Energy Efficient Appliance Choice under the EU Labeling Scheme

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Outline

1. Introduction

Energy efficiency labeling schemes are often promoted as a cost-effective measure to overcome incomplete information and search costs when evaluating the energy efficiency of technologies (Sutherland, 1991; Howarth et al., 2000). Labeling schemes are expected to shift consumers' purchasing decisions towards more energy efficient products. At the same time, improving consumer information on appliance energy performance is expected to create market incentives for manufactures to design more energy-efficient products. The EU appliance energy consumption labeling scheme adopted in 1992 via the framework Energy Labeling Directive (CEC 1992) requires retailers to display a compulsory label that contains information on the energy class and the level of energy consumption for household appliances (white goods and lighting). These requirements, which are common for all Member States, are designed to make consumers aware of the relative energy-efficiency of appliances through the provision of observable, uniform, and credible standards (e.g. Truffer et al., 2001). Currently, the European Union is in the process of substantially expanding the scope of the "Labeling Directive" to cover all energy-related products, including televisions, computers, monitors, electric motors, ventilation fans, or electric pumps.[1]

Increasing the energy efficiency of these products is considered crucial for meeting the EU's intended target of a 20 percent reduction in energy consumption by 2020 relative to 2005 compared to expected baseline levels (European Commission, 2008; European Council, 2006). The EU appliance energy consumption labeling scheme is expected to make a major contribution through the increased diffusion of energy efficient appliances. According to the European Commission (2008), the energy labeling scheme for household appliances could account for about 35 TWh of final energy savings per year in 2010. In general though, there has been little quantitative evaluation of the impact of energy efficiency labeling schemes. Evaluation studies based on aggregate observed data for the EU, the US, and Australia have found a positive correlation between the uptake of energy efficient appliances and the implementation of energy labeling programs for household appliances (e.g. Sanchez et al., 2008; Lane et al., 2007; Banerjee and Solomon, 2003; Schiellerup, 2002; Bertoldi, 1999). Using the observed increase in the market share of energy-efficient appliances as an indicator, 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) concur that the scheme was successful. According to CECED (2006), the average efficiency of newly purchased appliances between 1996 and 2004 improved by 30 percent for cold appliances, by 35 percent for dishwashers, and by 23 percent for washing machines. However, correlation does not imply causality and it is empirically challenging to separate the impact of the labeling scheme on the generation

[1] See ECEEE (2010) for an up to date overview of ongoing regulation.

and diffusion of more energy-efficient appliances from other factors such as electricity prices, minimum efficiency standards or "business as usual" technical development. Likewise, these factors may interact with the labeling scheme. For example, as pointed out by Newell et al. (1999) in the case of water heaters and air conditioners in the US, labeling schemes may reinforce price-induced technological innovation. Reiss and White (2008) observe that consumers respond to both energy prices and information campaigns to reduce energy consumption. Recent studies based on experimental data are able to directly address the effects of labeling on consumers' choices. Using survey-based conjoint analyses, the findings by Sammer and Wüstenhagen (2006) for washing machines in Switzerland and by Heinzle and Wüstenhagen (2009) for televisions in Germany suggest that labeling increases consumers' (stated) willingness to pay for more eco-efficient products. However, few studies have explored the socio-economic or technology-related factors underlying consumers' choices of energy efficient appliances when exposed to label schemes.[2]

The effectiveness of the energy labeling scheme in terms of influencing 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. Besides socio-economic and technology-related factors, the multivariate analyses also allow for observed energy efficiency behavior and respondent stated importance of electricity savings for both financial reasons and greenhouse gas reductions. The econometric analyses are based on a unique data set of almost 5,000 households in ten EU countries (Belgium, Bulgaria, The Czech Republic, Denmark, France, Germany, Greece, Hungary, Portugal, and Romania) and Norway who purchased a refrigerator, freezer, refrigerator – freezer combination unit, dishwasher, or washing machine in the five years prior to the 2007 survey. Unlike single-country studies, which dominate the literature, the cross-country nature of the survey also allows us to examine the impacts of country labeling scheme compliance rates and country purchasing-power-parity-adjusted energy prices on labeling scheme knowledge and choice of energy efficient appliances.

Since only households who are aware of the appliance energy label 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 appliance energy class choice.

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[2] Mills and Schleich (2010) are a notable exception, but their dataset for Germany does not allow them to identify households who made appliance purchases after the implementation of the labeling scheme.

The remainder of the paper is organized as follows. Section 2 provides a brief overview of the EU Energy Labeling Framework and its implementation. 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. The paper then concludes by distilling implications for enhancing the adoption of energy-efficient appliances.

2. The EU Appliance Labeling Scheme

In the EU 27, major household appliances are responsible for about 34 percent of total residential end-use electricity consumption (Bertoldi and Atanasiu, 2010). Refrigerators and freezers alone account for 15.2 percent of residential electricity end-use, washing machines for 6.4 percent and dishwashers for 2.7 percent. To address energy use from household appliances, the EU adopted the "Labelling Directive" in 1992 (CEC 1992). Accordingly, retail stores are obliged to provide certain household appliances with energy labels at the point of sale that include 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.[3] 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 2004, the labeling scheme for cold appliances was extended to A+ and A++ to account for substantial energy efficiency improvements in the highest energy efficiency category.

