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Household Environmental Attitudes and Energy Efficiency in Buildings: Evidence from Spanish Data

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Abstract

Buildings are an essential driver of current and future energy consumption and associated emissions with large energy-efficiency (EE) improvement potentials in both emerging and developed countries. Yet, especially in this sector, there are several and persistent barriers that prevent the attainment of EE gains. With a revealed-preferences approach from a 2008 national representative survey of Spanish households, we analyze some determinants of EE investment and behavior. In particular, our discrete-choice logit model empirically determines whether Spanish households that indicated to be concerned with the environment, or show eco-friendly practices, are more likely to invest in EE and to incorporate EE matters into their daily consumption decisions. Results suggest that pro-environmental attitudes indeed have positive effects on energy consumption habits and low-cost EE investments. Such findings, together with other information provided by the paper, may be useful for the design and implementation of future EE policies in this area.

Keywords: Barriers, environment, concern, policies, investment, behavior

JEL Classification: Q41, Q48, Q58

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1. Introduction

Buildings have become a centerpiece for energy and environmental policies due to their large contribution to energy demand and related emissions (for instance, residential and commercial sectors account for approximately 40% of final energy consumption in industrialized countries). Unlike other sectors, the stock or inertia effect of buildings is especially worrying as many units were built under old (or without) codes and thus without significant attention to energy efficiency or environmental issues. As buildings are long-term durable goods, their contribution to future energy consumption and emissions will likely be large unless specific actions and policies are introduced (Gago et al., 2013).

Energy efficiency (EE) offers an opportunity to change this trend through the application of cost-effective measures to reduce energy consumption (Levine et al., 2007). In the last few years, international institutions such as the IPCC, the IEA, or the European Commission, have actually emphasized the potential energy savings achievable from building design and retrofitting, and have urged governments to introduce policies to promote EE in this sector. Some of these measures consist in improving the technical conditions of buildings so that they need less energy to provide the same service, e.g. through insulation, more efficient heating systems or the use of highly energy-efficient appliances. Moreover, consumers can reduce their daily energy consumption by adopting energy-responsible behavioral practices such as switching off lights or targeting lower (upper) interior temperatures in winter (summer).

In this setting, this paper attempts to determine empirically what factors drive Spanish households' decisions in two areas: investment in EE and adoption of EE habits. On the one hand, we use the acquisition of EE major appliances (those with A or A+ label), low consumption bulbs and double glazing as measurement of EE investment. On the other hand, indoor temperature of the heating system is used to analyze the degree of EE habits. In particular, we focus on analyzing how consumers' environmental concerns affect investment and non-investment decisions (Nair et al., 2010). *Ceteris paribus*, environmental attitudes could explain differences on household's EE decisions as shown by recent academic explorations of the issue.

We use the Spanish National Statistics Institute (INE) 2008 survey, '*Encuesta Social: Hogares y Medio Ambiente'* (ESHMA, Social Survey: Households and the Environment). This is a single-year representative survey, containing micro data on Spanish households with multiple detailed questions about their environmental concerns and attitudes. We feel that this exercise is interesting for at least two reasons: to our knowledge, it is the first empirical application on these particular matters (but also on the empirics of household energy efficiency) for Spain, which could also provide new insights to a novel but growing international literature on the effects of consumer attitudes on EE. Moreover, Spain has seen a construction boom in the period 1998-2008 that has considerably expanded the stock of buildings and thus demands a detailed analysis of EE options and responses in residential buildings. In this sense we believe that this paper, by determining the factors that influence EE adoption in terms of investment and behavioral change, may be useful for the design and implementation of future policies so that they could overcome the multiple market failures and barriers that exist in this area (see e.g. Linares and Labandeira, 2010). Indeed, we suggest that some of our results may further support the use of certain EE policy instruments or packages, such as grants or capital access for the purchase of EE appliances and structures.

The paper is organized in five sections and two annexes, including this introduction. Section 2 reviews the existing literature in the field, whereas Section 3 describes the source of data used in our analysis and the main variables. Section 4 presents the results of the empirical model and discusses some implications. Finally, Section 5 summarizes the main conclusions of the article.

2. Literature

Although most experts and commentators identify buildings as a sector with large possibilities to reduce energy consumption through cost-effective measures, with the so-called 'win-win' options in some cases, widespread EE adoption has been hardly observed in this sector (see e.g. Levine et al., 2007, European Commission, 2011). The residential building sector, focus of this paper, is apparently affected by a series of strong factors that prevent agents from taking advantage of EE potentials. Some of the most important barriers are scarce and asymmetric information, a complex sector with multitude of agents and high costs, and limited access to capital. This situation explains the proliferation of public policies encouraging EE in the last few years, with the introduction of several EE instruments and packages such as codes and standards, labeling systems, information programs, subsidies or taxes, etc. (see e.g. Gillingham et al., 2006, 2009; Levine et al., 2007; Linares and Labandeira, 2010; Ryan et al., 2011). However, these policies are unlikely to be successful unless they are designed with large knowledge of the residential market. That is why several empirical studies have attempted to identify not only the socio-economic characteristics that determine households' adoption of EE but also other features and constraints that prevent the implementation of cost-effective EE measures.

In this context, most academic research has focused on principal/agent problems[1] in both EE investment and EE habits. One of the first contributions in this area was Brechling and Smith (1992) who used micro-data from the 1986 'English House Condition Survey' to explain the probability to have wall and loft insulation and double glazing in UK households. The paper showed that small income effects suggested no barriers to capital access, whereas home ownership was the only socio-economic characteristic that influenced EE investment decisions. A few years later, Levinson and Niemann (2004) used US data from the 'Residential Energy Consumption Survey' (RECS) and the 'American Housing Survey' to analyze principal/agent problems in household winter indoor temperatures, comparing results from OLS and selection probit models that showed the negative EE effects of contracts which included energy costs in rental payments. Davis (2012) again employed data from the 2005 RECS and a linear probability model to study the importance of principal/agent problems in EE appliances and lighting, showing the effectiveness of command-and-control approaches. A recent paper by Maruejols and Young (2011) used data from the 2003 Canadian 'Survey of Household Energy Use' to determine whether multi-family dwellings should be specially targeted in EE programs, and it showed that higher temperature settings were associated to those who did not pay the bills directly, while income effects were small for temperatures but income was an important determinant of household eco-friendly actions. Finally, Gillingham et al. (2012) employed the 2003 'California Statewide Residential Appliance Saturation Study' to find the effects of certain variables on morning heating temperatures, change of heating system or insulation level. Using probit models they identified principal/agent problems both in heating and insulation. They attributed the lower heating temperatures in colder regions and larger houses to higher marginal costs.

