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Determinants of households' investment in energy efficiency and renewables – Evidence from the OECD survey on household environmental behaviour and attitudes[1]

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ABSTRACT

This paper provides novel evidence on the main factors behind consumer choices regarding investments in energy efficiency and renewable energy technologies using the OECD Survey on Household Environmental Behaviour and Attitudes. The empirical analysis is based on the estimation of binary logit regression models. Empirical results suggest that households' propensity to invest in clean energy technologies depends mainly on home ownership, income, social context and household energy conservation practises. Indeed, home owners and high-income households are more likely to invest than renters and low-income households. In addition, environmental attitudes and beliefs, as manifest in energy conservation practises or membership in an environmental non-governmental organisation, also play a relevant role in technology adoption.

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Introduction

Investments in energy efficiency (EE) and renewable energy sources (RES) are key to reduce greenhouse gas emissions and thus limit climate change. Global emissions have continued to grow by 44% from 2000 to 2011 (IEA 2013) and policy action to reverse this trend is urgently needed. In most OECD countries, the residential sector currently accounts for roughly 30% of final energy consumption and of related CO_2 emissions (IEA, 2013). Further improving the efficiency of energy use as well as boosting the energy production from renewable sources will be essential to make the necessary progress. By adopting energy efficiency measures and renewable energy technologies, households can make an important contribution to reducing greenhouse gas emissions. This paper seeks to make a contribution to the technology adoption literature by exploring the determinants of such investments, which can include households' socio-economic characteristics, characteristics of their dwellings, attitudes regarding environmental problems or energy saving measures, households' knowledge about their energy consumption or the cost and performance of energy conservation measures and renewable technologies, along with policy and economic context, such as available subsidies and energy prices (Poortinga et al. 2003, Sardianou 2007, Mahaptra and Gustavsson 2008, Mills and Schleich 2009, Di Maria et al. 2010, Willis et al. 2011, Mills and Schleich 2012, Michelsen and Madlener 2012, Sardianou and Genoudi 2013).

Previous studies suggest that households' socio-economic characteristics play a relevant role in technology adoption. Generally a positive correlation between income and the probability of investing in energy technologies is observed (Long 1993, Mills and Schleich 2010b, Sardianou and Genoudi 2013). It should be noted that this is indicative of credit constraints. In the presence of perfect credit markets poor households should be able to borrow as long as their investments are profitable. Generally, individuals with higher levels of education and those with children are found to be more likely to adopt energy efficient technologies (Mahaptra and Gustavsson 2008, Mills and Schleich 2009, Mills and Schleich 2012, Michelsen and Madlener 2012, Sardianou and Genoudi 2013). The impact of age on households' probability to invest is less clear. Some authors find that the propensity to adopt energy efficient or renewable technologies declines with age (Mahaptra and Gustavsson 2008, Mills and Schleich 2009, Mills and Schleich 2012, Michelsen and Madlener 2012), while other results suggest that middle-aged people are more likely to adopt such technologies than younger ones (Mills and Schleich 2010a, Sardianou and Genoudi 2013).

A number of studies underline the importance of dwelling characteristics behind consumer choices. In particular, the ownership of the primary residence is an important driver of technology adoption. Evidence on the owner-effect is provided by Davis (2010) who shows that renters are significantly less likely to have energy-efficient refrigerators, clothes washers or dishwashers than owners, while Gillingham et al. (2012) demonstrate that owner-occupied dwellings are more likely to be insulated than renter-occupied dwellings. Other studies suggest that dwellings' characteristics, such as location in a rural area and/or detachment from other houses may be indicators of space availability for investing in particular energy technologies, while the climate zone can influence the performance of specific energy measures (Mills and Schleich 2009, Di Maria et al. 2010, Michelsen and Madlener 2012) and thus people's propensity to invest.