Some variation exists in the date of country implementation of EU directives (table 1), i.e. when the EU directive became national law in the individual Member States (MS). Since most of the Eastern European countries joined the EU only in 2004, and Bulgaria and Romania in 2007, implementation dates for new MS are later than for the old MS. However, some MS implemented the Labeling Directive and associated amendments prior to formally joining the EU. Among the study countries, indicated in bold in the table, Denmark, France, Greece, Norway, and Portugal show relatively early implementation for refrigerators, freezers, and washing machines, while most recent members of the EU (Bulgaria, Czech Republic, Hungary and Romania) are late implementers. Many countries implemented labeling directives for dishwashers after the other appliances, with the most recent entrants into the EU again being the last to implement. It is worth noting that in many cases, particularly for late implementers, households were exposed to appliance energy labels before country implementation of the directive because most appliance producers sell to many countries across the EU market, and thus will have already generated the required labeling information.

Schlomann et al. (2009) measure country compliance using criteria on completeness of the labeling, proper placement on the appliance, and size and color of the label in 2007. The results for study countries in table 1 indicate substantial variation in compliance, with Norway having the highest share of correctly labeled appliances (over 90 percent on average across appliances) followed by Hungary,

[3] The EU A to G label has been used as a model in other countries, such as Brazil, China, Argentina, Chile, Iran, Israel and South Africa (European Commission, 2008).

Denmark and Portugal (between 80 and 90 percent), Romania, Germany and France (between 60 and 70 percent), the Czech Republic and Belgium (between 50 and 60 percent). Greece (below 35 percent) and Bulgaria (below 25 percent) rank at the bottom of the list in terms of compliance.

Looking at historic rates, the diffusion of higher energy class appliances has been greater in the EU-15 than in the new Member States (European Commission 2008). However, market data for the New Member States suggests that these countries are rapidly adopting energy efficiency class appliances (Bertoldi and Atanasiu, 2009), in part because manufacturers no longer produce and offer low energy efficiency appliances.

3. Study Framework

Survey-based analyses often have to deal with missing data. In the current dataset 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 than non-responders, 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 the class of energy efficient appliances may be biased. In this study potential knowledge-based sample selection bias is controlled for by jointly estimating the determinants of appliance energy class choice and the determinants of knowledge of the energy class of the appliance. Previous efforts have focused on controlling for sample selection with discrete appliance energy class choice (e.g. Mills and Schleich, 2010). However, we allow for appliance energy class choices among multiple ordered classes with a sample of households that purchased the specific appliance type in the five years prior to the survey.

3.1. Statistical Model

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

$$y_i^* = x_i B + \varepsilon_i, \quad \varepsilon_i \sim N(0,1) \qquad (1)$$

where y_i^* is a latent measure of household preferences for appliance class, x_i is a row vector of household *i* characteristics, B is the parameter vector to be estimated, and ε_i is a residual term. Appliance classes are ordered from 0 to J, where J is associated with the highest energy efficiency class. The observed outcome is:

3. Study Framework

$$
\begin{aligned}
&y_i = 0 \quad \text{if} \quad y_i^* \le \mu_0 \\
&y_i = 1 \quad \text{if} \quad \mu_0 < y_i^* \le \mu_1 \\
&\cdot \\
&\cdot \\
&\cdot \\
&y_i = J \quad \text{if} \quad y_i^* > \mu_{J-1}
\end{aligned}
\qquad (2)
$$

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

$$d_i^* = z_i\Gamma + u_i \qquad (3)$$

where d_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 $u_i \sim (0,1)$ is an error term. Observed response to the survey question on energy-class on the appliance is:

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

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

$$E(y_i^*) = x_i B + E(\varepsilon_i \mid x_i, d^* \ge 0) \qquad (5)$$

In order to correct for this potential bias, the energy class choice equation (1) and the sample selection equation (3) are jointly estimated by the maximum likelihood method with the assumption of joint normality of the error term, $\varepsilon_i, u_i \sim N_2(0,0,1,1,\rho)$ as:

$$\text{LogL} = \sum_{d=0} \log \Phi(-z\Gamma) + \sum_{d=1} \log\{\Phi_2(a_j, z\Gamma, \rho) - \Phi_2(a_{j-1}, z\Gamma, \rho)\}$$

where $\Phi(\bullet)$ is a standard normal CDF, $\Phi_2(\bullet,\bullet,\bullet)$ is a bivariate standard normal CDF, $a_j = \mu_j - xB$, $a_{j-1} = \mu_{j-1} - xB$, and *j* is the value taken for the observation.

3.2. Model specification

3.2.1. Knowledge of energy class

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 purchased a certain type of appliance in the last five years but do not provide a labeling scheme classification on the questionnaire are categorized as unaware of the energy-rating of the appliance.