Although environmental attitudes could be a crucial determinant in the decision-making processes of households and could explain differences in the level of energy consumption of households with similar characteristics (Vassileva et al., 2012; Ek and Söderholm, 2010), none of the above-mentioned papers includes variables for household environmental attitudes. Indeed, Van den Bergh (2008) stressed the scarcity of empirical studies that combine socio-economic and psychological determinants of environmental behavior, which would call for further efforts in this area. So far only a few papers have introduced different variables to measure these possible effects, such as Kahn (2007), who studied the relationship between a green political ideology and private consumer choices, and Kotchen and Moore

[1] In this area the principal/agent problem refers to those situations in which the person in charge of the EE investment (agent) does not benefit from it (principal). Due to this split of incentives, agents take inefficient decisions that lead to a sub-optimal allocation of resources (IEA, 2007).

(2007) who use household environmental attitudes as one of the explanatory variables that determine the participation in green-electricity programs.

Specific results for EE in residential buildings have shown mixed evidence regarding the effects of household environmental attitudes (see Table 1 below). Di Maria et al. (2008) used 2001 data from a representative survey of Irish households, to find positive effects of environmental attitudes on the adoption decision of compact fluorescent light bulbs. Similarly, Costa and Kahn (2010) included variables on ideology to study the determinants of California's residential electricity consumption. They suggested that green voters and those enrolled in the utilities' renewable energy program, used less energy. In a subsequent paper, Kahn and Vaughn (2009) studied whether the share of green voters explained the share of hybrid cars and LEED certified buildings in each community. In a medium position, Traynor et al. (2012) employed the 'British Household Panel Survey' to test the 'green hypocrisy' hypothesis on UK's residential space heating expenditures and showed that only those households who actively applied their beliefs to daily life had lower heating expenditures. Similar results were found by Brounen et al. (2012) with data from the 2011 'Dutch National Bank Household Survey': households that declared to drive efficiently to save petrol were more likely to know their energy bills and use green power, although this did not have any effect on the indoor heating temperature, and no singular effect was found in green party voters.

3. Data

As indicated before, this paper uses micro-data from the Spanish National Institute of Statistics (INE) 2008 'Social Survey: Households and the Environment' (ESHMA), a single-year representative survey with almost 27,000 household principal dwellings that was carried out between April and December 2008 through internet, telephone and face-to-face interviews. The survey was intended to gather comprehensive information on Spanish household consumption and environmental habits (energy conservation, water saving, recycling, etc.), even though the data does not allow any dynamic analysis. Nine blocks compose the survey: i) information about household characteristics (income, education, number of members, etc.); ii) water supply and adoption of water saving measures; iii) energy sources of the house and installed heating, air conditioning and lighting systems (type of energy they use, type of heating fuel, thermostat temperature settings chosen by the members, proportion of rooms with air conditioning, low-consumption bulbs, etc.); iv) recycling practices; v) equipment and appliances; vi) noises and bad smells; vii) transport (number and type of vehicles); viii) general issues on lifestyle and consumption and ix) specific questions for survey respondents.

The strength of this database is the vast number of questions related to household environmental attitudes and habits. This would allow us to know the extent to which households that report to be environmentally concerned or show eco-friendly practices are more likely to invest in EE in their buildings, and to translate that behavior into their daily energy consumption. As explained in the previous section, together with other socio-economic variables such as income or education, this could be an important determinant of EE household decisions. Given the weakness of international literature on this issue, and the virtual absence of economic studies on household EE decisions in Spain, it would certainly be positive to include attitudinal variables in an empirical model. Yet, it is first necessary to choose the variables that best define the environmental attitude of households. Table 1 shows the questions employed by previous papers regarding this matter.

Table 1. Attitudinal Variables in EE Studies in Buildings

Paper	Environmental attitude variable
Di Maria et al. (2008)	-Respondent's support of the Kyoto Protocol -Importance given to the protection of the environment -Whether the respondent has heard of global warming and the greenhouse effect
Kahn and Vaughn (2009)	-Neighborhood's Green Party's share of registered voters
Costa and Kahn (2010)	-Whether the household has donated money to environmental groups -Whether the household has signed up for utilities renewable power program
Traynor et al. (2012)	-Whether the respondents believe that their country will be affected by climate change in the future -If households consider that their actions are influenced by carbon dioxide emissions -If the respondents agreed with the statement that the environment was a low priority compared to many other things in their life -Whether the respondent believes that it takes too much time and effort to do things that are environmentally friendly -If respondents are environmentally friendly in most things they do
Brounen et al. (2012)	-Efficient drivers

Source: the authors

The ESHMA contains several questions that could be used to measure environmental attitude: yet we ignore all questions related to the importance people assign to the environment or similar, since the majority of respondents reported to be very environmentally concerned and this might not necessarily express their real ideology. Consequently, we have selected only three questions that we believe that reveal real concerns about the environment: agreement with a penalty (fine) to those who do not recycle (penalty for no-recycling), agreement with a new environmental tax on the most pollutant fuels (tax on fuels), and positive willingness to pay for renewable energies (WTP renewable energy). Summary statistics of these variables are displayed in Table 2.

Yet the ESHMA shows important weaknesses due, first of all, to the absence of information on structure, age or size of dwellings. As research in the field has usually found these issues to be important factors explaining the likelihood of adoption of EE measures (e.g. Brechling and Smith, 1992), this should be taken into account when interpreting our results. In addition, the survey lacks two other important variables for the purpose of this research: energy consumption and ownership status. The last missing variable does not allow for principal/agent analysis, another important factor explaining EE investment and energy consumption according to the literature (Brechling and Smith, 1992; Davis, 2012; Gillingham et al., 2012). Nevertheless, the magnitude of this effect may not be as important in Spain as in other countries due to the high rate of owner-occupied dwellings (82% in 2008).

