appliances purchased in the 1998 to 2002 period.

Table 1: Descriptive Statistics by Appliance Type

	Refrigerator		Freezer		Combination		Dishwasher		Washing Machines	
Description	Mean	St. Err.	Mean	St. Err.	Mean	St. Err.	Mean	St. Err.	Mean	St. Err.
yes = 1	0.172		0.189		0.204		0.159		0.242	
yes = 1	0.094		0.104		0.115		0.095		0.157	
residence m^2	104.152	44.601	110.504	43.850	95.499	42.318	112.212	43.189	101.236	43.031
(base = built pre-1985)										
yes = 1	0.004		0.004		0.005		0.005		0.004	
yes = 1	0.006		0.007		0.009		0.010		0.007	
yes = 1	0.009		0.010		0.011		0.013		0.009	
yes = 1	0.024		0.025		0.027		0.031		0.024	
yes = 1	0.026		0.028		0.032		0.034		0.029	
yes = 1	0.048		0.048		0.049		0.058		0.048	
yes = 1	0.036		0.037		0.034		0.042		0.034	
yes = 1	0.056		0.057		0.053		0.061		0.055	
yes = 1	0.038		0.043		0.039		0.053		0.038	
yes = 1	0.404		0.336		0.524		0.349		0.442	
yes = 1	0.329		0.338		0.306		0.267		0.331	
truncated at 5 persons	2.367	1.108	2.528	1.092	2.290	1.085	2.610	1.094	2.351	1.093
under 6 years = 1	0.092		0.101		0.099		0.126		0.095	
age of main income earner	52.417	14.932	53.087	14.184	51.166	15.184	50.430	13.657	52.400	14.933
main income earner, yes=1	0.757		0.752		0.784		0.807		0.764	
senior official, exec. or skilled professional=1	0.108		0.112		0.106		0.133		0.105	
lowest = 1 and highest = 16	8.735	3.868	9.109	3.785	8.574		9.607	3.716	8.653	3.828
yes = 1	0.175		0.170		0.250		0.161		0.208	
appliance type	0.196		0.120		0.038		0.010		0.018	
for Refrigerators and Freezers	0.183		0.191							
for Combination					0.524					
yes=1	0.203		0.218		0.216		0.249		0.176	
yes = 1	0.634		0.654		0.633		0.729		0.628	
annual, yes=1	0.693		0.715		0.685		0.701		0.698	
share of households in Federal State	0.133	0.016	0.123	0.016	0.076	0.031	0.101	0.013	0.231	0.037
average electric price in Federal State (€cents/kWh)	0.156	0.005	0.156	0.005	0.157	0.006	0.156	0.005	0.156	
	15526		12943		6993		12814		19014	

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 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.

Descriptive statistics for model covariates are also provided in table 1. The results are not discussed in detail, but a couple of differences in means across appliance types are worth noting. First, 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. Second, 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.

5 Results

Parameter estimates for the knowledge of energy class equation and class-A choice equation are presented in table 2 for all five appliances. The results are discussed separately by appliance type.

Refrigerators

As expected, a household's knowledge of the refrigerator's energy class is associated with several residence characteristics that proxy for recent purchase of an appliance. Specifically, renters and households living in residences built in 2002, 2001, or 2000 are more likely to know the energy class of the household's refrigerator.[3] The likelihood of knowing the energy class of the refrigerator is also higher for larger and rented residences (both at the $p=0.10$ level).

A number of household characteristics also influence knowledge of refrigerator energy class. Specifically, the likelihood of knowing the energy class increases with household size and with household income level. Knowledge of refrigerator energy class is also higher for households headed by a retiree and by a person with a secondary school or higher level of education ($p=0.10$ level). Younger households are also more likely to know the energy class of the refrigerator, as results indicate that the likelihood of knowing the appliance energy class peaks at 18 years of age and declines exponentially thereafter. The result, again, suggests that recent purchase due to new household formation plays a key role in awareness of the energy labeling scheme. Households with heads in senior management positions are less likely to know the energy class of the appliance ($p=0.10$). As mentioned, this result may stem from higher opportunity costs of gathering information.

