CHEETAH

Changing energy efficiency technology adoption in households

D 4.4 Working Paper on the role of policies and key factors for household stated adoption of energy-efficient technologies in the EU

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1 Introduction

This report is submitted as Deliverable 4.4 in the CHEETAH project. Based on the CHEETAH survey, it presents the findings of the discrete choice experiments (DCE) carried out for refrigerators in eight EU countries (France, Germany, Italy, Poland, Romania, Spain, Sweden, and the United Kingdom). In particular, Deliverable 4.4 focusses on the role of energy labels and rebates for A^{+++}-labelled refrigerators. In addition, the analyses consider the effects of household income on the effectiveness of rebates, and of energy literacy on the effectiveness of energy labels. Since Deliverable 4.4. allows household response to policies to vary by household characteristics, it also fulfils one of the key objectives of CHEETAH.

Deliverable 4.4 is organized as follows: The literature review in Section 2 surveys the existing empirical literature on the role of energy labels and rebates for appliances, summarizes findings of DCEs for household appliances, and takes stock of previous work analysing the role of income and energy literacy on household adoption of energy-efficient technologies (EETs). The methodology Section 3 briefly presents the CHEETAH survey, describes in detail the DCE for refrigerators, presents the items capturing energy literacy in the survey, and depicts the econometric models employed to analyse the DCE and the correlates of energy literacy. Results are presented in Section 4. The final Section 5 concludes and discusses policy implications.

2 Literature review

The literature review first summarizes the findings of the extant empirical literature on the role of energy labels and rebates for household appliances. Then, findings from DCEs for household appliances are summarized, thereby highlighting the findings on the effects of policies. A third subsection summarizes the results of empirical studies on the relation of income and EET adoption. The final subsection surveys the emerging empirical literature on the role of energy literacy for household adoption of EETs.

2.1 Energy labels for household appliances

Labelling schemes are expected to provide observable, uniform, and credible information on appliances energy performance and costs (e.g., Truffer et al., 2001). In this sense, energy labelling schemes are often considered as a cost-effective measure to overcome barriers related to information and search costs (transaction costs), or to bounded rationality on the part of appliance purchasers (Sutherland, 1991; Howarth et al., 2000; Mills and Schleich, 2010). In turn, providing consumer information on appliance energy efficiency is expected to create market incentives for appliance manufacturers to design more energy-efficient products (see, e.g., Fraunhofer ISI, 2014).

Mandatory energy labels, originally introduced in the 1990s through the Framework Directive 92/75/EEC, are also the key EU policy instrument to accelerate the diffusion of energy-efficient appliances.[1]·As of today, the EU labelling scheme is the most widespread energy labelling program worldwide and served as a model for similar schemes in Argentina, Brazil, China, Egypt, Iceland, Iran, Israel, Norway, Russia, South Africa, Switzerland, and Tunisia (Harrington and Damnics, 2004; World Energy Council, 2013).

Evaluation studies based on aggregate observed data typically find that the existing energy labelling programs for household appliances in the EU, the US or Australia are effective in terms of energy and carbon reductions (e.g., Sanchez et al., 2008; Lane et al., 2007; Banerjee and Solomon, 2003; Bertoldi, 1999; Waide, 2001; Waide, 1998). Reiss and White (2008) observe that consumers respond to both energy prices and information campaigns to reduce energy consumption. For example, Newell et al. (1999) find that the mean energy

[1] Labels have been introduced in the EU for refrigerators, freezers, washing machines, dryers, dishwashers, air-conditioners, TVs, and household lamps; the system was recently extended to cover further appliances, including vacuum cleaners and ventilation fans. See also http://www.eceee.org/ecodesign/products

efficiency of water heaters and air conditioners sold in the US rose significantly once a labelling scheme was introduced in 1975.

2.2 Rebates for energy-efficient household appliances

The adoption of energy-efficient appliances is occasionally promoted via rebates. In providing up-front financial incentives, rebates help overcome lack of capital, present bias (in time discounting), or inertia. Rebates also lower financial risk.

Many rebate programs exist in the US and Canada, where utilities and federal and local governments offer financial incentives for the purchase of ENERGY STAR-labelled appliances, typically via mail-in-rebates. In some US states, these rebate programs help utilities fulfil their obligations under the Energy Efficiency Resource Standard (EERS) program. Similarly, in Europe, rebate schemes may be part of utilities' efforts to meet the provisions of energy efficiency obligations according to the Energy Efficiency Directive (EED 2012/27/EU) or of national tendering schemes for energy savings. A few programs limit rebates to particular socio-economic groups, such as the "Stromspar-Check-PLUS" program for low-income households in Germany (Seifried and Albert-Seifried, 2015).

Only a few studies have analysed the impact of rebate programs at the individual (i.e., microeconomic) level. For dishwashers, Galarraga et al. (2013) conclude that a subsidy scheme promotes adoption of energy-efficient appliances in Spain. Evaluating a large-scale program in Mexico that, among others, subsidizes households' purchases of energy efficient refrigerators, Davis et al. (2014) conclude that refrigerator replacement lowers household electricity consumption by 7%. For the same program, Boomhower and Davis (2014) report that about two thirds of the participants would have purchased an energy-efficient appliance in the absence of rebates, suggesting a high share of free riders. Relying on state-level data, Datta and Gulati (2014) analyse the effects of rebates for US ENERGY STAR-labelled washing machines, dishwashers, and refrigerators. Their estimates suggest that a rebate amount increase by one US dollar increases the share of ENERGY STAR-labelled washing machines by 0.4%, but does not appear to affect the adoption of dishwashers or refrigerators. Similarly, employing US state level data for washing machines, dishwashers, refrigerators, as well as air conditioners, Datta and Filippini (2016) find rebate programs to increase the sales shares of ENERGY STAR appliances between 9% and 18%, depending on the estimation approach. Thus, the estimated effectiveness of the US state level rebate programs is substantially higher in Datta and Filippini (2016) than in Datta and Gulati (2014). Finally, Houde and Aldy (2014) evaluate the US "Cash for Appliances" State Energy Efficient Appliance Rebate Program (SEEARP), which was implemented through the 2009 American Recovery and Reinvestment Act. The program offered rebates to consumers purchasing residential appliances that met or exceeded the ENERGY STAR requirement. Using transaction-level data on the sales of refrigerators, washing machines, and dishwashers, they find the impact of the rebate to be marginal, even though some participants replaced their old appliances a few years earlier than planned in response to the rebate. Most notably though, the estimated shares of the "free riders" appears large: 91% for refrigerators, 92% for washing machines, and 73% for dishwashers. Also, most consumers adjusted the timing of their purchase by simply postponing their purchases (by a few weeks) until their state's rebate program became effective; other consumers purchased larger appliances or appliances with more features, implying rebound effects.

Overall, previous research therefore suggests that rebate programs for energy-efficient appliances have some effects on the share of energy-efficient appliances sold, but also attract many free riders.

2.3 Findings from discrete choice experiments

Originally applied in the context of transportation (Ben-Akiva and Lerman, 1985), discrete choice experiments (DCEs) have recently also been applied to residential energy use. So far, there are few DCEs on household appliances (see Table 1). They typically conclude that stated adoption is negatively related with the purchasing price and – if it is included as an attribute – with energy consumption (or energy costs).

Sammer and Wüstenhagen (2006) find that the EU energy label, which is also applied in Switzerland, affects Swiss consumers' stated purchasing decisions. In particular, Swiss consumers are willing to pay a premium of 30% of the average price of products in their sample for energy-efficient (i.e., A-labelled at the time the survey was conducted) washing machines. Interestingly, they find consumer willingness to pay for A-labelled products to be higher than the actual cost savings expected over the lifetime of the product. Similarly, for households in Germany, Heinzle and Wüstenhagen (2012) observe a higher willingness to pay for television sets with a higher energy efficiency class. Jain et al. (2018) find that 71% (78%) of households in the Mumbai suburban area in India place a positive value on the highest energy class for refrigerators (air conditioners). Moreover, they find that income has an effect on the valuation of higher energy classes for air conditioners but not for refrigerators. The evidence is mixed: For air conditioners, high-income households value the highest energy class less compared to low-income households, whereas middle-income households value it more compared to low-income households.