Technology adoption can also be affected by households' limited ability or willingness to collect and process the information that is necessary to assess whether an investment is profitable. Whether consumers know the costs and benefits of different energy solutions, how much energy they use in their homes, or what rates of return to expect from energy efficiency measures is likely to affect the adoption of energy-efficient technologies (Mills and Schleich 2012). Attari et al. (2010) provide evidence on households' misperceptions about energy use or savings. They suggest that there is relatively little knowledge regarding the effectiveness of different energy saving measures. Such limited knowledge is likely to determine the probability to invest in energy efficiency and renewables. Indeed, when consumers are aware about potential energy savings, the probability of investing in energy conservation measures increases (Scott 1997). Di Maria et al. (2010) find that the over 50% of their respondents are not aware of the potential energy savings of compact fluorescent light bulbs compared to the traditional bulbs.

Regarding households' limited ability to process information, studies often refer to the concept of bounded rationality suggesting that customers use simplified decision-making processes, by using only a subset of the available information for complex decisions (Simon, 1959). Research on bounded rationality suggests that individuals are more likely to take into account aspects that are easy to perceive than those that are difficult to assess, when they make an investment decision (Yates and Aronson 1983). Indeed, consumers tend to perceive the upfront investment cost relatively easily, while assessing the total present value of energy savings over the life of an investment is a more difficult task given the uncertainty surrounding energy savings and fluctuations in energy prices (Jaffe and Stavins 1995, Hassett and Metcalf 1995). This salience effect can lead households to give initial costs a higher weight than energy savings. Another phenomenon that might explain the stronger emphasis on initial costs than future energy savings often observed in consumer behaviour is termed the "status quo bias". Kahneman and Tversky (1979) suggest that people normally perceive outcomes as losses and gains relative to a reference point, usually the status quo. The authors' empirical results suggest that people exhibit loss aversion in decision making under uncertainty, giving much more weight to a possible loss than to an equivalent uncertain gain. In the energy efficiency context, loss aversion can partly explain why consumers do not take up cost-effective investments, as they weight the certain initial costs (the loss) much more strongly than future uncertain benefits, even if these are in principle of an equivalent value.

Attitudes, beliefs and social practises may also play a role as a motivation to invest in addition to pure monetary benefits and costs of an investment. Indeed, several studies find that people with strong environmental preferences are more likely to invest in energy conservation technologies (Olli et al. 2001, Kollmus et al. 2002, Di Maria et al. 2010). Often, households' energy use and energy conservation actions are driven by habits, routines and social practises (Shove 2012). Kahn (2007) underlines the importance of living in environmentalist communities as a driver for environment-friendly behaviour. He shows that individuals living in communities with a higher share of green party members are more likely to use public transit, purchase green vehicles (e.g. hybrid), and consume less gasoline than people in other communities. Also Olli et al. (2001) suggest that social context is important for environmental behaviour, as social participation correlates positively with responsible environmental behaviour. However, although several studies suggest that peoples' attitudes are predictors of energy saving behaviour, often this relationship is weak, explaining only a small part of household energy choices (Viklund 2004, Sjoberg and Engelberg 2005, Di Maria et al. 2010).

Finally, energy prices and a favourable policy context should also affect household technology adoption. In particular, recent studies underline the relevance of urban climate governance, that is the policies and measures undertaken by local governments for energy investment to occur (Bulkeley 2010, Bulkeley et al. 2013).

This paper provides novel evidence on the main factors behind consumer choices regarding the adoption of energy efficiency and renewable energy technologies. It is based on the OECD Survey on Household Environmental Behaviour and Attitudes comprising household data from 11 OECD countries. Results suggest that households' propensity to invest in clean energy technologies depends on home ownership, confirming a previous OECD study (OECD, 2013a), income, as well as attitudes and beliefs. Indeed, home owners and high-income households are more likely to invest than renters and low-income households. Households, who demonstrate environmental consciousness, e.g. through membership in a non-governmental organisation (NGOs), in particular when it is environmental, or through regular energy conservations actions, are more likely to invest than others.