Finally, to estimate the effects of household characteristics we use nationality, employment situation of the main preceptor (professional situation), educational level, number of members (#members), children (#members<16), retired (#members>65) and income. Additionally, we include some control variables for geographic localization: a variable that classifies municipalities by size (municipality size); dummies for climatic zones[2], and a dummy for each Spanish region (autonomous community). These last dummies

[2] For the climatic zones, we follow the classification used by IDAE (Spanish Institute for Diversification and Energy Saving) in the SECH-SPAHOUSEC project (IDAE, 2011). This divides the country in three areas based on maximum, medium and minimum average temperatures during the period 1997-2007. Hence the variable takes values equal to one for North Atlantic, two for Continental and three for Mediterranean areas.

control for different subsidy programs that regional governments have voluntarily implemented in order to promote EE (for example, the *Renove* programs for the substitution of all appliances or the installation of double glazing). These dummies collect the divergence in the magnitude, the time of implementation and other important characteristics of the subsidies. Table 2 summarizes the results for the main variables, which are fully depicted in the annexes of the paper.

Table 2. Summary Statistics of the Main Variables

Variable	Measurement	Observations	Mean	Standard deviation	Min.	Max.
Nationality	Dummy	26034	0.94	0.24	0	1
Professional situation	Three-point-scale	26034	1.78	0.89	1	3
Educational level	Six-ascending-point-scale	26030	3.19	1.70	1	6
#members	Number	26034	2.67	1.25	1	13
#members<16	Number	26034	0.38	0.73	1	6
#members>65	Number	26034	0.47	0.72	0	5
Income	Four-ascending-point-scale	20530	2.09	1	1	4
Municipality size	Five-ascending-point-scale	26034	3.22	1.64	1	5
Climatic zone	Three-point-scale	24423	2.21	.86	1	3
Penalty for no-recycling	Dummy	23977	0.52	0.5	0	1
Tax on fuels	Dummy	23979	0.63	0.48	0	1
WTP renewable energy	Dummy	23977	0.23	0.42	0	1

Source: the authors

4. Models and results

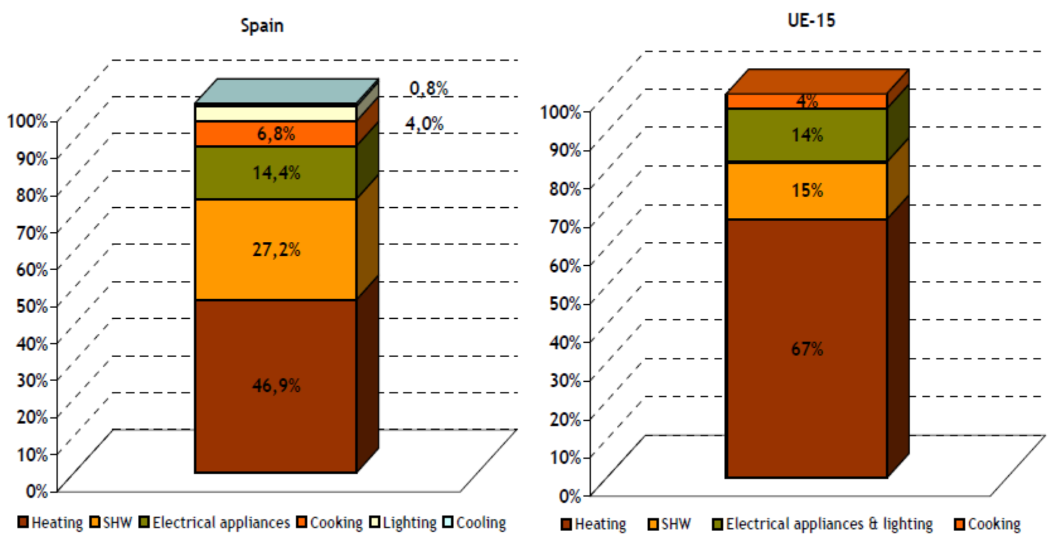
Following the usual distinction between EE investment decisions and EE consumption habits in the literature (see Sections 1 and 2), in this empirical application we also deal with those issues separately. To study EE investments we employ the ESHMA questions regarding the high EE labels of major appliances, the use of low consumption bulbs, and the existence of double glazing. Regarding EE consumption habits and behavior we use the heating temperature chosen by the households when they are at home during the day.

4.1. EE investment

With the objective of validating results, we study investment across well-differentiated sections of the house following the findings of the existing technical literature on the most important EE measures. Subsequently, we present a regression model to estimate the socio-economic and environmental attitude effects on the probability of having invested on one of the preceding measures.

The selection of measures is based on the fact that appliances and equipment respectively represent the second and third largest group of household energy consumption in industrialized countries (Laustsen, 2008; Levine et al., 2007; European Commission, 2011). Figure 1 shows the residential breakdown of energy consumption for Spain and the EU-15 in 2007, which justifies why renovation of energy inefficient major appliances has been the target of many EE public policies. In particular, our survey asks respondents whether their fridge, washing machine, dishwasher and oven has A or A+ label, although we follow Gillingham et al. (2012) and restrict the sample to only those households who have bought their major appliances during the last five years. Therefore, we exclude situations where labels had not yet been implemented, and also reduce possible effects of changing trends in the supply side. We then define a discrete choice logit model for each one of the appliances, where the dependent variable is the probability of having A or A+ label in the corresponding appliance.

Figure 1. Spanish and EU-15 Residential Energy Breakdown in 2007



Source: IDAE (2009)

Assuming a logistic distribution of the disturbances, we first construct a latent variable y_i^*, defined as follows:

$$y_i^* = \beta' x_i + u_i = \propto + \theta X_i + \gamma G_i + \delta F_i + \rho A_i + \sigma E_i + u_i \qquad (1)$$

where X_i is a vector with household's *i* socio-economic characteristics and G_i is a vector to control the geographic variables that were previously described. Vector F_i contains dummies for the type of fuel used and vector A_i collects variables related with appliances, as the age of the corresponding appliance. Tables A1.1 and A1.2 (Annex I) describe all those variables and associated statistics. Finally, E_i is the vector with the three variables representing the environmental attitude of the household (see above).

Then, the binary variable y_i equals one if household *i* invests in the corresponding appliance, such that:

$$y_i = \begin{cases} 1 \ if \ y_i^* > 0 \\ 0 \ if \ y_i^* \leq 0 \end{cases} \qquad (2)$$

Hence, we can describe the probability of investment by household *i* as follows:

$$Prob(y_i = 1) = Prob(y_i^* > 0) = Prob(u_i > -\beta' x_i) \quad (3)$$

Given the standard logistic cumulative distribution function Λ (.) of u_i, Equation (3) is rewritten as:

$$Prob(y_i = 1) = \Lambda(\beta' x_i) = \Lambda(\propto + \theta X_i + \gamma G_i + \delta F_i + \rho A_i + \sigma E_i + u_i) \quad (4)$$

Equation (4) is repeated for each of the four appliances, with the same right-hand side in the four models.