In the DCE by Revelt and Train (1998), rebates induced 8.5% of customers to switch from a standard refrigerator to a higher efficiency refrigerator. For the US, Li et al. (2016) find that offering a mail-in rebate for ENERGY STAR-labelled refrigerators induces uncertainty about the quality of those refrigerators. Hence, such a label may backfire and actually lower the willingness-to-pay for energy-efficient appliances.

We note that so far only few DCEs for appliances were carried out in an EU country, and no DCE involved multiples countries. In addition, while in practice rebates are offered for energy-efficient appliances only, no DCE has yet simultaneously explored the effects of labels and rebates. Further, with the exception of Jain et al. (2018), no DCE has explicitly allowed participants' responses to policy (and other attributes) to differ by household characteristics, notably income. Finally, previous DCEs did not analyse the effects of energy literacy on the effectiveness of policies, notably energy labels.

2.4 Income and adoption of energy-efficient appliances

Income is likely to affect adoption of energy-efficient appliances (see Schleich 2019). In particular, low-income households may not have the financial means to purchase energy-efficient appliances, which typically have a higher purchase price than less efficient appliances. Similarly, low-income households are more likely to suffer from credit constraints because they often cannot offer adequate collateral. At the same time though, low-income households typically spend a higher share of their income on energy services. Thus, low-income households may particularly benefit from adopting energy-efficient technologies (e.g., Schleich and Mills, 2012), or from rebates for energy-efficient appliances.

Existing empirical studies tend to find a positive relation between (household) income and the adoption of energy-efficient appliances (e.g., Mills and Schleich, 2010, 2012; Ramos et al., 2015; Trotta, 2018, Schleich et al., 2019, Schleich, 2019).

2.5 Energy literacy and adoption of energy-efficient appliances

In the past, several empirical analyses have included education as a covariate when exploring the adoption of EET. Typically, they find higher levels of education to be positively related with household purchase of EET (e.g., Mills and Schleich, 2012; Ramos et al. 2016) or household awareness of the energy label (Mills and Schleich, 2010). In Brounen et al. (2013), more educated individuals were more likely to make rational decisions when comparing two heating systems differing in up-front costs and fuel bills. Defining rational decision makers in this decision exercise as "energy literate", Brounen et al. (2013), however, do not find respondents who are more "energy literate" or more aware of their energy costs to exhibit more energy conserving behaviours. Brounen et al. (2013) further find evidence that energy literacy is higher for male respondents, and positively related with education. Finally, Zografakis et al. (2008) find that introducing energy literacy into school curricula has a positive effect on energy-saving behaviour of students.

Blasch et al. (2018a) define energy literacy as "an individual's ability to make informed and deliberate choices in the domain of household energy consumption". Defining energy literacy as an index reflecting individual knowledge about energy prices and energy use of different appliances, they find individuals having a higher energy literacy to be more likely to identify the refrigerator with the lowest lifetime costs in an experiment. In this experiment, participants were shown two refrigerators which differed only in purchase price, energy use, and energy efficiency rating (A^{+++} versus A^{+}). In one treatment group, the label provided information on annual electricity use (as in the EU label); in another treatment group, the label showed annual energy cost.

Overall, while there is substantial empirical literature analysing the relation of income and energy-efficient technology adoption, the literature analysing the role of energy-literacy is just emerging.

Table 1. Overview of findings from choice experiments on appliances in the residential sector

Study	**Country**	**Product & measures**	**Attributes in choice experiment**					
			Financial attributes	**Product characteristics**	**Environmental benefit**	**Energy label /warranties**	**Other policies**	**Econometric model**
Jain et al. (2018)	India	Air conditioner and refrigerator	Price (-)	Brand (+ for two out of three brands) Air filters (+) Noise level (0) Freezer space (+) Deodorizer (0)		Energy label (+)		Mixed logit with correlated random parameters and interactions between attributes and consumer variables
Li et al. (2016)	US	Refrigerator	Price	Brand (+ for well-known brands) Capacity (+) Ice dispenser (+) Water dispenser (+)		Energy star (+)	Mail-in rebate (but not included as an attribute)	GMNL with scale factor, willingness to pay (WTP) space, ordered probit
Zhou and Bukenya (2016)	China	Air-Conditioner	Price (-)	Brand (+ for well-known brands Variable speed (+))		Energy label (+)		Mixed logit
Jeong and Kim (2015)	Korea	Refrigerator/ laptop	Price (-) Electricity costs (-)		CO_2 emissions (-)	Efficiency grade (+) E-Standby Label (+) Carbon footprint (+) Eco-Label (+)		Mixed logit
Heinzle and Wüstenhagen (2012)	Germany	TV	Price (-)	Brand (+ for well-known brands) Equipment version (+ for higher versions)		EU-energy label (+ for higher energy classes)		Hierarchical Bayesian (HB) estimation

Study	Country	Product & measures	Attributes in choice experiment					
			Financial attributes	**Product characteristics**	**Environmental benefit**	**Energy label /warranties**	**Other policies**	**Econometric model**
Ward et al. (2011)	US	Refrigerator	Price (-)	Brand (+ for well-known brands) Capacity (+) Ice dispenser (+) Water dispenser (+)		Energy star (+)		Mixed logit
Shen and Saijo (2009)	China	Air-conditioner and refrigerator	Price (-) Electricity consumption (-)	Brand (+ for well-known brands) Capacity (refrigerator) (+) Noise reduction (refrigerator) (+) Air purifier (air conditioner) (+)		Energy label (+)		Mixed logit, Latent Class logit
Sammer and Wüstenhagen (2006)	Switzerland	Washing machine	Price (-) electricity consumption (-) Water consumption (-)	Brand (+ for well-known brands) Equipment version (+ for higher versions)		EU energy label (+ for higher energy classes)		Multinomial logit
Revelt and Train (1998)	US	Refrigerator	Price (-) Electricity cost savings (+) Amount borrowed (+) Interest rate (-)			Efficiency label (+)	Rebate dummy (0) /loan dummy (0) for high efficiency units	Mixed logit

Note: statistically significant effect on WTP: positive (+) / negative (-); not significant: (0)

3 Methodology

The first part of this section describes the survey, including the DCE for refrigerators, the items used to create an index for energy literacy, and the socio-economic and attitudinal variables employed. The second part describes the econometric methods used to analyse the DCE and the correlates of energy literacy.

3.1 Household survey

We implemented an online survey via computer-assisted web interviews (CAWI) among households in eight EU member states: France (FR), Germany (DE), Italy (IT), Poland (PL), Romania (RO), Spain (ES), Sweden (SE), and the United Kingdom (UK). The household panel was provided by NORSTAT.

The survey was fielded in July and August 2018. In each country, participants were selected via quota sampling to be representative in terms of gender, age, income, and regional population dispersion.

The main part of the survey consisted of a stated preference discrete choice experiment (DCE) on hypothetical technology adoption. Socio-demographic information was gathered both at the beginning of the questionnaire (to ensure that quota requirements were met), and at the end of the questionnaire.

3.1.1 Discrete choice experiment on refrigerator purchase decisions

The discrete choice experiment (DCE) is a method founded in random utility theory (McFadden, 1974). It assumes that products in a given market can be thought of as consisting of different vectors of characteristics. Consumers derive utility from characteristics of products and then choose their preferred product by comparing options available in the market. Therefore, a DCE simulates market transactions by constructing hypothetical choice scenarios where alternatives are described by a range of attributes, and where respondents are expected to make trade-offs between different attributes and select their most preferred alternative. This allows estimating values for multiple attributes of a product and their trade-offs simultaneously.