The contribution to the literature on households' technology adoption behaviour is threefold. First, the unique dataset underlying this study includes data from 11 OECD countries. To our knowledge, this is the first cross-country analysis of household investment in energy technologies for countries across the OECD. Mills and Schleich (2012) analysed the adoption of residential energy technologies at the European level, while other studies focused on technology adoption for single countries. Second, the data allow us to account for a rich set of variables, including respondents' beliefs, attitudes and behaviour regarding the environment and their knowledge about their energy use and spending, in addition to more commonly investigated factors, such as households' socio-economic characteristics, dwelling characteristics and economic variables. This provides novel insights into technology adoption behaviour. Third, this study covers seven different technologies, including energy efficiency measures and renewable energy technologies, revealing differences and similarities regarding the determinants of investment in these technologies.

The paper is structured as follows. The following section presents the data, while the third section presents the econometric model. The fourth section presents and discusses the empirical results. The final section concludes.

Data description

The Survey data were collected through an online questionnaire, the second of its kind, which was carried out in early 2011, while the first was launched in 2008. The more recent survey, which is the basis for the analysis in this paper, collects data from a sample of more than 12 000 respondents, approximately 1 000 households for each country: Australia (shorthand: AUS), Canada (shorthand: CAN), Chile (shorthand: CHL), France (shorthand: FRA), Israel (shorthand: ISR), Japan (shorthand: JPN), Korea (shorthand: KOR), the Netherlands (shorthand: NLD), Spain (shorthand: ESP), Sweden (shorthand: SWE) and Switzerland (shorthand: CHE).

For representativeness, the sample was stratified in each country according to different parameters: age, gender, region and socio-economic groups[1]. Age was stratified using the following groups: 18 to 24, 25 to 34, 35 to 44, 45 to 54 and

[1] The OECD ran "Call for Tender" to select a survey service provider specialised in the implementation of large international web-surveys using online consumer panels in different countries. Global Market Insite (GMI) was selected to run the survey and respondents were recruited from GMI's in-country panels. In some countries, GMI partnered with in-country firms with their own

55 to 69. Gender was approximately half male and female for all countries. Region was stratified and quotas created using three to five regions. For income stratification, households' after-tax income quintiles were estimated for each country, then responses from the survey income question were used to fill the quotas. When quotas were filled, respondents with these characteristics were stopped from completing the questionnaire. The target respondent was between 18 and 70 years of age and had influence on household purchasing decisions and expenditures. Despite rigorous efforts regarding stratification and quota sampling, it is important to acknowledge that there may be some respondent characteristics that were not observed and which correlate with internet use. This correlation of unobserved characteristics could introduce a selection bias in the sample. More details on the questionnaire design, respondent targeting and quota sampling are provided in OECD (2013a), annex B.

The aim of this study is to investigate which factors might drive household decision making when it comes to the adoption of clean energy technologies. The survey data provides a good basis for this, as households were asked whether they installed or bought appliances that received a top rating in terms of energy efficiency between 2001 and 2011. The shorthand for the corresponding variable used in this paper is "Appl"; the variable takes a value of 1 for households who invested and zero for households, who could have invested, but decided against it. The same variable is constructed for low-energy light bulbs (shorthand: Bulb), energy-efficient windows (double or triple glazing, shorthand: Windows), thermal insulation of walls or the roof (shorthand: Thrm), heat thermostats[2] (shorthand: Heat), solar panels for electricity or hot water (shorthand: Solar) or ground source heat pumps (shorthand: Pump). The survey also includes data regarding wind turbine investments. However given the limited number of investors, namely 158 households, those data were not included in the analysis. To study the determinants of household investment decisions only those households were considered who could in principle have invested, while those who declared that their house was already equipped or that, as renters, they were not allowed to invest were not included in the analysis. Table 1 shows descriptive statistics for the adoption of different technologies.