Household knowledge of refrigerator energy class shows a strong positive response to higher regional energy prices. Ease of access to information and energy-use awareness also appear to be important. Knowledge of energy class is more likely when the household owns a personal computer, when the household knows its annual electric bill, and when the regional share of other households with knowledge of the energy class of their refrigerator is high. Knowledge of the energy class of the refrigerator is lower, however, if the household also owns a combination refrigerator – freezer unit. Again, as the market has trended towards combination units, concurrent ownership of a combination unit may im-

3 Discussed relationships are statistically significant at the p=0.05 level unless noted.

ply the refrigerator is older. Finally, the estimated correlation coefficient between the knowledge of refrigerator energy class and class-A choice equation error terms is positive and significant, implying parameter estimates generated from separate estimation of the class-A choice equation are likely to be biased.

Overall, there are fewer statistically significant associations in the class-A choice equation for refrigerators than in the knowledge of energy class equation. Renting rather than owning the residence increases the probability of class-A refrigerator purchase ($p=0.10$). The probability of class-A purchase also increases with the size of the residence ($p=0.10$). Parameter estimates for residences built in 2002, 2001, and 2000 are all positive, however only the year 2000 estimate is significant at conventional levels.

Turning to personal characteristics, households headed by retirees ($p=0.10$) and individuals with secondary school education are more likely to purchase class-A refrigerators. Households with middle-aged heads are also most likely to purchase class-A refrigerators, as in the quadratic specification of household head age the propensity for class-A purchase increases up to 48 years of age and then declines. Concurrent ownership of a combination refrigerator – freezer unit decreases the propensity for class-A refrigerator purchase. However, the propensity for class-A purchase increases strongly with the ownership of another type of appliance with a class-A energy efficiency rating. The significant influence of purchase of other class-A appliance likely implies that there are factors influencing the general propensity to purchase class-A appliances that are not fully captured in the current specification.

Freezers

The estimation results for knowledge of energy class of freezers are, for the most part, the same as for refrigerators; with recently built residences, retirees, size of household ($p=0.10$), age, schooling, income, regional electricity prices, knowledge of household electric bill, and regional rates of knowledge of freezer energy class playing important roles in freezer energy class awareness. Two differences in the freezer and refrigerator results are worth noting. First, tenancy status of residence and residence size do not influence knowledge of energy class for freezers. Second, the correlation coefficient for the knowledge of energy class and class-A appliance choice error terms is not statistically different from zero for freezers, implying unobserved heterogeneity in knowledge of appliance energy class may not be an important source of bias in the estimation of class-A appliance choice for freezers. Only two parameter estimates are significant in the class-A freezer choice equation. These are residence sizes and ownership of other types of class-A appliances, both of which show significant positive associations with the choice of class-A freezers.

Refrigerator-freezer combination units

Estimation results for knowledge of the combination refrigerator – freezer unit energy class are also similar to those for refrigerators. Renters, recently built residences, retirees, younger households (*p=0.10*), and households headed by someone with a secondary school or higher level of education are more likely to know the energy class of the combination unit. Owning a PC and knowing the household annual electrical bill also increases the probability of knowing the energy class of the combination unit. Several differences in the results when compared to refrigerators are worth noting. In the case of combination units, residence size, regional rates of household knowledge of energy class, and regional electricity prices do not influence knowledge of energy class. On the other hand, the probability of knowing the energy class of combination units is significantly higher in East Germany. The correlation coefficient for the error terms is also not significantly different from zero in the combination unit case. As with freezers, few parameter estimates are significant in the class-A choice equation for combination units. Households in residences built in 2002 are more likely to choose class-A units (*p=0.10*), as are those households who own more than one combination unit and who own another type of class-A appliance. Ownership of a separate refrigerator or freezer as well as a combination unit reduces the likelihood of owning a class-A combination unit.

Dishwashers

Covariates in the knowledge of dishwasher energy class equation largely show the same relationships as in the refrigerator model, with the following groups more likely to know the energy class of the dishwasher: renters, households in recently built residences, larger households (*p=0.10*), younger households, households headed by a retiree, households living in East Germany (*p=0.10*), and households owning a PC. High regional energy prices also increase knowledge of dishwasher energy class, as do household knowledge of its energy bill and high regional rates of knowledge of appliance energy class (*p=0.10*). The correlation coefficient for the model error terms is not statistically significant in this case.

Few parameter estimates in the choice of class-A dishwasher equation are statistically significant. The propensity to purchase class-A dishwashers is higher in rented residences and larger residences (*p=0.10*). High electricity prices also increase the propensity to purchase class-A dishwashers at the *p=0.10* level and, as usual, the propensity to purchase class-A dishwashers increases when the household owns another class-A appliance.