In our DCE, participants were asked to imagine that their refrigerator had broken down and thus needed to be replaced.[2] They were then asked to make a series of choices between different refrigerator purchase options. These options differed by capacity, energy efficiency class, length of warranty, customer review ratings, purchase price and subsidies available (attributes and levels are summarized in Table 2). Attributes were chosen to represent relevant information for customers choosing a refrigerator and to be independent of one another. Attributes for capacity, energy consumption, purchase price and financing measures have already been used in choice experiments on refrigerator purchase decisions (see Table 1). We adapted the attributes to fit the EU refrigerator market and added to the list two quality attributes, length of warranty and customer review ratings.

Overall, the attributes were chosen to cover the majority of the refrigerator market in the EU, therefore covering the most common range of sizes and prices available at the time of the study. Extreme values (for instance mini-refrigerators) were left out so that the choices proposed could be realistic and comparable and that the majority of consumers could seriously consider each option proposed. Information on energy efficiency class was provided in the same form as on the EU energy label for refrigerators. Accounting for the fact that most newly sold refrigerators on the EU market have an energy efficiency class A^{+} or higher, respondents were shown refrigerators with energy efficiency class A^{+}, A^{++}, or A^{+++}. Subsidies varied from 25€ to 100€ and were only available for refrigerators with energy efficiency class A^{+++}. Length of warranty was chosen to vary from 2 to 6 years.

[2] The exact wording used in the DCE was as follows: "Imagine that your refrigerator has broken down and you need to buy a new one. On the following pages, we will show you different refrigerator purchase options. We would like to know which refrigerator you would choose, if these were your only options .Please assume that all refrigerator options fit properly in your kitchen and are currently available in color and finish of your choice."

Customer ratings, which have been shown to have a great impact on purchase decisions (Chevalier and Mayzlin, 2006; Moe and Trusov, 2011), were also included with the typical five-star representation used in many online stores; we included three levels, ranging from 3.5 stars to 4.5 stars.

Table 2. Levels of different attributes considered in the refrigerator choice experiment

Attribute	Levels
Size	220 L, 240 L, 260 L, 280 L, 300 L, 320 L
Energy class	A+, A++, A+++
Warranty	2 years; 4 years; 6 years
Customer rating	3.5/5 stars; 4.0/5 stars; 4.5/5 stars
Purchase price	250 €, 350 €, 450 €, 550 €, 700 €, 850 €
Subsidy	0 €, 25 €, 50 €, 100 €[a]

[a] Subsidies were only offered for refrigerators with energy class A+++.

To reduce the large numbers of possible treatment combinations and increase the efficiency of design, we applied a B-efficient design (Sándor and Wedel, 2001) using the NGENE software (ChoiceMetrics, 2014). The priors used for the design were obtained from a pilot study with 50 UK respondents from Prolific Academic.[3] Our choice experiment consisted of 24 scenarios divided into three blocks (each respondent was randomly assigned to one of the blocks). An example for a scenario as shown to respondents is depicted below for the experiment in the UK.

Since the survey was conducted in countries with different currencies, the monetary amounts used in the DCEs were adjusted to keep the relative value similar between countries in terms of purchasing power. To this end, the following rates were applied: Poland: 1€ = 3 PLN; Romania: 1€ = 3 RON; Sweden: 1€ = 10 SEK; UK: 1€ = 1£. In all Euro-zone countries, the monetary amounts shown to participants were identical; for Sweden, the UK, Poland, and Romania, monetary amounts were multiplied by their respective factors.

An example for a choice card as shown to participants is depicted in Figure 1.

Scenario 1

Which refrigerator would you choose?

	Refrigerator A	Refrigerator B
Size	280 L	260 L
Energy class	A+++	A++
Warranty	2 years	6 years
Customer rating	3.5 stars	4.0 stars
Purchase Price	£700	£850
Subsidy	£25	£0

	Refrigerator A	Refrigerator B
I choose:	○	○

Figure 1. Example for a scenario as shown to respondents in the UK.

[3] Prolific Academic is a crowdsourcing platform that permits recruitment of participants for academic research studies; the platform has been tested and validated by academic researchers (Peer et al. 2017).

3.1.2 Individual and household characteristics

In addition to the DCE, the survey included items on socio-economic characteristics, attitudes, and dwelling characteristics. These are further described in Table 3. Descriptive statistics appear in Appendix Table A1.

Table 3. Household and individual characteristics

Label	Description
Female	Dummy = 1, if respondent is female.
Age	Continuous, between 18 and 65 years old
Low income	Dummy = 1, if reported household income falls into the lowest income quartile in a country, and 0 else.
High education	Dummy = 1, if level equal to or higher than country median. Considered levels: no degree or certificate/trade or vocational certificate /high school or equivalent/higher education.
High CRT score	Dummy = 1, if level equal to or higher than country median of number of correct answers to the following questions from the Cognitive Reflection Test (CRT) (Fredericks, 2005): *(1) "A bat and a ball cost 1.10€ in total. The bat costs 1.00€ more than the ball. How much does the ball cost?* *(2) If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets?* *(3) In a lake, there is a patch of lily pads. Every day, the patch doubles in size. It takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake?"*
Region	Dummy = 1, if the household lives in Ile-de-France (FR), Eastern Germany (DE), Southern Italy (IT), Eastern Poland/*Poland B* (PL), Central or Eastern Romania (RO), Basque Country, Canary Islands or Catalonia (ES), Northern Sweden (SE), Northern Ireland, Scotland or Wales (UK)
City	Dummy = 1, if the household lives in or close to a major city
Tenant	Dummy = 1, if the household is renting the current dwelling.
Detached housing	Dummy = 1, if house is detached.
High heating costs	Dummy = 1, if heating cost are higher than country median. (Calculations are based on respondents' self-reported annual heating costs in 2017. In case respondents did not know these, heating costs were estimated based on housing characteristics such as size and geographical location.
Big family	Dummy = 1, if the number of household members > 2
Environmental identity	Score reflecting environmental identity (adapted from Whitmarsh and O'Neill 2010). Constructed as the average of the equally weighted responses to the subsequent scale items (1= strongly disagree to 5= strongly agree): *"Please rate how much you agree with the following statements (i) To save energy is an important part of who I am. (ii) I think of myself as an energy conscious person. (iii) I think of myself as someone who is very concerned with environmental issues. (iv) Being environmentally friendly is an important part of who I am."* The z-score is used in the analysis.
Low energy literacy	Dummy = 1, if the number of correct answers in a three-item energy literacy test was below (or equal to) the median score in a country. These items were adapted from Blasch et al. (2018a) and deWaters and Powers (2011):

Label	Description
	(1) "Which of the following typically uses more electricity? (i) 5 minutes drying hair with a hair dryer, (ii) 1 hour watching TV, (iii) both consume about the same, (iv) Don't know. *(2) "Which of the following typically uses more electricity? (i) bringing one litre of water to boil in an average pot with a lid on an electric stove, (ii) Bringing one litre of water to boil in an electric kettle, (iii) both consume about the same, (iv) Don't know.* *(3) "Over the course of one year, which of the following uses the most electricity in an average [country name] household? (i) Computer, (ii) Television, (iii) Telephone, (iv) Lights, (v) Refrigeration, (vi) Cooking*

3.2 Econometric methods

To analyse the choice experiment, we employed a mixed logit model. Further, to identify sources of heterogeneity in household response to policies, we interacted the policy attributes in the DCE with dummy variables for low income and low energy literacy, respectively. Lastly, to explore the relation between energy literacy and socio-economic and attitudinal factors, we ran a standard probit model for each country. To save space, and since the probit model is straightforward, we only present the mixed logit model with and without interaction terms.

3.2.1 Standard mixed logit model

In contrast to conditional logit models, mixed logit models do not rely on the so-called Independence of Irrelevant Alternatives (IIA) assumption and allow for unobserved heterogeneity of individual preferences (Revelt and Train, 1998). Thus, coefficients may vary across individuals.