Table 1. Rates of Technology adoption across countries

Country	Appl Mean	Bulb Mean	Pump Mean	Solar Mean	Thrm Mean	Heat Mean	Windows Mean
Australia	0.69	0.91	0.03	0.20	0.58	0.15	0.13
Canada	0.67	0.87	0.04	0.04	0.38	0.65	0.51
Chile	0.41	0.95	0.01	0.02	0.31	0.06	0.14
France	0.74	0.86	0.05	0.06	0.45	0.44	0.59
Israel	0.59	0.84	0.03	0.67	0.20	0.11	0.13
Japan	0.48	0.48	0.01	0.04	0.20	0.07	0.19
Korea	0.69	0.63	0.03	0.07	0.38	0.59	0.49
Netherlands	0.61	0.89	0.02	0.04	0.49	0.48	0.73
Spain	0.74	0.91	0.02	0.06	0.21	0.47	0.54
Sweden	0.62	0.87	0.16	0.04	0.29	0.34	0.39
Switzerland	0.62	0.79	0.07	0.05	0.37	0.43	0.49
Total	0.62	0.82	0.04	0.11	0.34	0.33	0.38

Among the investments considered, low-energy light bulbs were particularly frequently adopted across countries, with more than 80% of households stating that they had bought such bulbs over the last ten years. Energy efficient appliances were also relatively frequently adopted, by more than 62% of households, while ground source heat pumps were adopted by only a small minority of households, 3.9% across all countries. Those numbers suggest that technology adoption is more likely for investments with relatively low initial investment cost and easy

panels in order to further increase panel size. All partners were selected on the basis of quality of panel management. Specifically GMI and its partners managed their respondents in line with ESOMAR 26, which is a standard for transparency and accountability in the use of respondent panels for web-based survey research. To limit the risk of recruiting "professional respondents", GMI only permitted panellists to answer and receive compensation for up to five questionnaires per year. Moreover, potential respondents who started the questionnaire were asked whether they met the screening criteria (living in non-institutional settings and influential in household financial decisions). If they did not meet the criteria, they were screened out of the sample.

[2]Heat thermostat is a device that establishes and maintains a desired temperature automatically or signals a change in temperature for manual adjustment.

implementation. However, technology adoption varies significantly across countries. Israel is the only country showing a high rate of adoption for solar panels (66%), while on average 11% of households have invested in solar technologies. In the Netherlands relatively large shares of households seem to have invested in thermal insulation, heat thermostats and energy-efficient windows. Australia, as well, shows a high rate of adoption for thermal insulation (58%), while Canadian households are particularly likely to invest in heat thermostats (65%). In general, Japanese and Chilean households invest relatively infrequently in most of the technologies considered in this study, except for energy efficient appliances and low-energy light bulbs.

Based on the empirical literature and data availability, factors that might influence the decision to invest in energy technology have been grouped in four different categories: (1) socio-economic characteristics of households; (2) the characteristics of their dwelling; (3) households' attitudes, knowledge and behaviour regarding the environment; (4) households' knowledge about their energy spending and use.

Socio-economic variables available in the household data set include the respondent's age (Age), gender (Female), household size, the number of years of education after high school (Education), annual net household income (Log_Income), the educational status of the household head, operationalised as a dummy variable for household heads who are highly qualified professionals (Prime-earner is high skilled worker). There is also a dummy variable that takes a value of 1 for households stating that they cannot cope with their current income (NoCope). Descriptive statistics are shown in Table 2.