A number of covariates are included in the specification of the knowledge-based selection equation (4) and the energy class choice equation (2). In order to maintain a relatively parsimonious specification, indexes of household knowledge and household behavior with respect to energy use and energy saving technologies are generated and employed in the specification. The index of household knowledge is generated through factor analysis based on the following underlying variables: household knowledge of the energy class of other appliance types purchased in the past five years, household knowledge of energy consumption in the past year, and household knowledge of the meaning of the Energy Star label (relating to office equipment). A higher index number is associated with greater knowledge of household energy use and efficiency options, and is thus expected to be positively associated with knowledge of the energy-rating of appliances purchased in the last five years.

Factor analysis is also used to generate an index of household stated energy conservation behavior. The index includes an indicator of efficient loading of the washing machine to full capacity, an indicator of frequent cooking with a pressure cooker, an indicator for always turning off lights when leaving a room, an indicator for replacement of burned out bulbs with compact fluorescent bulbs, an indicator for turning the TV off at the switch rather than leaving it in standby mode, and an indicator of plans to replace the current TV with a LCD model. A higher index number for household energy conservation behavior indicates a household is more likely to implement energy conservation practices and is hypothesized in this study to be positively related with knowledge of the energy class of a specific appliance.

Household characteristics included in the energy class knowledge equation specification include indicators for the highest level of education in the household, through indicators for a trade or vocational degree and a university degree, relative to the base of a high school degree or less. 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. Family composition is captured through a measure of family size and measures of the share of the household below the age of 12 years and the share above the age of 65

years. 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. The impact of children under 12 on energy label knowledge is unclear, a priori. However knowledge of appliance energy class is expected to be lower in households with a high share of elderly, as previous research suggests that older household heads have lower level of knowledge of energy efficient technologies (Linden, Carlsson-Kanyama, and Eriksson, 2006; Mills and Schleich, 2009).

Two measures for the intensity of reasons that the household feels it is important to save electricity are also included in the specification. The first measure is an indicator that the household responded that it was very important to save electricity for financial reasons. The second measure is an indicator that the household responded that it was very important to save electricity due to greenhouse gases and global warming. These indicators allow for differential knowledge of energy labels based on stated attitudes with respect to energy conservation.

Cross-EU-county differences in knowledge are captured through three country-level variables. The first variable is average purchasing-power-parity adjusted country electricity prices. Individuals are expected to have greater knowledge of appliance energy efficiency classes when electricity prices are higher. The second variable is an indicator for countries (Belgium, The Czech Republic, Denmark, Norway, and Portugal) who generated survey data primarily through on-line surveys. Online surveys are likely to generate selection bias in survey respondents, particularly with respect to the level of knowledge and comfort level with new technologies when compared to non-respondents. Online survey respondents may also be more likely to provide a response to the question on the energy class of an appliance purchased in the last five years even if they are unsure because, when compared to telephone surveys, they know there will not be a follow-up question on their response. The third variable is the Schlomann et al. (2009) estimates of country labeling compliance rates for each appliance type presented in table 1. Higher compliance rates are expected to increase knowledge of the energy class labeling scheme.

3.2.2. Energy class choice

For the most part, the same set of variables employed the label knowledge equation specification are included in the energy class choice equation. The important exception is the exclusion of the index of household knowledge of energy use and energy efficiency. The exclusion of this variable from the energy class choice equation assists in model identification and is based on the rationale that

the knowledge measured in the index only influences energy class choice indirectly through its impact on household knowledge of the labeling scheme.[4]

The index of household conservation behavior is expected to be positively related to the choice of more energy efficient classes of appliances. The propensity to choose more energy efficient appliances is also thought to increase with education (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. Further, attitudes towards the environment and association in social groups disposed to environmentally friendly behavior tend to be positively related with education (e.g. Lutzenhiser, 1993; Weber and Perrels, 2000). It should also be noted that education is highly correlated with income. A number of studies find that the propensity to invest in energy saving technologies increases with income (Dillman, Rosa, and Dillman, 1983; Long, 1993; Walsh, 1989; Sardianou, 2007; Mills and Schleich, in press). Since no household income data was collected in the surveys, the education variable may pick up some income effects.

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. On the other hand, older household heads have weaker preferences for state-of-the-art technologies, weaker preferences for environmental preservation, and generally lower propensities to carry out energy efficiency improvements (Carlsson-Kanyama, Linden, and Eriksson, 2005; Torgler et al., 2008; Walsh, 1989). Households in single family homes may also have different preferences for energy efficient appliance than those in multi-occupancy buildings, but the potential nature and magnitude of this single family home effect is left as an empirical question.

The two measures for the intensity of reasons households feel it is important to save electricity are also included in the energy class choice specification. Indications by the household that it was very important to save electricity either for financial reasons or due to greenhouse gases and global warming may increase the propensity to purchase more energy efficient appliances. Brandon and Lewis (1999) conclude that environmental attitudes and beliefs are relevant, but financial considerations are at least as important. Poortinga, Steg, and Vlek (2004) note that responses to these types of questions may suffer from ‘social desirability’ response bias and may not translate into observed behavior. Most previous studies, however, do not allow for a distinction between the potential contributions of atti-

[4] Although the model is technically identified through the non-linearity of the estimator.

tudes on the importance of financial savings and attitudes towards the environment.