The next determinant of EE investment selected is whether the household has double glazing. Despite being one of the measures with the highest energy-saving potentials, improving the insulation level of an existing building is one of the most difficult and costly measures (see e.g. Ürge-Vorsatz and Novika, 2008). However, installing double glazing does not require structural changes in buildings and therefore it could be one of the cheapest and easiest ways to improve the building envelope.

Based on Equation (4), we now replace the dependent variable by the probability of having installed double glazing. In addition, we replace the specific vector for appliances characteristics, $\mathrm{A_i}$, by a new one that is related with the acquisition of double glazing (D_i). D_i contains indicators for the acquisition of heating and air conditioning systems, dummies for the number of rooms with heating and cooling systems and, the temperature of the heating and air conditioning thermostats. More information on these issues can be retrieved from Table A1.3 (Annex I).

The probability of having installed low consumption bulbs is the last dependent variable used to study EE investment. Unlike the preceding EE investment options, bulbs do not have high acquisition costs and long lifecycles. Yet, technical studies point out the high percentage of energy that can be saved in lighting through low-cost EE measures (see e.g. Levine et al., 2007) and this makes it an attractive area to foster EE improvements.

As in previous models, we replace the dependent variable in Equation (4) by the probability of using low-consumption bulbs. Control variables for socio-economic and environmental attitudes, geographic characteristics and type of fuel are kept constant. More information on these questions can be obtained from Table A1.4 (Annex I).

> *Results on EE Investment*

Given that the interpretation of the coefficients in discrete choice models is not straightforward due to the non-linearity properties of the model, the complete regression output is provided in Annex II. For simplicity and easy interpretation, Table 3 only displays the signs of the most relevant coefficients in the EE investment model that resulted to be statistically significant. The sign "+" means that the variable has a positive effect on the probability of having invested in the corresponding EE measure, while "-" refers to negative effects on the same probability.

It should be noted, first of all, that income and education, together with presence of elderly are the socio-economic variables with the most remarkable effects on the analyzed EE measures: all regressions show that households with higher income or educational levels are more likely to invest in EE, whereas four out of the five models indicate that the number of household members over 65 has the opposite effect. Given the high costs and future paybacks associated with most EE investments, such income and 'elderly' effects should be expected. Similarly, households whose reference member has Spanish nationality have positive effects on EE investments. Results for other variables are inconclusive: employment status was not found to be statistically significant in all models, although they have the expected sign (unemployed or retired reference member show negative effects on the probability of EE investment).

Regarding environmental attitudes, not all selected variables are statistically significant for types of EE investment. This is the case for appliances, where almost every measure of environmental attitude is not statistically significant. Only households that reported to agree on fostering recycling by the introduction of a penalty are more likely to have double glazing, although not for every specification of the model (see Annex II). On the contrary, all variables on environmental attitudes resulted to be significant and with the expected sign for low-consumption bulbs, which may be explained by shorter lifecycle and low-cost investment that allow concerned consumers to follow their preferences more easily. Appliances and windows are costly and with less frequent replacement so, although eco-friendly consumers may be willing to substitute their inefficient appliances, they may wait to complete their lifespan or may be subject to budget constraints. In any case, the lack of data on ownership may be underestimating the results as environmentally-proactive consumers who are tenants and may be less interested in major investments that would be lost if they moved to another dwelling.

Table 3. Energy Efficiency Investment Decisions of Spanish Households

Model	Logit				Logit	Logit
Dependent variable	**Appliances** (purchased in the last 5 years)				**Double glazing**	**Low-consumption bulbs**
	Fridge	**Washing machine**	**Dishwasher**	**Oven**		
Spanish	+	+	.	.	+	+
Professional situation (retired and unemployed)	-	.	.	.	-	-
Educational level	+	+	+	+	+	+
#member>65	.	-	.	-	-*	-
Income	+	+	+	+	+	+
Penalty for no-recycling	.	.	.	.	+*	+
Tax on fuels	+	.	.	.	.	+
WTP renewable energy	.	.	.	.	.	+
Age of the corresponding appliance	-	-	-	-		
Heating in most of the rooms					+	
A/C in most of the rooms					+	
Heating temperature					.	

Notes: +(-) positive (negative) effect of the explanatory variable on the probability of investment; * not for all specifications of the model; shadow areas are variables that were not included in the regression
Source: the authors

Finally, with respect to the characteristics of specific appliances, age is a major determining factor because those purchased in the last five years are less likely to have A or A+ labels relative to those purchased in the previous year. Similarly, households that have heating or air conditioning systems in most of the rooms are more likely to have double glazing.

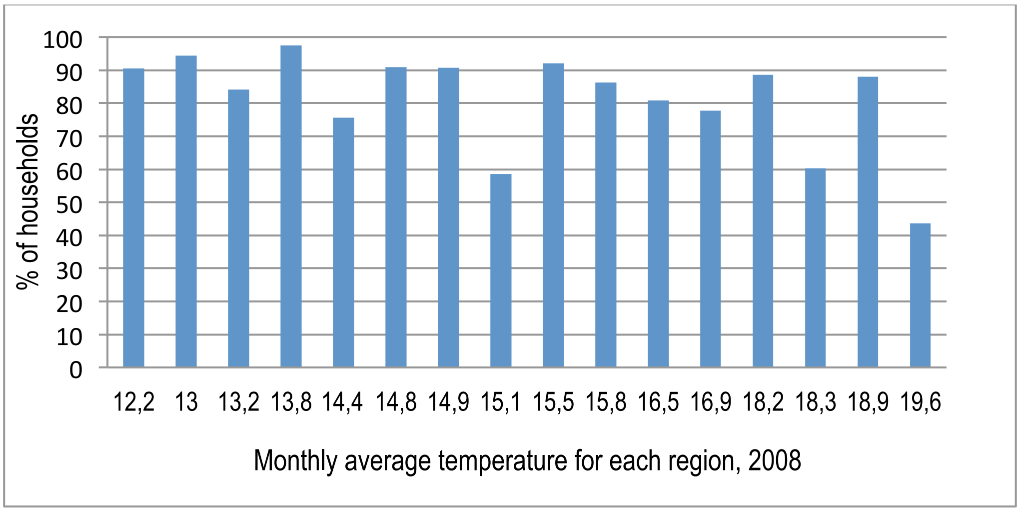
4.2. EE habits

As indicated before, we use winter indoor-heating temperature chosen by a household as a measure of its EE habits, and expect energy-responsible households to set lower temperatures. This is an indication of household eco-friendly behavior that has been commonly employed by the literature (see e.g. Levinson and Niemann, 2004; Maruejolds et al., 2011; and Gillingham et al., 2012). Moreover, as Figure 1 shows, heating space is the largest share of residential energy consumption in industrialized and developing countries and therefore a potentially important source of energy savings (Laustsen, 2008; European Commission, 2011).