Washing machines

The results for the knowledge of the energy class of washing machines are largely consistent with those for other appliances. Households that rent the residence and households in more recently built residences are more likely to know the energy class of the washing machine, as are larger households, households headed by a retired individual, households headed by an individual with secondary school education, younger households, and households with higher levels of income. The likelihood of knowing the energy class of the washing machine also increases with higher regional power prices, knowledge of annual electricity bill by the household, and the regional share of households with knowledge of the energy class of their washing machine. The error terms' correlation coefficient estimate is also significant at the *p=0.10* level. Again, there are considerably fewer significant covariates in the choice of class-A dishwasher equation. Household income, regional power prices, and ownership of other class-A appliances are positively related to choice of a class-A washing machine. While the size of the household and residence in East German show a weak (*p=0.10*) positive relationship with class-A washing machine purchase.

Table 2: Estimates of Choice of Energy-Saving A-Class 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			

6 Simulations

The economic impacts of major statistically significant factors are highlighted through the series of simulations that are presented in table 3. The first row of the table presents 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. Notably, 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. In fact, rates of class-A appliance purchase for the general population will be between eight percentage points (for refrigerator – freezer combination units and washing machines) and sixteen percentage points (for dishwashers), lower than those observed in the sub-sample of survey responders that provide information on appliance energy class.

Table 3: 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

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 all residences are built in 2002. For refrigerators and dishwashers, the probability of knowing the appliance energy class more than doubles when compared to the benchmark simulation. As new housing is a rough proxy for new appliance purchase, the results highlight the fact that responses to the EU labeling 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. The conditional probability of class-A choice increases for refrigerators, combination units, and dishwashers. This suggests that there has been an upward trend in class-A purchase propensity over time for these appliances. The impact of new housing on the conditional probability of refrigerator – freezer combination unit purchase is largest, increasing from 48 percent to 80 percent when all residences are simulated as built in 2002. Surprisingly, for freezers, and washing machines the conditional probability of choosing a class-A appliance actually decreases slightly in the simulation, despite positive parameter estimates for the residence built in 2002 indicator. The reason for this decline is that, based on parameter estimates, the simulation increases the probability that households with older housing stock will know the energy class of the appliance increases disproportionately. The other residence and household characteristics of households with older housing stock, however, imply a lower propensity to purchase a class-A appliance. For freezers and washing machines the direct positive impact of the 2002 residence parameter in the class-A purchase choice equation is not strong enough to overcome this indirect effect in calculation of conditional probabilities. Nevertheless, 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 also 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 incentives. Impacts of regional electricity prices on the conditional probability of class-A appliance purchase are, again, mixed. Conditional probabilities of purchase increase with electricity prices for dishwashers and washing machines, but decline slightly for refrigerators and freezers for the same reasons as described above for the new housing stock simulations.

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 of economic well-being. Similarly, increased education, simulated by giving each household at least secondary school education, has little impact. However, considerable room remains to explore the impact of education on the adoption of energy efficient appliances with a dataset that provides more detailed information on educational attainment.

Increasing household energy awareness, simulated by assuming all households 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 a number of unobserved factors that influence class-A appliance purchase across appliance types.

7 Policy Implications

The results generate a number of implications for the refinement of energy-efficiency labeling 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. This long lag period must be accounted for in the formulation and evaluation of energy-efficiency labeling schemes. 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 labeling scheme with the current cross-sectional dataset.

The results also suggest that consumers respond to economic incentives, as knowledge of energy classes increases with regional energy prices for most appliances. Thus policies that internalize the social costs of energy consumption can spur energy use awareness and, ultimately, 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 Labeling Directive can further influence purchase decisions. As mentioned, scope also exists for improving the correct presentation of information under the current directive. Increased awareness of household energy use and access to information though personal computers are also likely to influence consumer purchase decisions and should be incorporated into future energy classification scheme information awareness campaigns. Such efforts include publishing (and updating) lists of energy efficient appliances by energy agencies, consumer groups, or others on the Internet. 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. Similarly, consumers may be offered rebates or other financial incentives to purchase energy efficient appliances which transfer some of the associated social benefits to them.

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 environmental attitudes, psychological factors and social norms (Kahn, 2007; Gilg and Barr, 2006; Barr et al., 2005). For example, Brandon and Lewis (1999) find that environmental attitudes and beliefs are as relevant as financial considerations for household energy conservation. Incorporating these aspects would delineate the role of perceived environmental benefits in household energy-efficient appliance purchase decisions, and thus complement the attribute-based approach presented in this paper.

8 References

Aguiar, M. and Hurst, E., 2007. Life-cycle prices and production. American Economic Review 97, 1533-1559.