Country level purchasing-power-parity electricity prices and the indicator for on-line data collection in Belgium, The Czech Republic, Denmark, Norway, and Portugal through an on-line survey are included in the energy efficient appliance choice specification. Several previous studies have found that higher electricity prices lead to increased adoption of energy saving technologies (Walsh, 1989; Long, 1993; Mills and Schleich, 2009; Mills and Schleich, in press). As noted, on-line surveys may introduce sample selection bias if responders under this survey format tend to be more concerned about energy conservation. The country labeling compliance rate for each appliance type is also included. The compliance rate variable is expected to primarily impact knowledge of the appliance energy class. However, inclusion of the variable in the appliance energy class choice equations allows us to test for impacts that the proper labels may have on energy efficient appliance purchase propensities beyond just increasing consumer awareness of appliance energy class.

4. Data

The study dataset comes from a Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe Project survey conducted in eleven countries in 2007 using a common survey instrument that was translated into the country language. The goal was for each country to survey at least 500 households. However there was considerable variation in country data collection strategies. Belgium, The Czech Republic, Denmark, Norway, and Portugal relied primarily on internet based surveys. Bulgaria and Germany relied primarily on mail surveys, while France used telephone interviews and Hungary and Romania used face-to-face interviews. Greece used a mixture of face-to-face, online, email, and mail surveys. Data are available from the project website at: http://www.isr.uc.pt/~remodece/

The overall sample contains 4,902 households. The distribution of country responses from the website data are shown in appendix table A.1, and ranges from Romania with the highest number of responses at 622 households and France with the fewest responses at 100. Energy efficiency class purchase decisions for five appliance types are analyzed; refrigerators, freezers, refrigerator-freezer combinations, washing machines, and dishwashers. Only households that have purchased an appliance in the five years prior to the 2007 survey are included in the analysis of the energy class purchase decision for that appliance type. Table A.1 provides figures on the number of households by country purchasing each appliance type in the last five years. Note that there appears to be considerable variation in the propensity to purchase certain types of appliances by country. For example stand-alone refrigerator and stand-alone freezer purchases are most prevalent in Denmark, while the purchase of refrigerator-freezer combination units is most common in Portugal and Romania.

The number of appliance purchasers in the past five years who were able to provide information of the energy efficiency class of the appliance is also provided in table A.1. For refrigerators, over ninety percent of purchasers provided the energy class in Romania, while in Bulgaria less than fifty percent provided the energy class in the survey. Since Bulgaria only officially implemented the appliance energy class labeling scheme in 2006, it is not surprising that the response level on the energy class question is relatively low. Differences in response levels across countries also appear to correspond to variations in compliances rates. Romania is among the countries with the highest share of correctly labeled appliances, while Bulgaria ranks at the very bottom in terms of compliance (Schlomann et al. 2009). Overall, across appliances the percentage of purchasers in the last five years who where able to provide the energy class of the appliance ranged from 72 percent for washing machines to 77 percent for dishwashers.

4. Data

The distribution of efficiency classes among those purchasing an appliance in the last five year who know the label class is also presented in table A.1 by country and appliance. Most refrigerators (88 percent), freezers (81 percent), and refrigerator-freezer combination units (86 percent) are type A, A+, or A++. Based on this distribution, refrigerator, freezer, and refrigerator-freezer combination units are grouped into four classes (B and below, A, A+, and A++) for the multivariate analysis. Washing machines and dishwashers are grouped into three classes (C and below, B, and A), as 82 percent of washing machine purchasers and 87 percent of dishwasher purchasers reporting a type A rating. Descriptive statistics on the covariates employed in the analysis are presented in table 2 by appliance type.

5. Results

5.1. Energy class knowledge

Selection equation estimation results for knowledge of the energy label class of each appliance are presented in table 3. The household knowledge index parameter is positive and significant for all appliance types,[5] which indicates that household knowledge of the energy class of other appliance types purchased in the last five years, of household electricity consumption, and of other energy labeling schemes broadly translates into greater awareness of the energy class of the specific appliance purchased. The household propensity to employ energy conserving methods at home, as measured through the efficiency index parameter shows a weaker association with knowledge of the appliance energy label. The associated parameter estimate is positive and significant for freezers and positive and weakly significant ($p=0.10$) for refrigerators and dishwashers. However, the parameter estimate is negative ($p=0.10$) for washing machines.

Relationships between household characteristics and household reporting of energy class are also inconsistent across appliances. Households where the highest degree is a vocational degree show no differential propensity to know the energy efficiency class of appliances purchased in the past five years (relative to the high school or below base level) for four of the five appliance types and a weak negative propensity for washing machines. A university degree does, however, increase the probability of knowing the energy class of refrigerator – freezer combination units and weakly *(p=0.10)* increases the probability of knowing the energy class for refrigerators and dishwashers. Family size and the share of children under 12 in the household have no impact on label knowledge. However, as expected, households with a large share of elderly show a lower propensity to know the energy class of purchased appliances for all appliances except refrigerators. Thus old age appears to be associated with substantial information barriers to household knowledge of the EU appliance energy class scheme. Residents living in single family homes also appear to have a lower propensity to report the energy class of appliances for refrigerator – freezer combination units, dishwashers, washing machines, and weakly for refrigerators ($p=0.10$). Thus, awareness appears to decrease, not increase, with consumption of housing.