In the ESHMA respondents are asked to report the Celsius degrees set in the heating thermostat on a normal day when at home. We thus follow Gillingham et al., (2012) and construct a discrete variable that is 1 when the temperature stated by the respondent is equal or below 15 ºC; 2 if the stated temperature is within the 16-18ºC interval; 3 when the temperature is within the 19-21ºC interval, 4 with temperature within 22-24ºC interval; 5 with temperature within 25-27ºC; and 6 for temperatures equal or above 28˚C. Subsequently we use an ordered logit model to explain the effects of household socio-economic and environmental characteristics on the winter indoor-heating temperature, also controlling for other relevant factors. Table A1.5 (Annex I) contains a description of the variables used in the regression[3].

However, Spain has great climatic differences and even the above-mentioned climatic zones might be too wide to collect temperature differences. Since this may affect the intensity and frequency of residential heating use (see Figure 2), we compare the results from the full sample with the results from a reduced sample. The reduced sample, as in Gillingham et al. (2012), considers only colder regions[4].

Figure 2. Availability of Heating Devices in Spanish Households by temperatures, 2008



Source: the authors

[3] For the estimation of indoor heating temperatures we exclude the regions of Ceuta, Melilla and the Canary Islands due to their sizable climatic differences with respect to peninsular Spain.

[4] Based on Figure 2 we construct the reduced sample with those regions that had monthly average temperatures below 19 in year 2008, resulting in the exclusion of Andalusia.

> Results on EE Habits

Following the same procedure of Section 4.1, Table 4 summarizes the main results for household winter indoor-heating temperature (full estimation results are again available in Annex II). Now sign "+" ("-") means that a variable has a positive (negative) effect on the probability of increasing indoor temperature, thus being associated to less (more) energy-responsible habits. The two columns in Table 4 incorporate the previous sample specifications: full sample and a sample restricted to regions with average monthly temperatures below 19°C. As indicated before, with this approach it is possible to test the significance of our results under different climatic conditions.

Table 4. EE Habits: Targeted Heating Temperature

Model	Ordered logit	Ordered logit
Variable	**Full sample**	**Only <19 °C**
Educational level	.	.
#member>65	+	+
Income	+	+
Climatic zone	+	+
Penalty for no-recycle	-	-
Tax on fuels	.	.
WTP renewable energy	.	.
Type and fuel of heating system	-(wood) +(heat pumps) -(gas and radiator heating)	-(wood) +(heat pumps) -(gas and radiator heating)
Heating in most of the rooms	-	-

Note: +(-) positive (negative) effect of the explanatory variable on the probability of increase the temperature
Source: the authors

With regard to socio-economic characteristics, income and elderly are again two important determinants of indoor temperature. Households belonging to higher income levels are more likely to choose higher winter temperatures as do households with members who are older than 65. These results coincide with the findings of the international literature although, contrary to other international evidence, we have not found any significance in the effects of the number of children. In addition, our results suggest that the level of education does not have any effect on indoor temperature.

Once again, not all variables for environmental attitudes show a clear effect although they follow the expected tendency. While the coefficient for levying a penalty on those who do not recycle shows a statistically significant negative effect (meaning that households with that attitude have EE habits), willingness to pay more for 'green' energy appears as not significant although it has the expected sign (see Annex II).

Even though geographic characteristics are not the focus of this piece of research, an analysis of the effects of climatic zones is especially interesting because the existing academic evidence on temperature variable is mixed. On the one hand, some authors have suggested that colder regions choose higher temperatures, regardless of the associated higher costs (Friedman, 1987). On the other hand, some researchers have proved the opposite hypothesis (Dewees and Wilson, 1990; Gillingham et al., 2012). Our results coincide with the latter, showing that the variable climatic zone has positive effects on indoor temperatures: that is, households from warmer regions of the Continental and Mediterranean zones set higher heating temperatures with respect to those from the Atlantic area. This may be related to the fact that colder regions have higher marginal costs of heating, as found by Gillingham et al. (2012) regarding housing size too. Although the ESHMA does not provide data on dwelling sizes, the dummy variable 'heating in most of the rooms' (equaling one when households have heating systems installed in most of the rooms) can be used as a proxy to study such effect. Again, our results indicate negative effects of households with heating in most of the rooms, and reinforces the idea that colder regions and larger houses set lower temperatures due to higher marginal costs.

Finally, with respect to specific heating system characteristics, households using wood as a fuel source or individual gas and electric (radiators) heating systems are more likely to set lower temperatures, while those with heat pumps show the opposite effect.

5. Conclusions

Buildings are a major source of energy consumption in both emerging and developed economies and thus a cause for environmental and energy-dependence concerns. Contrary to other sectors, buildings are usually associated to a stock of future energy consumption that is mainly related to their design and structural characteristics and to behavioral decisions by the agents who use them. By acting in both areas, societies may achieve a sizable and cost-effective reduction of energy consumption in buildings. Proper building design and construction, retrofitting processes, replacement of old equipment by new EE appliances, and fostering energy conservation behavior by building users would thus be essential to successful overall EE strategies and plans. However, progress of EE in the building sector has been rather limited due to the existence of numerous market barriers, such as imperfect information, split incentives or uncertainty, that result in a sub-optimal level of EE action. Therefore, EE benefits, the importance of buildings in EE strategies, and market failures and barriers against EE, justify public intervention in the field. However, public policies to promote EE should be defined and implemented with proper information on the agents' stances in this domain.

This paper attempts to shed light on the factors affecting household decisions in two areas: EE investment and EE behavior in residential buildings. Using a Spanish representative household survey with detailed micro-data on environmental attitudes and related decisions, we empirically estimate the effects of certain variables on the probability of investing in EE measures and adopting EE behavior. In particular, we study the effects of household environmental attitudes on the probability of having installed double glazing, EE major appliances and low-consumption bulbs. Moreover, winter indoor-heating temperature is used as a measure of EE (or energy-aware) behavior by households. Although the paper focuses on the preceding issues, it is also one of the first contributions to the international literature on residential EE that employs Spanish data. The paper also provides a rich set of information regarding household decisions in this field for a country with significant climatic variability and that has recently seen a construction boom, that is, where EE policies in the building sector may play a prominent role in the future.