In a given sample, a total of *N* respondents is assumed to face *T* choice situations with a choice set of J alternatives. The utility for respondent n choosing alternative j in the choice set in choice situation t may be expressed as:

$$U_{njt} = \beta_n X_{njt} + \varepsilon_{njt}, \quad n = 1, \dots, N, \quad j = 1,2, \quad t = 1, \dots, T \qquad (1)$$

where X_{njt} is the observed attributes vector of refrigerators in our choice experiment and β_n is a vector of individual-specific parameters associated with each attribute. The unobserved error term ε_{njt} is assumed to be Gumbel-distributed. In our DCE, participants faced 8 choice situations, i.e., T=8. Each situation involved two alternatives, i.e., J=2. As is standard in mixed logit models, coefficients for all attributes except price were allowed to vary across individuals. Due to the nested structure of the policy attributes *energy label* and *rebate* (i.e., rebates were only available for A^{+++}-labelled refrigerators), we included these attributes using three dummy variables for A^{++}-labelled options, A^{+++}-labelled options with no rebate, and A^{+++}-labelled options with a rebate. The remaining attributes were treated as continuous variables.

Conditional on knowing β_n, the probability of an individual n to choose alternative j in situation t can be expressed by:

$$P_{njt}(\beta_n) = \frac{\exp(\beta_n X_{nit})}{\sum_{j=1}^{J} \exp(\beta_n X_{njt})} \qquad (2)$$

The parameter β_n varies among respondents according to a distribution with a density $f(\beta|\theta)$, where θ is a vector of parameters of the distribution (Train, 2003). In this paper, each individual-specific parameter is assumed to be normally distributed.

Knowing β_n, the conditional probability of the observed sequence of choices is given by:

$$\Gamma_n(\beta_n) = \prod_{t=1}^{T} P_{njt}(\beta_n) \tag{3}$$

Since β_n is unknown, the unconditional probability of the observed sequence of choices is the conditional probability integrated over the distribution of β:

$$\Lambda_n(\theta) = \int \Gamma_n(\beta_n) f(\beta|\theta) d\beta \tag{4}$$

The log likelihood function is given by:

$$LL(\theta) = \sum_{n=1}^{N} \ln \Lambda_n(\theta) \tag{5}$$

Since this function cannot be solved, it is approximated through simulation (Train, 2003). The simulated log likelihood is given by:

$$SLL(\theta) = \sum_{n=1}^{N} \ln \left\{ \frac{1}{R} \sum_{1}^{R} \Gamma_n(\beta^r) \right\}, \tag{6}$$

where R is the number of replications and β^r is the rth draw from $f(\beta|\theta)$. We used 500 Halton draws.

The marginal willingness-to-pay (WTP) for an attribute x is calculated as the negative of the ratio of the respective parameter β_x to the price parameter β_p.

$$WTP_x = -\frac{\beta_x}{\beta_p} \tag{7}$$

3.2.2 Mixed logit with interaction effects for income and for energy literacy

To test to what extent heterogeneity in household response to policies arises from observable differences in household income and energy literacy, we include dummy variables for low income and low literacy in interaction with the alternative's energy class and rebate. We thus estimated the following function:

$$U_{njt} = \beta_{n,price} priceb + \beta_{n,size} size + \beta_{n,wa} warranty + (\beta_{n.A2} + \beta_{lowincA2} lowinc + \beta_{lowlitA2} lowlit) \times A2 + (\beta_{n,A30} + \beta_{lowincA30} lowinc + \beta_{lowlitA30} lowlit) \times A3\_0 + (\beta_{n,A3sub} + \beta_{lowincA3sub} lowinc + \beta_{lowlitA3sub} lowlit) \times A3\_sub + \beta_{n,star4} star4 + \beta_{n,star45} star45 + \varepsilon_{njt}, \tag{8}$$

where *lowinc* and *lowlit* denote the dummy variables for low household income and low energy literacy, respectively, and coefficients of interactions are assumed to be fixed.

4 Results

4.1 Descriptive statistics

After dropping incomplete survey responses and speeders (i.e., respondents who took less than one fourth of the median response time in the discrete choice experiment), we were left with sample sizes ranging from 415 (Italy) to 599 (Sweden) respondents in each country. Table A1 in the Appendix provides the descriptive statistics for the variables described in Table 3.

It is worth noting that energy literacy was overall found to be higher in Germany, Italy, and Sweden compared to the other countries. In these 3 countries, respondents with less than 2 correct answers were labelled as having a low energy literacy (50% in Germany and Sweden, 48% in Italy)[4]. In the remaining countries, respondents who answered none of the questions correctly were labelled as having a low energy literacy (33% in France, 29% in Poland, Romania, and the UK, and 26% in Spain).

4.2 Results for discrete choice model

Table 4 shows estimates for the parameters in equation (8). Mixed logit results for the model without interaction terms are reported in Appendix Table A2. Standard errors appear in parenthesis below parameter estimates. The upper part of the table shows the mean values of the coefficients, the lower part shows the standard deviations. The variable *priceb* denotes net price, i.e., price minus rebates. *A3_0* is a dummy variable for energy class A^{+++} and no rebate, while *A3_sub* is a dummy variable for energy class A^{+++} combined with a rebate. The standard deviations of most parameter estimates are statistically significant, suggesting (unexplained) heterogeneity of these parameters across respondents, and therefore corroborating the appropriateness of using a mixed logit model.

The coefficient associated with *priceb* in Table 4 is negative and statistically significant in all countries. Thus, as to be expected, an increase in net price lowers the latent utility and hence the propensity to purchase a refrigerator. Higher capacity, higher energy class, longer warranty periods and better customer ratings generally increase respondents' propensity to purchase a refrigerator.

A higher parameter estimate for *A3_sub* than for *A3_0* implies that rebates provide an additional, non-monetary benefit. For repondents with high energy literacy from households in high income groups, this is the case in all countries except the UK (compare parameters for *A3_0* and *A3_sub* without interaction terms). For the average respondent from a household in the lowest income quartile, in Italy, Romania and Spain, rebates do not provide additional non-monetary benefits (compare the sum of parameters *A3_0* and *lowinc_A3_0* to the sum of parameters *A3_sub* and *lowinc_A3_sub*). Moreover, in Poland respondents from households in the lowest income quartile value higher energy class less compared to respondents from higher income households, independent of whether or not a rebate is available. In Germany (Sweden), on the other hand, respondents from households in the lowest income quartile value energy class A^{++} (A^{+++} without rebates) more, compared to respondents from higher income households.

In France, Poland and Sweden, we observe negative and statistically significant parameter estimates for the interactions between low energy literacy and A^{+++} energy class with and without rebates. This suggests that respondents with low energy literacy value an A^{+++} label less compared to respondents with higher energy literacy. In Germany, we observe a similar effect, but only in the absence of rebates. In the UK, rebates further decrease the propensity to purchase an A^{+++} refrigerator for respondents with low literacy. Finally, in Italy, we find that respondents with low energy literacy value energy class A^{++} less, compared to respondents with high energy literacy.

[4] In Germany, Italy and Sweden, 14%, 16% and 9% of respondents, respectively, answered none of the questions correctly.