The impacts of the stated importance of saving energy for financial reasons and for greenhouse gas reductions on knowledge of appliance energy class also vary by appliance. The propensities to know the energy class increases for refrigerators, freezers, and washing machines ($p=0.10$) when survey respondents indicate it is very important to save energy for financial reasons. However, when survey re-

[5] Relationships are significant at the $p=0.05$ level in two-tailed *z*-tests unless otherwise noted.

spondents indicate it is very important to save energy in order to reduce greenhouse gases, the propensity to know the energy class only increases for washing machines. The results, combined, suggest economic concerns generate greater awareness than environmental concerns.

Turning to the country level variables, country electricity prices show a strong positive relationship with knowledge of appliance energy class for refrigerators, refrigerator – freezer combination units and dishwashers. Thus, economic incentives to conserve appear to increase knowledge of energy efficient technology options. The online survey indicator is also positive and significant for dishwashers and refrigerators ($p=0.10$), suggesting that either online surveys attract respondents who have greater knowledge of and interest in the energy labeling scheme (and perhaps energy efficiency options more generally) or online surveys make respondents more likely to report an energy efficiency class when their recall is unsure. Compliance rates have a strong positive impact on knowledge of energy class for all appliances except dishwashers, suggesting that awareness of the energy class labeling scheme can be improved through stricter compliance. Finally, it is worth noting that the Rho parameter estimates for the presence of selection bias in appliance class choice are negative and significant for refrigerator – freezer combination units and washing machines. Sample selection in these cases implies that greater than expected awareness of the energy class label is associated with lower than expected propensity to purchase energy efficient appliances.

5.2. Energy class choice

Energy class choice equation estimation results are presented in table 4. Overall, relationships between model covariates and appliance energy class choice are weaker than those found in the knowledge of energy class equation. For example, the efficiency index measure of household propensity to employ energy conserving practices at home is only positive and significant for refrigerator – freezer combination units, suggesting that energy conserving behavior in the home does not have a strong positive impact on choice of energy efficient appliances.

Only one household characteristic shows a consistently strong impact on appliance energy class choice. If the highest degree in the household is a vocational degree relative to secondary school or less, the propensity to purchase energy efficient appliances is higher for refrigerators, refrigerator – freezer combination units, dishwashers, and washing machines. Perhaps more surprisingly if the highest degree is a university degree, except for dishwashers ($p=0.10$), there is no increase in the propensity to purchase more energy efficient appliances. Again, as there is no separate variable for income, this may represent a propensity for middle class families to take advantage of energy-cost-savings associated with energy efficient appliances. Household income data would be needed to test if this is, indeed, the case. Another significant household characteristic is family size, with a

higher propensity for large families to purchase energy efficient refrigerator – freezer combination units. Households with a high share of members over 65 years of age also show a lower propensity to purchase energy efficient classes of refrigerators. Residents of single family homes, while less aware of appliance energy classes, also show a higher propensity to purchase energy efficient refrigerators ($p=0.10$) and freezers ($p=0.10$).

Expressed importance of electricity savings for financial reasons and for greenhouse-gas reductions have no impact on the choice of energy efficient appliances. Country level variables also have relatively limited impacts on the choice of energy efficient appliances. Higher country electricity prices are actually estimated to decrease the propensity to purchase energy efficient washing machines, but have no significant impact for other appliances. The use of on-line surveys by a country is positively related to the propensity to purchase energy efficient refrigerators and washing machines ($p=0.10$). As noted, this result may stem from selection bias in those who respond to online surveys or reporting bias. Compliance rate impacts differ across appliances. Higher compliance rates have a strong negative impact on the purchase of energy efficient refrigerators, but a positive impact on energy efficient washing machine and freezer ($p=0.10$) purchase.

6. Conclusions and Policy Implications

This paper extends the existing empirical literature on consumers' choices when exposed to energy labeling schemes by allowing choices to depend on household socio-economic characteristics, technology-related factors, behavioral and motivational factors, and country conditions in a multi-country analysis. To account for a possible knowledge-based selection bias, the econometric model distinguishes label class knowledge from the energy class choice decision.

As a general finding, most covariates show stronger relationships with knowledge of labeling class than with the choice of energy efficiency class. Four factors show particularly strong and expected influences on label class awareness. First, general awareness of household energy use and energy saving technologies spills over into awareness of the energy class of specific appliances. Second, socioeconomic characteristics mater, as education increases label class awareness and older age reduces awareness. Third, economic incentives matter, as stated economic importance of energy saving and higher country electricity prices both generate greater label awareness. By contrast, stated concerns about global warming do not appear to have a broad impact on awareness. Fourth, effective country implementation of the labeling scheme raises label awareness.