Banerjee, A. and Solomon, B.D., 2003. Eco-labeling for energy efficiency an sustainability: a meta-evaluation of the US programs. Energy Policy 31, 109-123.

Bertoldi, P.,1999. Energy efficient equipment within SAVE: Activities, strategies, success and barriers. Proceedings of the SAVE Conference for an Energy Efficient Millenium. Graz, Austria, 8-10 November 1999 (www.eva.wsr.ac.at).

Bertoldi, P. and Atanasiu, B., 2007. Electricity Consumption and Efficiency Trends in the Enlarged European Union. Status Report 2006. European Commission, Directorate-General Joint Research Center. Institute for Environment and Sustainability. Ispra, Italy.

Black, J., Stern, P. and Elworth, J., 1985. Personal and contextual influences on household energy adaptations. Journal of Applied Psychology 70, 3-21.

BMU (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit), 2004. Umweltbewusstsein in Deutschland 2004 - Ergebnisse einer repräsentativen Bevölkerungsumfrage.

Brandon, G., Lewis, A., 1999. Reducing household energy consumption: a qualitative and quantitative field study. Journal of Environmental Psychology 19, 75-85.

Brechling, V. and Smith, S., 1994. Household energy efficiency in the UK. Fiscal Studies 15, 44-56.

Carlsson-Kanyama, A., Linden, A.L. and Eriksson. B., 2005. Residential energy behavior: does generation matter? International Journal of Consumer Studies. 29, 239–252.

CEC (Council of the European Communities), 1992. Council Directive 92/75/EEC of 22 September 1992 on the indication by labeling and standard product information of the consumption of energy and other resources by household appliances. Official Journal L 297, 13/10/1992, p. 0016 – 0019.

Dillman, D., Rosa, E. and Dillman, J., 1983. Lifestyle and home energy conservation in the United States: the poor accept lifestyle cutbacks while the wealthy invest in conservation. Journal of Economic Psychology 3, 299–315

Dupont, D.P., 2004. Do children matter? An examination of gender differences in environmental valuation. Ecological Economics. 49: 273-286.

European Commission, 2008. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - 20 20 by 2020 - Europe's climate change opportunity, COM(2008) 13 final.

European Council, 2006. Presidency Conclusions of 23/24 March 2006. 7775/1/06 REV1 of 18.05.2006).

Europe Economics, 2007. Impact Assessment on a Possible Extension, Tightening or Simplification of the Framework Directive 92/5 EEC on Energy Labeling of Household Appliances. Report by Europe Economics and Fraunhofer-ISI. London, England.

Fransson, N. and Garling, T., 1999. Environmental Concern: Conceptual Definitions, Measurement Methods, and Research Findings. Journal of Environmental Psychology, 19, 369-382.

Gilg, A. and Barr, S., 2006. Behavioral attitudes towards water saving? Evidence from a study of environmental actions. Ecological Economics 57, 400-414.

Heckman, J.J., 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. Annals of Economic and Social Measurement 5, 475-492.

Hirst, E. and Goeltz, R., 1982. Residential energy conservation actions: analysis of disaggregated data. Energy Systems and Policy 6, 135–150.

Howarth, R.B., Haddad, B.M. and Paton, B., 2000. The economics of energy efficiency: insights from voluntary participation programmes. Energy Policy, 28(6-7), 477-486.

Jaffe, A.B. and Stavins, R.N., 1994a. Energy-efficiency investments and public policy. The Energy Journal 15:43-65.

Kahn, M.E., 2007. Do greens drive Hummers or hybrids? Environmental ideology as a determinant of consumer choice. Journal of Environmental Economics and Management 54, 129-154.

Lane, K., Harrington, L. and Ryan, P., 2007. Evaluating the impact of energy labeling and MEPS – a retrospective look at the case of refrigerators in the UK and Australia. In: European Council for Energy-Efficient Economy (Paris): Proceedings of the 2007 eceee Summer Study. Saving energy – just do it! La Colle sur Loup, Côte d’Azur, France, 4–9 June, pp. 743-751.

Long, J., 1993. An econometric analysis of residential expenditures on energy conservation and renew-able energy sources. Energy Economics 15, 232-238.

Lutzenhiser, L., 1993. Social and behavioral aspects of energy use. Annual Review of Energy and Environment 18, 247–289.

Mills, B. and Schleich, J., 2008. Why Don’t Households See the Light? Explaining the Diffusion of Compact Fluorescent Lamps. Paper presented at the 16th Annual Conference of the European Association of Environmental and Resource Economists (EAERE), June 25-28, Gothenburg, Sweden.