Our empirical results are in the expected direction and are largely consistent with the findings of the international literature: households that agree on imposing a penalty on those agents who do not recycle, i.e. those having strong environmental attitudes, are more likely to use low-consumption bulbs and to set lower heating temperatures. However, these environmental implications are not statistically significant for the costly investments associated to double glazing and major EE appliances. Such difference may be explained by the existence of high upfront costs, which may affect EE investment even among pro-environmental agents. If this is the case, and although other non-observed factors may be also behind this finding, results may provide yet another justification for the use of subsidies to EE appliances and EE-driven structural changes or for the introduction of packages that may facilitate access to capital for EE investments in buildings.

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Annex I: Summary Statistics

Table A1.1. Summary Statistics for Household Type of Fuel (F_i)

Variable	Measurement	Observations	Mean	Standard deviation	Min.	Max.
Electricity	Dummy	26034	0.999	0.01	0	1
Solar	Dummy	26034	0.009	0.09	0	1
Natural Gas	Dummy	26034	0.379	0.48	0	1
LPG	Dummy	26034	0.437	0.49	0	1
Wood	Dummy	26034	0.074	0.26	0	1
Liquid fuels	Dummy	26034	0.137	0.34	0	1
Other	Dummy	26034	0.064	0.24	0	1

Table A1.2. Summary Statistics for Specific Appliances Characteristics (A_i)

Variable	Measurement	Observations	Mean	Standard deviation	Min.	Max.
Availability of A or A+ fridge	Dummy	17574	0.55	0.49	0	1
Availability of A or A+ fridge	Dummy	17330	0.58	0.49	0	1
Availability of A or A+ fridge	Dummy	8089	0.66	0.47	0	1
Availability of A or A+ fridge	Dummy	14535	0.40	0.49	0	1
Age of fridge	Four-ascending-point-scale	25999	2.71	0.90	1	4
Age of washing machine	Four-ascending-point-scale	25809	2.57	0.89	1	4
Age of dishwasher	Four-ascending-point-scale	11319	2.47	0.82	1	4
Age of oven	Four-ascending-point-scale	23010	2.80	0.91	1	4

Table A1.3. Summary Statistics for Specific Double-glazing Characteristics (D_i)

Variable	Measurement	Observations	Mean	Standard deviation	Min.	Max.
Availability of double glazing	Dummy	26034	0.43	0.49	0	1
Most rooms with heating	Dummy	18911	0.71	0.45	0	1
Most rooms with A/C	Dummy	7722	0.22	0.42	0	1
Heating temperature	˚C	12780	21.06	2.24	10	30
A/C temperature	˚C	7460	22.37	2.36	10	30

Table A1.4. Summary Statistics for Low-consumption Bulbs (LCB)

Variable	Measurement	Observations	Mean	Standard deviation	Min.	Max.
Availability of LCB	Dummy	26034	0.65	0.47	0	1

Table A1.5. Summary Statistics for Specific Heating Variables

Variable	Measurement	Observations	Mean	Standard deviation	Min.	Max.
Individual electric boiler	Dummy	18842	0.059	0.236	0	1
Electric radiator	Dummy	18842	0.212	0.410	0	1
Underfloor heating	Dummy	18842	0.010	0.100	0	1
Central gas heating	Dummy	18842	0.089	0.285	0	1
Individual gas heating	Dummy	18842	0.326	0.488	0	1
Non-piped gas	Dummy	18842	0.040	0.197	0	1
Piped heat pump	Dummy	18842	0.025	0.157	0	1
Non-piped heat pump	Dummy	18842	0.048	0.215	0	1
Individual oil heating	Dummy	18842	0.105	0.307	0	1
Central oil heating	Dummy	18842	0.075	0.264	0	1
Central coal heating	Dummy	18842	0.004	0.066	0	1
Wood	Dummy	18842	0.045	0.208	0	1
Other	Dummy	18842	0.053	0.225	0	1

Annex II. Regression Results

Table A2.1. Results for EE Appliances

VARIABLES	Fridge	Washing machine	Dishwasher	Oven
SPANISH	**0.535*** **	**0.548*** **	**0.514***	**0.606*** **
	(0.154)	(0.144)	(0.291)	(0.153)
2.UNEMPLOYED	-0.120	-0.0709	-0.0381	-0.171
	(0.113)	(0.103)	(0.169)	(0.109)
3.RETIRED	**-0.363*** **	-0.0578	-0.149	-0.0818
	(0.110)	(0.104)	(0.166)	(0.105)
2.EDUCATION	0.0371	**0.379*** **	**0.422***	**0.388*** **
	(0.128)	(0.115)	(0.218)	(0.126)
3. **EDUCATION**	-0.201	0.0979	0.330	0.247
	(0.159)	(0.141)	(0.253)	(0.156)
4. EDUCATION	0.0759	**0.414*** **	0.310	**0.607*** **
	(0.157)	(0.142)	(0.244)	(0.152)
5. EDUCATION	0.263	**0.663*** **	**0.599** **	**0.669*** **
	(0.165)	(0.148)	(0.245)	(0.153)
6. EDUCATION	**0.335** **	**0.595*** **	**0.619** **	**0.461*** **
	(0.166)	(0.148)	(0.241)	(0.150)
#MEMBERS	-0.0570	-0.0216	-0.0835	0.0302
	(0.0411)	(0.0386)	(0.0604)	(0.0400)
#MEMBER<16	0.0517	0.0753	0.0650	0.0317
	(0.0670)	(0.0621)	(0.0860)	(0.0626)
#MEMBER>65	-0.00840	**-0.193*** **	-0.0577	**-0.191*** **
	(0.0671)	(0.0614)	(0.106)	(0.0653)
2.INCOME	**0.319*** **	**0.167***	**0.302***	**0.232** **
	(0.0955)	(0.0905)	(0.158)	(0.0961)
3.INCOME	**0.684*** **	**0.567*** **	**0.428** **	**0.466*** **
	(0.126)	(0.118)	(0.180)	(0.116)
4.INCOME	**0.633*** **	**0.617*** **	**0.451** **	**0.513*** **
	(0.154)	(0.144)	(0.198)	(0.138)
2.MUNICIPALITY SIZE	0.0319	0.0540	0.293	-0.180
	(0.128)	(0.117)	(0.196)	(0.120)
3. MUNICIPALITY SIZE	**0.230***	**0.197***	0.0277	-0.186
	(0.126)	(0.115)	(0.175)	(0.116)
4. MUNICIPALITY SIZE	**-0.341** **	**-0.246***	**-0.324***	**-0.292** **
	(0.136)	(0.128)	(0.193)	(0.137)
5. MUNICIPALITY SIZE	-0.157	0.0241	0.0287	-0.324***
	(0.104)	(0.0982)	(0.151)	(0.0996)
2.APPLIANCE AGE	**-1.257*** **	**-1.304*** **	**-1.482*** **	**-0.889*** **
	(0.129)	(0.117)	(0.216)	(0.102)
Penalty for no-recycling	-0.116	0.0463	0.0369	0.0150
	(0.0772)	(0.0716)	(0.109)	(0.0713)
Tax on fuels	**0.147***	-0.120	-0.0701	-0.0330
	(0.0796)	(0.0756)	(0.116)	(0.0756)
WTP for renewable energy	-0.0308	0.0641	-0.00833	0.0585
	(0.0878)	(0.0815)	(0.120)	(0.0815)
SOLAR	-0.456	0.390	-0.120	0.482
	(0.319)	(0.384)	(0.393)	(0.386)
PIPED GAS	-0.0904	-0.00503	-0.0219	-0.172*
	(0.118)	(0.106)	(0.168)	(0.104)
LPG	**-0.303*** **	-0.0434	-0.0459	**-0.357*** **
	(0.116)	(0.105)	(0.183)	(0.108)
WOOD	-0.0313	0.0723	0.389	-0.0628
	(0.161)	(0.145)	(0.264)	(0.161)
LIQUID FUELS	0.167	**0.283** **	**0.407** **	0.119
	(0.134)	(0.126)	(0.195)	(0.125)
OTHER	0.0408	0.0137	0.192	0.0442
	(0.171)	(0.156)	(0.264)	(0.165)