More surprisingly, most factors that promote awareness of appliance energy classes have a limited influence on actual appliance energy class choice. Efficient energy behavior in the household is not strongly linked to appliance energy class choice. Socio-economic characteristics also have limited influence. This finding is inline with other studies that find that household socio-economic characteristics have relatively weak associations with the adoption of energy efficient technologies (Mills and Schleich 2010, Brohmann et al. 2009). In fact, with education it is vocational degrees rather than university degrees that are positively associated with the propensity to purchase energy efficient appliances. Economic incentives, both as the stated importance of financial savings and in the form of country energy prices, also do not translate into energy efficient appliance purchases. Similarly, there is no clear indication that proper country compliance with labeling directives increases energy efficient appliance purchase propensity. This latter finding casts some doubt on the effectiveness of current labels in influencing appliance energy class choice.

The findings have important implications for the design of more effective appliance energy efficiency labels. Energy labeling scheme awareness appears to respond to financial incentives, but purchase decisions are not directly influenced by financial incentives. This disconnect may stem from the fact that current labels provide no information on expected energy costs savings associated with the appliance purchase. Thus, consumers can not readily calculate if the additional investment associated with a more energy efficient appliance is justified by future

energy costs savings. The need to clearly identify energy-savings associated with energy efficient products has also been highlighted in the eco-marketing literature, which stresses that customers need to benefit (in this case via lower energy costs) from environmental innovations in order to generate green market demand (e.g. Kammerer 2009). Hence, a re-designed energy label for household appliances should not just include energy use (in kWh) but also energy costs, based on average energy prices for households in the country of sale in a particular year.

Stated preferences for energy savings for environmental reasons appear to have a more limited impact on label awareness. Thus, the provision of label information on environmental amenities associated with energy efficient appliance choice (e.g. reductions in CO_2 output) may have a weaker effect on purchase propensities than cost information. However, controlled experiments to identify the importance of different types of financial and environmental information on consumer energy efficient purchase propensity are an important area for further research.

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Table 1: Year of Country Implementation of EU Energy Consumption Labelling Energy Directives and Compliance Rates

	Year of Country Directive						
	Refrigerators and Freezers	Washing Machines	Dishwashers	Refrigerator and Combo Units	Freezers	Washing Machines	Dishwashers
Austria	1994	1996	1999				
Belgium	**1999**	**1999**	**1999**	0.51	0.55	0.69	0.52
Bulgaria	**11/2006**	**11/2006**	**11/2006**	0.26		0.24	0.26
Czech Republic	**2004**	**2004**	**2004**	0.62	0.61	0.57	0.62
Denmark	**1995**	**1996**	**1999**	0.87	0.85	0.85	0.84
Finland	1995	1996	1999				
France	**1995**	**1996**	**1998**	0.74	0.74	0.66	0.68
Germany	**1998**	**1998**	**1999**	0.63	0.8	0.82	0.62
Greece	**1996**	**1997**	**1997**	0.37	0.41	0.32	0.44
Hungary	**2002**	**2002**	**2002**	0.82	0.81	0.86	0.85
Italy	1998	1998	1999				
Ireland	1995	1996	1999				
Netherlands	1996	1996	1999				
Norway	**1996**	**1996**	**1996**	0.93	0.93	0.94	0.93
Portugal	**1995**	**1996**	**2000**	0.89	0.82	0.85	0.87
Romania	**2001**	**2001**	**2001**	0.7	0.69	0.74	0.95
Spain	1995	1996	1998				
Sweden	1995	1996	1999				
United Kingdom	1995	1996	1999				

Source: Mure2 database for implementation dates. Schlomann et al. 2009 for compliance rates.
Note: Bold indicates a study country

Table 2: Descriptive Statistics

		Refrigeration		Freezer		Refrigerator - Freezer		Dishwasher		Washing Machine	
Variable	*Description*	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
KNOWLEDGE INDEX	Index of energy saving appliance knowledge	0.275	0.771	0.274	0.777	0.108	0.668	0.340	0.815	0.144	0.787
EFFICIENCY INDEX	Index of energy saving behavior	0.052	0.496	0.066	0.492	0.014	0.502	0.105	0.497	0.026	0.505
VOCATIONAL DEGREE	1=yes	0.330	0.470	0.308	0.462	0.166	0.372	0.229	0.420	0.176	0.381
UNIVERSITY DEGREE	1=yes	0.434	0.496	0.410	0.492	0.553	0.497	0.549	0.498	0.547	0.498
FAMILY SIZE	No. persons in household	2.910	1.308	2.917	1.262	2.692	1.218	2.942	1.253	2.823	1.245
SHARE UNDER 12	Share of household under age 12	0.114	0.202	0.120	0.206	0.086	0.168	0.129	0.209	0.098	0.182
SHARE OVER 65	Share of household over age 65	0.086	0.255	0.097	0.267	0.073	0.228	0.063	0.220	0.088	0.254
SINGLE HOME	Live in single family home (1=yes)	0.664	0.473	0.645	0.479	0.359	0.480	0.543	0.498	0.433	0.496
GOAL ELECT SAVE	Important to saving electricity for financial reasons (1=yes)	0.641	0.480	0.645	0.479	0.642	0.480	0.586	0.493	0.642	0.479
GOAL GHG SAVE	Important to saving electricity for greenhouse effect (1=yes)	0.232	0.423	0.243	0.429	0.219	0.414	0.254	0.435	0.217	0.412
ELECTRICITY PRICE	Ave. country purchasing power parity price (unit?)	17.812	2.965	17.883	2.767	17.982	2.787	17.400	2.862	17.743	2.745
ONLINE SURVEY	Country implemented online survey	0.638	0.481	0.643	0.479	0.450	0.498	0.621	0.485	0.460	0.499
COMPLIANCE RATE	Share of country appliance correctly labeled	0.641	0.195	0.742	0.165	0.657	0.212	0.687	0.199	0.670	0.227