NAHB (National Association of Home Builders), 2007. Study of the Life Expectancy of Home Components.

Newell, R.G., Jaffe, A.B. and Stavins, R.N., 1999. The Induced Innovation Hypothesis and Energy-Saving Technological Change. The Quarterly Journal of Economics, 114, 941-975.

Sammer, K. and Wüstenhagen, R., 2003. The Influence of Eco-Labelling on Consumer Behaviour – Results of a Discrete Choice Analysis for Washing Machines. Business Strategy and the Environment 15, 185-199.

Sanchez, M.C., Brown, R.E., Webber, C., and Homan, G.K., 2008. Savings estimates for the United States Environmental Protection Agency’s ENERGY STAR voluntary product labeling program. Energy Policy 36, 2098-2108.

Sardinanou, E., 2007. Estimating energy conservation patterns of Greek households. Energy Policy 35, 3778-3791.

Schiellerup, P., 2002. An examination of the effectiveness of the EU minimum standard on cold appliances: the British case. Energy Policy 30, 327-332.

Schlomann, B., Eichhammer, W., Gruber, E., Kling, N., Mannsbart, W., Stöckle, F., 2001. Evaluating the Implementation of the Energy Consumption Labeling Ordinance. On behalf of the German Federal Ministry of Economics and Technology (BMWi). In cooperation with GfK Marketing Services (http://www.isi.fhg.de/e/eng/publikation/online/EnVKV/EnVKV.htm)

Schlomann, B., Gruber, E., Eichhammer, W., Kling, N., Diekmann, J., Ziesing, H.J., Rieke, H., Wittke, F., Herzog, T., Barbosa, M., Lutz, S., Broeske, U., Merten, D., Falkenberg, D., Nill, M., Kaltschmitt, M., Geiger, B., Kleeberger, H. and Eckl, R., 2004. Energieverbrauch der privaten Haushalte und des Sektors Gewerbe, Handel, Dienstleistungen (GHD), in Zusammenarbeit mit dem DIW Berlin, TU München, GfK Nürnberg, IE Leipzig, im Auftrag des Bundesministeriums für Wirtschaft und Arbeit, Karlsruhe, Berlin, Nürnberg, Leipzig, München.

Schultz, T.W., 1975. The Value of the Ability to Deal with Disequilibrium. Journal of Economic Literature 13, 827-46.

Scott, S., 1997. Household energy efficiency in Ireland: a replication study of owner of energy saving items. Energy Economics 19, 187-208.

Stewart B., Gilg, A.W. and N. Ford, 2005. The household energy gap: examining the divide between habitual- and purchase-related conservation behaviours. Energy Policy 33, 1425-1444.

Sutherland, R.J., 1991. Market barriers to energy efficiency investments.. The Energy Journal 12, 15-34.

Sutherland, R.J., 1996. The economics of energy conservation policy. Energy Policy 24, 361-370.

Torgler, B., Garia-Valinas, M.A. and Macintyre, A., 2008 Differences in Preferences Towards the Environment: the Impact of a Gender, Age and Parental Effect." Fondazione Eni Enrico Mattei, Nota di lavorno: 18.2008.

Truffer, B., Markard, J. and Wüstenhagen, R., 2001. Eco-labeling of electricity – strategies and tradeoffs in the definition of environmental standards. Energy Policy 29, 885-897.

van de Ven, W.P. and van Praag, B.S., 1981. The Demand for Deductibles in Private Health Insurance: A Probit Model with Sample Selection. Journal of Econometrics 17, 229-252.

Waide P., 1998. Monitoring of Energy Efficiency Trends of European Domestic Refrigeration Appliances, final report. PW Consulting for ADEME on behalf of the European Commission (SAVE). PW Consulting: Manchester.

Waide P., 2001. Monitoring of Energy Efficiency Trends of Refrigerators, Freezers, Washing Machines and Washer-Driers Sold in the EU, final report. PW Consulting for ADEME on behalf of the European Commission (SAVE). PW Consulting: Manchester.

Walsh, M., 1989. Energy tax credits and housing improvement. Energy Economics. 11, 275–284.

Weber, C. and Perrels, A., 2000. Modelling lifestyle effects on energy demand and related emissions. Energy Policy 28, 549-566.

Winward, J. et al., 1998. Cool Labels. Energy Environmental Programme, Environmental Change Unit, University of Oxford.

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