Table 4. Results for mixed logit model

	France	Germany	Italy	Poland	Romania	Spain	Sweden	UK
Mean								
priceb	-0.008***	-0.006***	-0.005***	-0.0050***	-0.0047***	-0.0058***	-0.0079***	-0.0086***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
lowinc_A2	-0.1030	0.5868*	-0.2835	-0.8420***	-0.0514	-0.0606	0.2189	0.3503
	(0.245)	(0.316)	(0.314)	(0.321)	(0.238)	(0.298)	(0.239)	(0.251)
lowinc_A3_0	-0.2301	0.3546	0.4812	-0.6408*	-0.2763	0.3588	1.0891***	-0.0414
	(0.324)	(0.376)	(0.388)	(0.385)	(0.282)	(0.416)	(0.323)	(0.344)
lowinc_A3_sub	-0.0731	-0.1202	-0.6034**	-0.9892***	-0.5020**	-0.5552*	-0.2036	-0.3478
	(0.227)	(0.283)	(0.304)	(0.289)	(0.225)	(0.288)	(0.223)	(0.218)
lowlit_A2	-0.2959	0.0694	-0.4164*	-0.3346	0.1304	0.0609	-0.2707	-0.3318
	(0.227)	(0.221)	(0.242)	(0.253)	(0.234)	(0.260)	(0.221)	(0.253)
lowlit_A3_0	-0.5880**	-0.4872*	-0.2241	-0.7905***	-0.4213	0.2562	-0.5576*	-0.1122
	(0.297)	(0.267)	(0.297)	(0.297)	(0.266)	(0.359)	(0.287)	(0.346)
lowlit_A3_sub	-0.631***	0.1614	0.0554	-0.5549**	-0.1147	-0.3882	-0.3480*	-0.3679*
	(0.213)	(0.205)	(0.235)	(0.232)	(0.222)	(0.247)	(0.206)	(0.222)
size	0.0066***	-0.0017	0.0111***	0.0107***	0.0056***	0.0124***	0.0147***	0.0103***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
warranty	0.2075***	0.2180***	0.1704***	0.2581***	0.2282***	0.1828***	0.3342***	0.2254***
	(0.022)	(0.021)	(0.023)	(0.023)	(0.021)	(0.021)	(0.025)	(0.024)
A2	0.7779***	0.3262*	0.8637***	0.6699***	0.7397***	0.5354***	0.8178***	0.4042**
	(0.160)	(0.173)	(0.189)	(0.157)	(0.152)	(0.158)	(0.184)	(0.167)
A3_0	1.2567***	0.7076***	1.1189***	1.1598***	1.3159***	1.0865***	1.3647***	1.2739***
	(0.229)	(0.228)	(0.246)	(0.202)	(0.189)	(0.229)	(0.248)	(0.253)
A3_sub	1.4996***	1.0605***	1.8188***	1.7955***	1.9830***	1.7581***	1.8915***	0.9110***
	(0.150)	(0.152)	(0.189)	(0.148)	(0.149)	(0.165)	(0.173)	(0.143)
star4	0.3846***	0.3647***	0.4844***	0.5783***	0.5036***	0.5028***	0.7625***	0.6576***
	(0.081)	(0.079)	(0.086)	(0.090)	(0.078)	(0.088)	(0.079)	(0.089)
star45	0.2862***	0.1294*	0.5308***	0.6651***	0.5108***	0.3623***	0.7966***	0.6429***
	(0.078)	(0.077)	(0.084)	(0.078)	(0.072)	(0.083)	(0.085)	(0.089)
SD								
size	-0.029***	-0.022***	-0.025***	-0.0269***	0.0212***	-0.0204***	0.0300***	0.0248***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
warranty	0.1991***	-0.0578	0.1433***	0.2158***	0.2241***	0.1209***	0.3004***	0.2087***
	(0.029)	(0.045)	(0.032)	(0.028)	(0.025)	(0.033)	(0.028)	(0.030)
A2	0.1247	-0.1221	0.0176	-0.0417	0.3219*	0.0156	-0.1081	0.0920
	(0.173)	(0.224)	(0.210)	(0.200)	(0.192)	(0.195)	(0.167)	(0.165)
A3_0	-0.6499	0.1611	0.1914	-0.4310	-0.1160	1.4644***	0.0367	-1.2107***
	(0.414)	(0.591)	(0.345)	(0.332)	(0.280)	(0.279)	(0.309)	(0.292)
A3_sub	1.1145***	0.9394***	1.0819***	0.9363***	1.2326***	1.1732***	0.9769***	0.9608***
	(0.121)	(0.124)	(0.132)	(0.127)	(0.117)	(0.141)	(0.130)	(0.133)
star4	0.5269***	0.3105	-0.3174	0.7390***	-0.6224***	0.6313***	0.1610	0.4561***
	(0.162)	(0.192)	(0.202)	(0.118)	(0.116)	(0.133)	(0.217)	(0.157)
star45	0.6788***	0.6237***	0.5534***	0.2786	0.5877***	0.6675***	0.8606***	0.8235***
	(0.118)	(0.115)	(0.136)	(0.175)	(0.110)	(0.124)	(0.121)	(0.110)
Model								
LL	-2543.50	-2019.30	-1887.36	-2245.67	-2761.62	-2127.99	-2606.26	-2200.22
LL0	-2869.88	-2189.36	-2071.04	-2494.87	-2985.77	-2294.56	-2926.34	-2417.16
BIC	5278.766	4224.542	3959.538	4679.782	5715.596	4442.646	5405.046	4588.795
AIC	5128.991	4080.591	3816.720	4533.347	5565.247	4297.988	5254.521	4442.445
N	9248	7008	6640	7888	9504	7248	9584	7856

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

To check the robustness of our results, we also estimated parameters in a model without interaction terms between low income and low literacy and A++ energy class. Moreover, we tested an alternative low literacy dummy variable constructed based on answers to energy literacy questions (2) and (3) only (see Table 3). Results are reported in Table A3 in the Appendix and are consistent with those presented in Table 4.

Table 5. WTP results for mixed logit model

	France WTP	Germany WTP	Italy WTP	Poland WTP	Romania WTP	Spain WTP	Sweden WTP	UK WTP
lowinc_A2 (in €)	-	99.46	-	-168.40	-	-	-	-
lowinc_A3_0 (in €)	-	-	-	-128.16	-	-	137.86	-
lowinc_A3_sub (in €)	-	-	-118.31	-197.84	-106.81	-95.72	-	-
lowlit_A2 (in €)	-	-	-81.65	-	-	-	-	-
lowlit_A3_0 (in €)	-70.84	-82.58	-	-158.10	-	-	-70.58	-
lowlit_A3_sub (in €)	-76.06	-	-	-110.98	-	-	-44.05	-42.78
size (in €/L)	0.80	-	2.18	2.14	1.19	2.14	1.86	1.20
warranty (in €/year)	25.00	36.95	33.41	51.62	48.55	31.52	42.30	26.21
A2 (in €)	93.72	55.29	169.35	133.98	157.38	92.31	103.52	47.00
A3_0 (in €)	151.41	119.93	219.39	231.96	279.98	187.33	172.75	148.13
A3_sub (in €)	180.67	179.75	356.63	359.10	421.91	303.12	239.43	105.93
star4 (in €)	46.34	61.81	94.98	115.66	107.15	86.69	96.52	76.47
star45 (in €)	34.48	21.93	104.08	133.02	108.68	62.47	100.84	74.76

Table 5 reports the WTP estimates in those cases where the coefficients reported in Table 4 were statistically significant at least at the 10 percent level. For ease of interpretation, Tables 6 to 9 report the average WTP estimates for

- respondents with high energy literacy from households in above quartile income groups (Table 6),[5]
- respondents with high energy literacy from households in the lowest income quartile (Table 7),[6]
- respondents with low energy literacy from households in above quartile income groups (Table 8),
- and respondents and with low energy literacy from households in the lowest income quartile (Table 9).

Overall, we find that average willingness to pay for energy labels A++ and A+++ is positive for all countries and groups of respondents, with the exception of low-income respondents in Poland who are not willing to pay for an increase in energy class from A+ to A++ (see Table 6 to Table 9).

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[5] Values correspond to those reported in Table 5 for A2, A3_0, and A3_sub without interaction terms.

[6] Values are computed by adding up the WTP estimates for A2, A3_0 and A3_sub and the WTP estimates for the respective interaction terms.