Table 3: Knowledge of Energy Class Selection Equations

	Refrigerator		Freezer		Refrigerator - Freezer		Dishwasher		Washing Machine	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
CONSTANT	-1.2896 **	0.4309	-0.3967	0.4208	-1.6088 **	0.2622	-0.9995 **	0.3299	0.0680	0.2305
KNOWLEDGE INDEX	0.6236 **	0.0767	0.6097 **	0.0692	0.7810 **	0.0629	1.0057 **	0.0715	0.7984 **	0.0491
EFFICIENCY INDEX	0.2019 *	0.1166	0.2136 **	0.1005	0.0144	0.0745	0.1830 *	0.0987	-0.1104 *	0.0632
VOCATIONAL DEGREE	0.1192	0.1568	-0.0172	0.1291	0.1138	0.1085	-0.0042	0.1430	-0.1881 *	0.0978
UNIVERSITY DEGREE	0.2330 *	0.1323	0.1585	0.1211	0.2606 **	0.0835	0.2030 *	0.1153	0.0420	0.0741
FAMILY SIZE	-0.0358	0.0454	-0.0415	0.0433	0.0401	0.0310	-0.0355	0.0420	-0.0063	0.0269
SHARE UNDER 12	0.2346	0.3065	0.0659	0.2879	-0.2745	0.2313	0.0807	0.2406	0.2086	0.2035
SHARE OVER 65	-0.2921	0.2066	-0.4734 **	0.1750	-0.6278 **	0.1399	-0.8176 **	0.2012	-0.6409 **	0.1285
SINGLE HOME	-0.2126 *	0.1274	-0.0685	0.1105	-0.2392 **	0.0772	-0.2633 **	0.1008	-0.3215 **	0.0678
GOAL ELECT SAVE	0.2488 **	0.1208	0.2658 **	0.1040	0.0989	0.0804	0.0129	0.1009	0.1255 *	0.0700
GOAL GHG SAVE	-0.0499	0.1419	-0.0052	0.1221	-0.0896	0.0912	0.1658	0.1213	0.2326 **	0.0859
ELECTRICITY PRICE	0.0631 **	0.0171	0.0264	0.0184	0.0840 **	0.0138	0.0812 **	0.0145	0.0128	0.0117
ONLINE SURVEY	0.2462 *	0.1364	-0.0742	0.1139	-0.0334	0.0972	0.3533 **	0.1106	0.1090	0.0797
COMPLIANCE RATE	0.7093 **	0.3294	0.7326 **	0.3073	1.1405 **	0.2113	0.2884	0.2665	0.4953 **	0.1632
Rho(u,e)	0.0505	0.2729	0.0571	0.2486	-0.3278 **	0.1473	0.0687	0.2286	-0.5440 **	0.2497
Log-likelihood	-1103.55		-1371.95		-2542.23		-970.16		-2007.71	

Note: * indicates significance at p=0.10 level and ** indicates significance at p=0.05 level.