Table 2. Socio-economic characteristics of households

Country	Age		Education		Log_Income		Household Size		Female*	NoCope*	Prime-earner is high skilled worker*
	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Sd	Mean	Mean	Mean
Australia	42.20	14.16	3.31	3.47	48700	27933	2.90	1.48	0.51	0.39	0.19
Canada	43.59	14.18	3.13	2.94	42026	26803	2.51	1.18	0.51	0.37	0.16
Chile	37.41	12.41	4.36	3.04	13585	10387	3.84	1.56	0.52	0.44	0.36
France	43.18	14.07	2.64	2.36	38157	17697	2.74	1.17	0.51	0.44	0.12
Israel	38.3	13.24	3.95	3.45	26562	15329	3.63	1.65	0.55	0.43	0.32
Japan	43.67	13.83	4.90	4.26	48394	28702	2.99	1.49	0.49	0.29	0.08
Korea	38.53	11.66	3.26	2.38	27012	13892	3.49	1.32	0.50	0.33	0.13
Netherlands	45.18	13.72	4.14	3.16	38708	16953	2.63	1.18	0.50	0.24	0.21
Spain	41.72	12.77	3.66	3.07	29360	16337	2.99	1.11	0.49	0.37	0.25
Sweden	43.63	14.45	2.39	2.51	41575	19181	2.39	1.17	0.48	0.34	0.16
Switzerland	44.21	14.14	2.74	2.66	62278	29666	2.67	1.37	0.52	0.36	0.09
Total	42.01	13.77	3.50	3.15	37868	24681	2.98	1.42	0.51	0.36	0.19

*For dummy variables, standard deviation is not computed

Households' average annual net income is approximately 37 868 dollars with considerable differences in means across countries. Households living in Chile declared the lowest average annual income (13 585 dollars), while households resident in Switzerland declared the highest level of annual average income (62 278 dollars). 36% of households stated that their salary was not enough to cover their needs, and difficulty to cope with income is particularly an issue in Chile (43.6%), France (43.8%) and Israel (42.8%). It is quite surprising that Chile and Israel are the two main countries with a higher percentage of professionals as household heads, 36% and 31.8% respectively, while France showed one of the lowest shares (11.5%). Those data could partly result from French respondents' difficulty to classify their occupation according to the categories they were given, as they particularly frequently classified their occupation as "other". The average length of education after high school is 3.5 years, suggesting that a number of respondents went to university.

The survey includes some characteristics of dwellings, such as home-ownership versus rental (Owner), dwelling type (House), years lived in the primary residence (Tenure) and whether households live in a rural area (Rural). Table 3 lists the variables used.

Table 3. Characteristics of dwellings

Country	House*		Tenure		Owner*		Rural*	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Australia	0.83	-	9.36	11.27	0.62	-	0.20	-
Canada	0.65	-	10.72	12.43	0.63	-	0.27	-
Chile	0.77	-	12.95	13.94	0.65	-	0.14	-
France	0.61	-	12.84	13.81	0.61	-	0.54	-
Israel	0.32	-	15.10	15.62	0.67	-	0.20	-
Japan	0.60	-	18.83	16.70	0.58	-	0.31	-
Korea	0.30	-	8.63	9.10	0.70	-	0.07	-
Netherlands	0.75	-	15.99	14.81	0.68	-	0.53	-
Spain	0.26	-	13.76	12.97	0.80	-	0.38	-
Sweden	0.47	-	10.74	12.34	0.60	-	0.47	-
Switzerland	0.36	-	11.70	12.05	0.38	-	0.61	-
Total	0.54		12.86	13.68	0.63		0.34	

*For dummy variables, standard deviation is not computed

The majority of respondents (63%) own their residence and more than half of households live in a detached house (53%). Higher rates of ownership are observed in Spain (79.8%), Korea (69.8%) and the Netherlands (68%), while relatively many households live in a detached house in Australia (82.6%), Chile (77%) and the Netherlands (74%). On average, households have lived for approximately 13 years in their primary residence, although average tenure is longer in Japan, around 18 years.

A number of variables reflect respondents' beliefs, attitudes and behaviours regarding the environment. This includes a dummy variable for households that participate in a non-governmental organisation (NGO) and another one for those that are specifically in an environmental NGO (Env NGO). There is a dummy variable for people who rated the environment as the most pressing concern (Env_top_cncrn) and another one for those who instead rated the economy as the most pressing concern (Eco_top_cncrn). Another dummy variable is used for those respondents who were able to identify the causes of climate change correctly (Understand_CC).