Constant	2.137***	1.595***	1.900***	0.749***
	(0.300)	(0.269)	(0.483)	(0.278)
Dummy for región	Y	Y	Y	Y
McFadden Pseudo R2	0.077	0.08	0.077	0.075
% of correct prediction	0.85	0.84	0.87	0.73
Overall significant test:p-value	0.00	0.00	0.00	0.00
Observations	6,459	7,225	3,617	4,761

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A2.2. Results for Double glazing (three specifications of the model)

VARIABLES	(1)	(2)	(3)
2.Continental zone	-0.471***	-0.102	-0.131
	(0.109)	(0.421)	(0.476)
3. Mediterranean zone	**-1.236*** **	**-0.807*** **	**-0.792** **
	(0.0618)	(0.298)	(0.340)
SPANISH	**1.026*** **	**0.836*** **	**0.677*** **
	(0.0832)	(0.188)	(0.224)
2.UNEMPLOYED	-0.122**	-0.0519	-0.0641
	(0.0540)	(0.118)	(0.142)
3.RETIRED	**-0.135** **	**-0.233* **	-0.241
	(0.0531)	(0.121)	(0.147)
2.EDUCATION	**0.478*** **	**0.638*** **	**0.559*** **
	(0.0571)	(0.143)	(0.175)
3. EDUCATION	**0.579*** **	**0.688*** **	**0.604*** **
	(0.0752)	(0.166)	(0.206)
4. EDUCATION	**0.691*** **	**0.920*** **	**0.619*** **
	(0.0739)	(0.168)	(0.203)
5. EDUCATION	**0.811*** **	**0.840*** **	**0.722*** **
	(0.0744)	(0.174)	(0.211)
6. EDUCATION	**0.843*** **	**0.829*** **	**0.632*** **
	(0.0750)	(0.170)	(0.205)
#MEMBERS	-0.00124	**-0.102** **	**-0.137** **
	(0.0199)	(0.0459)	(0.0546)
#MEMBER<16	**0.169*** **	**0.170*** **	**0.167** **
	(0.0315)	(0.0622)	(0.0722)
#MEMBERS>65	**-0.103*** **	-0.0988	**-0.161* **
	(0.0312)	(0.0738)	(0.0906)
2.INCOME	**0.442*** **	**0.281** **	**0.352** **
	(0.0466)	(0.114)	(0.142)
3.INCOME	**0.654*** **	**0.484*** **	**0.566*** **
	(0.0587)	(0.133)	(0.162)
4.INCOME	**0.770*** **	**0.604*** **	**0.736*** **
	(0.0735)	(0.164)	(0.195)
2.MUNICIPALITY SIZE	-0.00169	0.164	0.00786
	(0.0595)	(0.139)	(0.169)
3. MUNICIPALITY SIZE	**-0.159*** **	-0.0360	-0.101
	(0.0560)	(0.125)	(0.148)
4. MUNICIPALITY SIZE	**-0.428*** **	-0.0897	-0.191
	(0.0740)	(0.164)	(0.192)
5. MUNICIPALITY SIZE	**-0.337*** **	-0.152	-0.216
	(0.0491)	(0.117)	(0.143)
SOLAR	0.800***	0.162	0.529
	(0.202)	(0.348)	(0.467)
PIPED GAS	0.261***	-0.207*	-0.118
	(0.0514)	(0.122)	(0.139)
LPG	**-0.665*** **	**-0.614*** **	**-0.558*** **
	(0.0506)	(0.115)	(0.133)
WOOD	0.0301	0.0490	0.104
	(0.0691)	(0.177)	(0.241)

LIQUIED FUEL	0.436***	0.189	0.165
	(0.0578)	(0.141)	(0.171)
OTHER	0.159**	-0.0856	-0.144
	(0.0730)	(0.135)	(0.156)
MOST ROOMS WITH HEATING		0.812***	0.839***
		(0.101)	(0.119)
MOST ROOMS WITH A/C		0.245***	0.262**
		(0.0941)	(0.111)
Penalty for no-recycling	**0.118*** **	0.119	**0.200** **
	(0.0360)	(0.0792)	(0.0935)
Tax on fuels	0.00838	-0.100	-0.199**
	(0.0376)	(0.0843)	(0.0997)
WTP for renewable energy	-0.0342	-0.0316	0.0314
Penalty for no-recycling	(0.0419)	(0.0881)	(0.105)
Heating temperature			0.00656
			(0.0215)
A/C temperature			**0.0516*** **
			(0.0197)
Constant	-1.268***	-1.195***	-2.083***
	(0.123)	(0.396)	(0.736)
Dummy for región	Y	Y	Y
McFadden pseudo-R2	0.165	0.146	0.137
% of correct prediction	0.700	0.684	0.683
Overall significance test: p-value	0.000	0.000	0.000
Observations	18,015	3,643	2,596