In France, Germany, Poland and Sweden, respondents with low energy literacy are willing to pay considerably less for an A^{+++} label (on average 44€ less to 158€ less) compared to respondents with higher energy literacy (see Table 5). (Note that in Germany, low energy literacy does not negatively affect willingness to pay for A^{+++}-labelled refrigerators, if rebates are available.) In Italy, for respondents with low energy literacy, willingness to pay for A^{++}-refrigerators is reduced by 83€ compared to respondents with higher energy literacy. Furthermore, in Poland, respondents from households with above quartile income are on average willing to pay 128€ to 198€ more for an increase in energy class compared to respondents from households in the lowest income quartile (see Table 5). In Germany, low-income households are on average willing to pay 99€ more for an A^{++} refrigerator compared to higher income households. Lastly, in Sweden, the average low-income household is willing to pay 138€ more for an A^{+++}-labelled refrigerator without a rebate than the average higher income household. The fact that this is not the case for A^{+++}-labelled refrigerators with a rebate suggests that being low income has a negative effect on the valuation of rebates, which cancels out its positive effect on the valuation of increased energy efficiency.

In the absence of rebates, average willingness to pay for an A^{+++} label is higher than the willingness to pay for an A^{++} label for most but not all household groups. Notably German respondents with low household income or low energy literacy (see Tables 7 and 8) as well as French, Polish and Swedish respondents with low energy literacy (see Table 8) are not willing to pay for an increase in energy class from A^{++} to A^{+++} without rebates. When there is a rebate, willingness to pay for an A^{+++} label generally increases. The only exceptions are households in the UK (see Tables 6 to 9) and low-income households in Sweden (see Tables 7 and 9), whose willingness to pay for an A^{+++} label decreases when there is a rebate.

The increase in willingness to pay for A^{+++} refrigerators when there is a rebate is on average less pronounced for low-income households in Italy, Romania and Spain. In Italy, Romania and Spain, high-income respondents are on average willing to pay an extra 148€, 142€, and 116€, respectively, for an A^{+++} refrigerator if there is a rebate. Low-income households, on the other hand, are on average only willing to pay an extra 30€, 35€, and 20€, respectively.

Table 6. Willingness to pay estimates for energy labels and rebates for respondents with high energy literacy from households in the highest income quartile.

	France WTP	Germany WTP	Italy WTP	Poland WTP	Romania WTP	Spain WTP	Sweden WTP	UK WTP
A2 (in €)	93.72	55.29	169.35	133.98	157.38	92.31	103.52	47.00
A3_0 (in €)	151.41	119.93	219.39	231.96	279.98	187.33	172.75	148.13
A3_sub (in €)	180.67	179.75	356.63	359.10	421.91	303.12	239.43	105.93

Table 7. Willingness to pay estimates for energy labels and rebates for respondents with high energy literacy from households in the lowest income quartile.

	France WTP	Germany WTP	Italy WTP	Poland WTP	Romania WTP	Spain WTP	Sweden WTP	UK WTP
A2 (in €)	93.72	154.75	169.35	-32.42	157.38	92.31	103.52	47.00
A3_0 (in €)	151.41	119.93	219.39	103.8	279.98	187.33	310.61	148.13
A3_sub (in €)	180.67	179.75	238.32	161.26	315.10	207.40	239.43	105.93

Table 8. Willingness to pay estimates for energy labels and rebates for respondents with low energy literacy from households in above quartile income groups.

	France WTP	Germany WTP	Italy WTP	Poland WTP	Romania WTP	Spain WTP	Sweden WTP	UK WTP
A2 (in €)	93.72	55.29	87.70	133.98	157.38	92.31	103.52	47.00
A3_0 (in €)	80.57	37.35	219.39	97.98	279.98	187.33	102.17	148.13
A3_sub (in €)	104.61	179.75	356.63	248.12	421.91	303.12	195.70	63.15

Table 9. Willingness to pay estimates for energy labels and rebates for respondents with low energy literacy from households in the lowest income quartile

	France WTP	Germany WTP	Italy WTP	Poland WTP	Romania WTP	Spain WTP	Sweden WTP	UK WTP
A2 (in €)	93.72	154.75	87.7	-34.42	157.38	92.31	103.52	47.00
A3_0 (in €)	80.57	37.35	219.39	-54.30	279.98	187.33	240.03	148.13
A3_sub (in €)	104.61	179.75	238.32	50.28	315.10	207.40	195.38	63.15

To sum up, our findings suggest that being a low-income household reduces the positive effect of rebates on the propensity to purchase A^{+++} -labelled refrigerators (Italy, Romania, Spain). At the same time, the effects of low income on the valuation of energy class A^{++} and A^{+++} are limited and vary across countries (negative in Poland, positive for A^{++} in Germany and A^{+++} without rebate in Sweden). Moreover, our results suggest that low energy literacy reduces the propensity to purchase A^{+++}-labelled refrigerators (France, Germany, Poland, Sweden). In Germany, this effect is mitigated by rebates.

4.3 Results for correlates of energy literacy

To explore the relation between energy literacy and socio-economic and attitudinal factors, we ran a standard probit model for each country. To facilitate the interpretation of the findings, the results table reports the marginal effects for continuous covariates and the discrete probability effects for dummy variables such as gender. The findings help identify households that are more likely to suffer from energy illiteracy and may potentially be targeted by policies.

Table 10 presents the findings of running a probit model for energy literacy on our set of covariates. Similar to the finding by Brounen et al. (2013) for the Netherlands, the findings for Poland and Romania suggest that men are more likely to have a high energy literacy. For example, in Poland, being a woman lowers the likelihood of having a high energy literacy by about 14 percentage points. Likewise, age was found to be statistically significant in three countries. That is, older people in Italy, Sweden, and the UK were more likely to have a high energy literacy. For Italy, one additional year of age translates into an increase in the likelihood to have a high energy literacy by about one percentage point. In contrast, income did not turn out to be statistically significant in all eight countries, thereby suggesting no relationship between income and energy literacy. At the same time, and in line with Brounen et al. (2013), more highly educated participants appear to be more prone to have a high energy literacy in France and Spain. The effect size of education is particularly large in France. Participants with a higher CRT score are more likely to have a high energy literacy in five of the eight countries, i.e., in Germany, Italy, Poland, Spain and the UK. The factor supposed to reflect intrinsic motivation to have a high energy literacy, i.e., environmental ID, was only found to be statistically significantly (and positively) related with energy literacy in two countries: in France and Romania. Similarly, the factors supposed to reflect that economic incentives lead to high energy literacy turned out to be statistically significant in few countries only: participants from households with high heating costs in Italy and Spain, from large families in Sweden, and those living in detached houses in Germany were found to have a higher energy literacy. Living in an urban environment was associated with lower energy literacy in Germany, but with higher energy literacy in Spain. Finally, regional effects were found in Poland, Spain and Sweden.

Table 10. Marginal and discrete probability effects for the probit regression of energy literacy on individual and household characteristics