Table 4: Appliance Energy Class Choice Equations

	Refrigerator		Freezer		Refrigerator - Freezer		Dishwasher		Washing Machine	
Variable	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error	Parameter Estimate	Standard Error
CONSTANT	1.6509 **	0.6193	0.3802	0.4776	1.3009 **	0.3003	2.1472 **	0.5741	2.4971 **	0.3197
EFFICIENCY INDEX	0.0276	0.1023	0.1057	0.0887	0.1982 **	0.0575	0.0116	0.1139	-0.0164	0.0733
VOCATIONAL DEGREE	0.2662 **	0.1355	0.1851	0.1215	0.2173 **	0.0913	0.4425 **	0.1668	0.2399 **	0.1226
UNIVERSITY DEGREE	0.0417	0.1332	0.0753	0.1052	0.0735	0.0731	0.2455 *	0.1304	-0.0097	0.0897
FAMILY SIZE	-0.0712 *	0.0431	0.0242	0.0427	0.0551 **	0.0276	0.0265	0.0514	0.0094	0.0354
SHARE UNDER 12	0.1576	0.2493	-0.2764	0.2368	-0.2840	0.1894	-0.0916	0.2918	0.0213	0.2280
SHARE OVER 65	-0.4463 **	0.2236	0.0748	0.1986	0.1860	0.1528	0.0531	0.3291	0.1597	0.1843
SINGLE HOME	0.1855 *	0.1025	0.1652 *	0.0892	-0.0118	0.0643	0.1187	0.1148	-0.1061	0.0873
GOAL ELECT SAVE	-0.1696	0.1064	-0.1077	0.0936	-0.0113	0.0644	-0.1001	0.1122	0.1164	0.0822
GOAL GHG SAVE	0.1044	0.1193	-0.1080	0.0997	0.0329	0.0734	-0.0992	0.1264	0.1433	0.0981
ELECTRICITY PRICE	0.0058	0.0204	-0.0053	0.0173	-0.0198	0.0131	-0.0224	0.0227	-0.0554 **	0.0167
ONLINE SURVEY	0.3274 **	0.1285	-0.0183	0.1093	0.0693	0.0743	-0.1091	0.1399	0.1704 *	0.0898
COMPLIANCE RATE	-0.9459 **	0.2873	0.5693 *	0.3502	0.0272	0.2061	0.0705	0.4039	0.4415 **	0.2160
									for	index
Mu(1)	1.3894 **	0.0765	1.2654 **	0.0595	1.6101 **	0.0535	0.8995 **	0.0887	0.9158 **	0.0690
Mu(2)	2.2339 **	0.0875	2.0349 **	0.0751	2.3576 **	0.0731				

Note: * indicates significance at p=0.10 level and ** indicates significance at p=0.05 level.

Table A.1: Aggregate data on appliance purchases, energy class responses, and energy class choice by appliance and country

	Belgium	Bulgaria	Czech	Denmark	France	Germany	Greece	Hungry	Norway	Portugal	Romania	Total
Number of households	535	509	478	419	100	545	416	490	255	533	622	4902
Refridgerator												
Number of households purchasing in last 5 years	149	57	48	199	31	106	11	42	70	39	40	792
Number of households reporting energy class	109	28	39	171	21	55	4	35	44	30	37	573
Distribution of reported classes												
G												0
F												0
E												0
D		1	1	3								5
C	1	1		5	1		1		1	1		11
B	4	2	3	21	2	8		2	3	5	1	51
A	23	18	24	59	14	26		24	22	12	28	250
A+	46	3	8	63	3	15	2	3	8	3	2	156
A++	35	3	3	20	1	6	1	6	10	9	6	100
Refridgerator - Freezer Combination Units												
Number of households purchasing in last 5 years	99	192	244	182	38	138	224	206	80	258	256	1917
Number of households reporting energy class	63	109	232	153	23	90	122	175	60	201	241	1469
Distribution of reported classes												
G												0
F						1						1
E												0
D		1	2						1	1		5
C		3	5	2			2	1	1	8	1	23
B	4	13	25	29	1	11	19	21	1	22	25	171
A	26	62	130	59	16	53	73	112	37	96	162	826
A+	22	17	65	51	2	20	14	19	14	23	45	292
A++	11	13	5	12	4	5	14	22	6	51	8	151
Freezer												
Number of households purchasing in last 5 years	114	24	48	269	22	122	65	47	73	109	60	953
Number of households reporting energy class	74	11	42	228	17	84	37	38	53	77	53	714
Distribution of reported classes												
G									1			1
F												0
E												0
D				2					1	2		5
C	6	1	2	12	1		7	1		2	2	34
B	6	4	4	38	1	8	5	3	6	13	11	99
A	32	4	28	84	6	44	11	24	26	33	33	325
A+	20	1	7	67	7	22	9	5	13	6	3	160
A++	10	1	1	25	2	10	5	5	6	21	4	90
Washing Machine												
Number of households purchasing in last 5 years	143	262	262	236	50	224	218	157	134	268	311	2265
Number of households reporting energy class	80	150	239	224	33	148	114	56	94	194	290	1622
Distribution of reported classes												
G		1									1	2
F		1			1							2
E		1	1									2
D		1						1		2		4
C	2	11	5	3	1	2	5	8		2	7	46
B	14	24	30	22	2	23	25	15	10	15	53	233
A	64	111	203	199	29	123	84	32	84	175	229	1333
Tumble Dryer												
Number of households purchasing in last 5 years	117	22	28	145	17	99	27	7	71	72	27	632
Number of households reporting energy class	91	17	23	134	12	68	11	6	41	59	20	482
Distribution of reported classes												
G												0
F												0
E	1											1
D	3					3						6
C	9		6	21	3	10	1	2	3	7		62
B	13	3	5	41	1	16	4		11	6	1	101
A	65	14	12	72	8	39	6	4	27	46	19	312
Dish Washer												
Number of households purchasing in last 5 years	147	92	149	207	52	141	119	51	107	201	41	1307
Number of households reporting energy class	112	56	139	195	29	90	69	41	75	164	40	1010
Distribution of reported classes												
G												0
F												0
E			2									2
D			3							2		5
C			5	5		2	2		1	1		16
B	8	1	16	18	1	21	10	2	8	23	3	111
A	104	55	113	172	28	67	57	39	66	138	37	876