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A2.3. Results for low consumption bulbs

VARIABLES	(1)
SPANISH	**0.801*** **
	(0.0711)
2.UNEMPLOYED	**-0.112** **
	(0.0524)
3.RETIRED	**-0.0959* **
	(0.0525)
2.EDUCATION	**0.566*** **
	(0.0505)
3. EDUCATION	**0.612*** **
	(0.0685)
4. EDUCATION	**0.847*** **
	(0.0703)
5. EDUCATION	**0.939*** **
	(0.0718)
6. EDUCATION	**1.156*** **
	(0.0738)
#MEMBERS	**0.124*** **
	(0.0201)
#MEMBER<16	0.00679
	(0.0334)
#MEMBER>65	**-0.197*** **
	(0.0297)
2.INCOME	**0.331*** **
	(0.0441)
3.INCOME	**0.473*** **
	(0.0592)
4.INCOME	**0.488*** **
	(0.0754)

2.MUNICIPALITY SIZE	0.0457
	(0.0574)
3. MUNICIPALITY SIZE	**0.104***
	(0.0545)
4.MUNICIPALITY SIZE	**0.135****
	(0.0687)
5. MUNICIPALITY SIZE	**0.138*****
	(0.0476)
SOLAR	**0.685*****
	(0.245)
PIPED GAS	0.0709
	(0.0525)
LPG	**-0.258*****
	(0.0505)
WOOD	0.0351
	(0.0656)
LIQUIED FUELS	**0.285*****
	(0.0581)
OTHER	**0.173****
	(0.0734)
Penalty for no-recycling	**0.199*****
	(0.0355)
Tax on fuels	**0.166*****
	(0.0362)
WTP for renewable energy	**0.120*****
	(0.0422)
Constant	-1.347***
	(0.119)
Dummy for regions	Y
McFadden pseudo-R2	0.096
% of correct prediction	0.702
Overall significance test: p-value	0.000
Observations	18,015

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table A2.4. Results for Winter Indoor-heating Temperatures

VARIABLES	(1)	(2)
2.Continental zone	**0.607*** **	**0.967*** **
	(0.134)	(0.121)
3.Mediterraenan zone	**2.501*** **	**2.731*** **
	(0.114)	(0.112)
2.MUNICIPALITY SIZE	0.0778	0.0501
	(0.0774)	(0.0793)
3. MUNICIPALITY SIZE	0.102	0.121
	(0.0722)	(0.0754)
4. MUNICIPALITY SIZE	**0.450*** **	**0.447*** **
	(0.0889)	(0.0938)
5. MUNICIPALITY SIZE	**0.600*** **	**0.576*** **
	(0.0629)	(0.0648)
SPANISH	0.0585	0.0485
	(0.131)	(0.137)
2.UNEMPLOYED	0.0206	0.0110
	(0.0711)	(0.0764)
3.RETIRED	-0.0251	-0.0139
	(0.0690)	(0.0714)
2.EDUCATION	-0.158*	-0.131
	(0.0826)	(0.0861)
3. EDUCATION	-0.0155	0.00681
	(0.109)	(0.118)
4. EDUCATION	-0.0522	-0.00520
	(0.0991)	(0.104)
5. EDUCATION	-0.119	-0.117
	(0.0982)	(0.103)
6. EDUCATION	-0.158	-0.0745
	(0.0979)	(0.102)
#MEMBERS	0.0120	-0.00547
	(0.0263)	(0.0273)
#MEMBER<16	-0.0161	-0.0173
	(0.0364)	(0.0382)
#MEMBERS>65	**0.107*** **	**0.114*** **
	(0.0411)	(0.0428)
2.INCOME	0.0740	0.101
	(0.0643)	(0.0669)
3.INCOME	**0.230*** **	**0.285*** **
	(0.0759)	(0.0792)
4.INCOME	0.111	0.137
	(0.0872)	(0.0917)
Penalty for no-recycling	**-0.0869** **	**-0.105** **
	(0.0441)	(0.0460)
Tax on fuels	0.0632	0.0938*
	(0.0465)	(0.0485)
WTP for renewable energy	-0.0396	-0.0443
	(0.0500)	(0.0526)
PIPED GAS	-0.0364	-0.0282
	(0.0847)	(0.0908)
LPG	0.139*	0.107
	(0.0723)	(0.0771)
WOOD	**-0.536*** **	**-0.457** **
	(0.174)	(0.192)
LIQUID FUELS	-0.357	-0.241
	(0.252)	(0.284)
OTHER	-0.146	-0.0307
	(0.105)	(0.116)
Individual electric boiler	-0.157	-0.235**
	(0.102)	(0.111)
Electric radiator	**-0.286*** **	**-0.292*** **
	(0.0864)	(0.0931)
Underfloor heating	-0.156	-0.105
	(0.186)	(0.196)
Central gas heating	-0.140	-0.153

	(0.113)	(0.119)
Individual gas heating	**-0.350*** **	**-0.359*** **
	(0.0979)	(0.104)
Non-piped gas	**-0.733*** **	**-0.694*** **
	(0.172)	(0.185)
Pipe heat pump	**0.573*** **	**0.601*** **
	(0.123)	(0.137)
Non-piped heat pump	**0.493*** **	**0.434*** **
	(0.114)	(0.125)
Individual oil heating	-0.266	-0.295
	(0.266)	(0.295)
Central oil heating	0.492*	0.410
	(0.273)	(0.301)
Central coal heating	-1.144	-1.281
	(0.871)	(0.862)
Wood	0.0997	-0.0157
	(0.226)	(0.246)
Other	0.141	-0.486**
	(0.150)	(0.202)
Most rooms with heating	**-0.280*** **	**-0.182** **
	(0.0718)	(0.0793)
cut1		
Constant	-4.763***	-4.682***
	(0.239)	(0.249)
cut2		
Constant	-1.964***	-1.877***
	(0.205)	(0.214)
cut3		
Constant	1.456***	1.561***
	(0.204)	(0.213)
cut4		
Constant	3.943***	4.187***
	(0.212)	(0.224)
cut5		
Constant	5.834***	6.086***
	(0.230)	(0.251)
Dummy for region	Y	Y
McFadden pseudo-R2	0.139	0.125
% of correct prediction	0.627	0.639
Overall significance test: p-value	0.000	0.000
Observations	9,485	8,819

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1