	France	Germany	Italy	Poland	Romania	Spain	Sweden	UK
female=1	0.0106	-0.0311	0.0021	-0.141***	-0.126***	-0.0006	0.0171	0.0176
	(0.805)	(0.523)	(0.966)	(0.001)	(0.001)	(0.988)	(0.703)	(0.684)
age	0.0017	0.0006	0.009***	0.0021	0.0020	0.0014	0.0041**	0.0040**
	(0.333)	(0.768)	(0.000)	(0.197)	(0.246)	(0.466)	(0.016)	(0.014)
highinc=1	0.0045	0.1014	0.0623	0.0819	0.0066	-0.0325	-0.0135	0.0080
	(0.924)	(0.122)	(0.356)	(0.159)	(0.887)	(0.532)	(0.773)	(0.859)
higheduc=1	0.1524***	0.0650	0.0715	0.0168	-0.0380	0.1140**	0.0384	0.0331
	(0.000)	(0.204)	(0.152)	(0.686)	(0.368)	(0.014)	(0.362)	(0.417)
highcrt=1	0.0647	0.1125**	0.1099**	0.1138***	0.0517	0.115***	0.0561	0.122***
	(0.122)	(0.024)	(0.025)	(0.006)	(0.183)	(0.005)	(0.176)	(0.003)
z_env_id	0.0493**	0.0134	0.0129	0.0261	0.0334*	-0.0035	-0.0210	0.0114
	(0.015)	(0.571)	(0.596)	(0.201)	(0.091)	(0.856)	(0.298)	(0.568)
region=1	-0.0881	0.0551	0.0120	0.0889**	-0.0059	0.131***	-0.1078*	-0.0302
	(0.108)	(0.347)	(0.816)	(0.024)	(0.881)	(0.005)	(0.065)	(0.626)
city=1	0.0166	-0.1042**	0.0137	0.0124	-0.0363	0.1061*	-0.0429	0.0168
	(0.723)	(0.037)	(0.800)	(0.787)	(0.370)	(0.078)	(0.363)	(0.706)
detached=1	-0.0688	0.1847***	-0.0168	-0.0204	0.0278	0.0758	0.0352	-0.0550
	(0.201)	(0.006)	(0.773)	(0.707)	(0.567)	(0.132)	(0.590)	(0.310)
tenant=1	0.0210	0.0742	-0.0355	0.0402	-0.0175	-0.0062	-0.0010	0.0024
	(0.665)	(0.213)	(0.593)	(0.377)	(0.693)	(0.918)	(0.983)	(0.955)
highheat=1	0.0161	-0.0784	0.0984*	-0.0392	-0.0325	0.144***	-0.0315	-0.0115
	(0.718)	(0.180)	(0.080)	(0.440)	(0.404)	(0.001)	(0.592)	(0.788)
bigfam=1	0.0097	-0.0340	-0.0009	-0.0191	-0.0209	-0.0263	0.130***	-0.0062
	(0.827)	(0.539)	(0.985)	(0.641)	(0.589)	(0.550)	(0.009)	(0.886)
# of observations	527	422	415	493	559	444	599	484
Prob > chi^2	0.0125	0.0135	0.0001	0.0001	0.0236	0.0008	0.0364	0.0642

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5 Policy implications

Employing demographically representative discrete choice experiments on refrigerator purchase decision in eight EU countries and allowing participant responses to the EU energy labelling scheme and to rebates for A^{+++}-labelled refrigerators to vary by income and energy literacy, allows for various policy implications.

Overall, we find that respondents in all countries typically prefer A^{+++}-labelled refrigerators to refrigerators with lower energy classes. Thus, the EU energy label appears to effectively signal additional benefits of these appliances to the consumer such as energy-cost savings. Yet, low energy literacy was found to substantially lower the WTP for A^{+++}-labelled refrigerators in half the countries included in this study (France, Germany, Poland and Sweden). This finding holds for low- and high-income households. In addition, the findings suggest that rebates for A^{+++}-labelled refrigerators are an effective measure to boost the adoption of A^{+++-}labelled refrigerators in all countries. The results further suggest, that on average, rebates rebates are most effective for high income household in Italy, Poland and Romania, and low literacy households in Germany and Poland (looking at the difference between A+++ sub and A+++0). In some countries (Italy, Romania, Spain), the positive effect of rebates is stronger for high-income households than for low-income households. This finding tends to hold for low and high levels of energy literacy. Thus, in these countries, providing a rebate for energy-efficient refrigerators may be regressive, and thus have unwanted distributional effects. In this case, rebates could be offered to low-income households only. To keep transaction costs (e.g., for providing proof of income) low, such schemes could be linked to household eligibility for existing social-security support. Restricting rebates for A^{+++-}-labelled refrigerators to low-income households would also be expected to limit free riding.

In countries such as the UK, where consumers may perceive rebates as signalling low quality, rebate schemes could be complemented by customer ratings or by reports from organizations providing credible product ratings and reviews such as Consumer Reports.

The findings on energy literacy suggest that labelling schemes are more effective for customers with a higher energy literacy. Thus, raising the level of energy literacy via education and information programs (e.g., brochures, online or on-site courses) may be an effective means. Ideally, such programs would be targeted at particular socio-economic groups. Specifically, the results from running probit regressions on the factors related to energy literacy imply that such programs should be targeted at women in Poland and Romania, at younger people in Italy and Sweden, or at individuals with low formal education in France and Spain. For some countries, notably Poland, Spain and Sweden, focussing such programs on particular regions also promises to be effective. In addition, information and tools on how to calculate energy cost savings for the various appliances may be provided at the point of sale, i.e., either in the store or through an internet platform (see also Blasch et al., 2018b).

Finally, the results of the choice experiments (particularly concerning energy literacy) lead us to contemplate that if information on the energy label was more informative, energy literacy may not play as big a role. Arguably, providing energy costs (in €) rather than energy use (in kWh) would help customers to identify the refrigerator with the lowest costs (e.g., lowest total costs of ownership).

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Appendix

Table A1. Descriptive statistics for variables described in Table 2

	France	Germany	Italy	Poland	Romania	Spain	Sweden	UK
Female	52%	48%	53%	48%	51%	50%	48%	49%
Age (55 to 65 years old)	24%	25%	20%	24%	13%	19%	25%	28%
High income	74%	84%	83%	86%	75%	83%	69%	70%
HIgh education	51%	52%	42%	61%	67%	65%	44%	55%
High CRT score	41%	60%	44%	51%	45%	35%	54%	42%
Region	21%	20%	38%	42%	66%	18%	16%	13%
City	53%	49%	69%	68%	68%	84%	57%	66%
Tenant	55%	51%	18%	25%	28%	15%	56%	41%
Detached housing	37%	30%	33%	35%	24%	23%	26%	21%
High heating costs	46%	48%	49%	49%	47%	49%	42%	49%
Big family (> 2 members)	38%	32%	58%	51%	51%	64%	24%	42%
high environmental ID (sum >=16[7]) (%)	49%	43%	65%	39%	54%	52%	42%	35%
high energy literacy (%)	67%	50%	48%	71%	71%	74%	50%	71%
Number of respondents	578	438	415	493	594	453	599	491

[7] Share of respondents for which the sum of responses to 4 scale items (1=strongly disagree to 4= strongly agree) is larger or equal to 16. In the analysis, the z-score is used.

Table A2. Results from the mixed logit model without interaction terms

	France	Germany	Italy	Poland	Romania	Spain	Sweden	UK
Mean								
priceb	-0.0083***	-0.0059***	-0.0051***	-0.0049***	-0.0047***	-0.0058***	-0.0080***	-0.0085***
	(0.001)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
size	0.0068***	-0.0017	0.0112***	0.0105***	0.0060***	0.0124***	0.0144***	0.0102***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
warranty	0.2059***	0.2199***	0.1697***	0.2551***	0.2247***	0.1846***	0.3353***	0.2228***
	(0.022)	(0.021)	(0.023)	(0.023)	(0.021)	(0.021)	(0.025)	(0.023)
A2	0.6443***	0.4431***	0.6373***	0.4268***	0.7378***	0.5370***	0.7194***	0.4069***
	(0.123)	(0.126)	(0.139)	(0.129)	(0.121)	(0.129)	(0.129)	(0.131)
A3_0	0.9976***	0.5020***	1.1397***	0.8074***	1.0661***	1.2079***	1.4629***	1.2216***
	(0.180)	(0.170)	(0.184)	(0.168)	(0.156)	(0.198)	(0.197)	(0.207)
A3_sub	1.2586***	1.1256***	1.7555***	1.4555***	1.8011***	1.5444***	1.6376***	0.6923***
	(0.112)	(0.109)	(0.136)	(0.117)	(0.118)	(0.132)	(0.118)	(0.105)
star4	0.3874***	0.3622***	0.4781***	0.5792***	0.4829***	0.5016***	0.7832***	0.6545***
	(0.080)	(0.078)	(0.086)	(0.090)	(0.076)	(0.088)	(0.083)	(0.088)
star45	0.2870***	0.1267	0.5271***	0.6613***	0.5041***	0.3610***	0.8081***	0.6322***
	(0.078)	(0.078)	(0.086)	(0.078)	(0.072)	(0.082)	(0.087)	(0.089)
SD								
size	-0.0284***	-0.0224***	0.0245***	-0.0266***	0.0211***	-0.0206***	0.0297***	0.0248***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
warranty	0.1964***	-0.0570	0.1530***	0.2069***	-0.2337***	0.1112***	0.2882***	0.2010***
	(0.030)	(0.044)	(0.031)	(0.028)	(0.025)	(0.034)	(0.027)	(0.030)
A2	0.1383	-0.0898	-0.0379	-0.0216	0.4257**	0.0572	-0.0517	0.0914
	(0.173)	(0.230)	(0.222)	(0.200)	(0.188)	(0.193)	(0.188)	(0.174)
A3_0	-0.7031*	0.1237	0.0187	-0.4596	0.3169	1.4456***	-1.2155***	-1.1875***
	(0.382)	(0.644)	(0.385)	(0.360)	(0.411)	(0.273)	(0.339)	(0.292)
A3_sub	1.1056***	0.9339***	1.1112***	0.9416***	1.2161***	1.1914***	0.9366***	0.9546***
	(0.121)	(0.122)	(0.134)	(0.127)	(0.114)	(0.141)	(0.137)	(0.129)
star4	0.5208***	0.2843	-0.3469	0.7449***	-0.5951***	0.6139***	0.3817***	0.4237***
	(0.165)	(0.206)	(0.225)	(0.119)	(0.119)	(0.137)	(0.139)	(0.162)
star45	0.6793***	0.6429***	0.6053***	0.3030*	0.5334***	0.6649***	-0.8376***	0.8345***
	(0.118)	(0.112)	(0.122)	(0.162)	(0.119)	(0.120)	(0.117)	(0.110)
Model								
LL	-2548.98	-2026.08	-1896.07	-2257.46	-2768.91	-2134.50	-2613.27	-2207.46
LL0	-2875.32	-2203.66	-2081.10	-2507.87	-2991.28	-2309.98	-2948.86	-2427.34
BIC	5234.939	4184.980	3924.155	4649.522	5675.206	4402.321	5364.049	4549.445
AIC	5127.956	4082.158	3822.142	4544.926	5567.814	4298.994	5256.531	4444.909
N	9248	7008	6640	7888	9504	7248	9584	7856

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3. Results from the mixed logit model using an alternative specification of the low literacy index

	France	Germany	Italy	Poland	Romania	Spain	Sweden	UK
Mean								
priceb	-0.008***	-0.0059***	-0.005***	-0.005***	-0.005***	-0.006***	-0.008***	-0.009***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
lowinc_A2	-0.1261	0.5817*	-0.3489	-0.8203**	-0.0536	-0.0595	0.2163	0.3660
	(0.246)	(0.316)	(0.311)	(0.322)	(0.237)	(0.297)	(0.242)	(0.251)
lowinc_A3_0	-0.2673	0.2944	0.4419	-0.5946	-0.3062	0.3553	1.0325***	-0.0600
	(0.326)	(0.377)	(0.383)	(0.387)	(0.282)	(0.413)	(0.332)	(0.345)
lowinc_A3_sub	-0.1097	-0.1152	-0.6033**	-0.961***	-0.5100**	-0.5567*	-0.2234	-0.3498
	(0.227)	(0.284)	(0.303)	(0.290)	(0.224)	(0.288)	(0.221)	(0.218)
lowlit_alt_A2	-0.4801**	0.3534	-0.3198	-0.4562**	0.0313	-0.0670	-0.3943	-0.3589
	(0.218)	(0.266)	(0.258)	(0.232)	(0.214)	(0.234)	(0.284)	(0.230)
lowlit_alt_A3_0	-0.6836**	-0.3659	-0.1198	-0.927***	-0.3822	0.5018	-0.6928*	0.0383
	(0.291)	(0.319)	(0.311)	(0.279)	(0.248)	(0.324)	(0.380)	(0.318)
lowlit_alt_A3_sub	-0.747***	0.2987	0.0370	-0.621***	-0.2332	-0.3358	-0.3329	-0.2239
	(0.205)	(0.250)	(0.251)	(0.217)	(0.204)	(0.224)	(0.264)	(0.202)
size	0.0066***	-0.0017	0.0111***	0.0107***	0.0056***	0.0124***	0.0142***	0.0104***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
warranty	0.2080***	0.2195***	0.1692***	0.2581***	0.2276***	0.1822***	0.3358***	0.2252***
	(0.022)	(0.021)	(0.023)	(0.023)	(0.021)	(0.021)	(0.025)	(0.024)
A2	0.9386***	0.2799*	0.7644***	0.7764***	0.7619***	0.5737***	0.7587***	0.4737**
	(0.183)	(0.146)	(0.168)	(0.175)	(0.164)	(0.171)	(0.159)	(0.184)
A3_0	1.4327***	0.5457***	1.0495***	1.3404***	1.3603***	0.9450***	1.1986***	1.2351***
	(0.266)	(0.191)	(0.218)	(0.221)	(0.204)	(0.242)	(0.208)	(0.274)
A3_sub	1.6894***	1.0757***	1.8407***	1.9157***	2.0464***	1.7787***	1.7735***	0.9086***
	(0.174)	(0.127)	(0.167)	(0.166)	(0.160)	(0.175)	(0.146)	(0.157)
star4	0.3879***	0.3623***	0.4852***	0.5782***	0.5029***	0.5016***	0.7672***	0.6606***
	(0.081)	(0.079)	(0.086)	(0.090)	(0.078)	(0.088)	(0.079)	(0.090)
star45	0.2908***	0.1292*	0.5315***	0.6634***	0.5116***	0.3579***	0.8067***	0.6432***
	(0.078)	(0.077)	(0.084)	(0.078)	(0.072)	(0.082)	(0.086)	(0.089)
SD								
size	-0.029***	-0.0221***	-0.024***	-0.027***	0.0212***	-0.020***	-0.030***	0.0248***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
warranty	0.2037***	-0.0583	0.1419***	0.2157***	0.2237***	0.1201***	0.2936***	0.2094***
	(0.029)	(0.045)	(0.032)	(0.029)	(0.025)	(0.033)	(0.027)	(0.030)
A2	0.1349	-0.1194	0.0106	-0.0473	0.3250*	0.0485	-0.0258	0.0976
	(0.173)	(0.223)	(0.210)	(0.202)	(0.193)	(0.197)	(0.182)	(0.165)
A3_0	-0.6888*	0.0148	0.1782	-0.3700	-0.1419	1.4235***	0.2320	-1.212***
	(0.385)	(0.819)	(0.345)	(0.343)	(0.287)	(0.279)	(0.319)	(0.289)
A3_sub	1.1100***	0.9499***	1.0882***	0.9257***	1.2269***	1.1573***	0.9267***	0.9595***
	(0.122)	(0.124)	(0.133)	(0.126)	(0.117)	(0.139)	(0.123)	(0.132)
star4	0.5165***	0.3344*	-0.3265	0.7314***	-0.610***	0.6220***	0.1781	0.4608***
	(0.166)	(0.187)	(0.206)	(0.119)	(0.116)	(0.135)	(0.208)	(0.155)
star45	0.6826***	0.6250***	0.5578***	0.2687	0.5874***	0.6479***	0.8883***	0.8236***
	(0.118)	(0.116)	(0.136)	(0.181)	(0.111)	(0.122)	(0.113)	(0.110)
Model								
LL	-2541.35	-2019.31	-1888.90	-2243.49	-2761.75	-2127.19	-2601.96	-2200.15
LL0	-2868.37	-2189.04	-2072.81	-2493.51	-2985.00	-2293.00	-2924.53	-2416.98
BIC	5274.474	4224.574	3962.623	4675.419	5715.846	4441.039	5396.447	4588.655
AIC	5124.698	4080.623	3819.805	4528.984	5565.497	4296.381	5245.922	4442.305
N	9248	7008	6640	7888	9504	7248	9584	7856

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$