Respondents were asked questions regarding their willingness to make sacrifices to protect the environment, their assessment of the need to do so and the role of technology in solving environmental problems. Depending on their answers to those questions households were grouped in three clusters[3]: i) the environmentally motivated, who are willing to make sacrifices in their lifestyle to solve environmental problems (Altruists), ii) environmental sceptics who are not willing to make much effort to solve environmental problems, which they believe are often exaggerated (Sceptics), and iii) a group of technological optimists who believe that environmental problems are real and technological innovations are key to solving them (Green Growthers) (OECD, 2013b). Respondents were grouped according to their agreement on seven statements: 1) Policies introduced by government to address environmental issues should not cost me extra money, 2) I am willing to make compromises in my current lifestyle for the benefit of the environment, 3) Protecting the environment is a means of stimulating economic growth, 4) Environmental issues will be resolved in any case through technological progress, 5) Environmental impacts are frequently overstated, 6) I am not willing to do anything about the environment if others do not do the same, 7) Environmental issues should be dealt with primarily by future generations. Table 4 summarises the variables related to social context and environmental behaviour.

[3] To uncover these attitudinal profiles the latent class method (LCA) is used. LCA is a statistical method for identifying unmeasured class membership among subjects using categorical and/or continuous observed variables. A description and demonstration of LCA in the context of environmental attitudes can be found in Morey, Thatcher et al. (2006).

Table 4. Respondents' beliefs, attitudes and behaviours regarding the environment

Country	Green Growthers		Altruist		Sceptics		NGO*	Env NGO*	Env Top Concern*	Eco Top Concern*	Understand CC*	Cost Bias**
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	Mean	Mean	Mean	Mean	mean
Australia	0.10	0.30	0.42	0.49	0.44	0.50	0.52	0.09	0.18	0.32	0.27	0.35
Canada	0.14	0.35	0.46	0.50	0.37	0.48	0.53	0.10	0.13	0.36	0.30	0.31
Chile	0.26	0.44	0.54	0.50	0.19	0.39	0.69	0.17	0.19	0.27	0.29	0.45
France	0.10	0.30	0.56	0.49	0.33	0.47	0.44	0.08	0.11	0.44	0.24	0.25
Israel	0.12	0.32	0.64	0.48	0.23	0.42	0.50	0.12	0.09	0.21	0.15	0.39
Japan	0.19	0.39	0.31	0.46	0.46	0.50	0.32	0.03	0.17	0.49	0.26	0.36
Korea	0.25	0.44	0.38	0.48	0.36	0.48	0.42	0.05	0.28	0.37	0.21	0.33
Netherlands	0.24	0.42	0.29	0.45	0.43	0.49	0.52	0.12	0.11	0.27	0.32	0.32
Spain	0.22	0.42	0.37	0.48	0.38	0.49	0.57	0.10	0.04	0.62	0.21	0.41
Sweden	0.09	0.29	0.55	0.49	0.34	0.479	0.56	0.11	0.25	0.25	0.44	0.44
Switzerland	0.15	0.36	0.48	0.50	0.36	0.48	0.63	0.20	0.22	0.26	0.33	0.40
Total	0.17	0.38	0.45	0.50	0.35	0.48	0.52	0.11	0.16	0.35	0.27	0.36

*For dummy variables, standard deviation is not computed
** This variable considers that the rating given to initial investment cost exceeds the rating for future energy prices by three points on the scale

The percentage of respondents who believe that environmental problems are real and express a willingness to make compromises in their lifestyle to solve them is 45%, although with some country variation, as almost 65% of respondents are "Altruists" in Israel and around 55% in France and Sweden. On the other hand, on average across countries 35% of respondents are sceptical about environmental problems. Japan showed the highest level of scepticism (45%), while Chile showed the lowest level (18.8%). This mirrors the share of environmental "Altruists" in those two countries, 30% in Japan and 53.8% in Chile.

In most countries, more than 50% of respondents are engaged in some non-governmental organisation (NGO). Only in Japan is this share much lower, just above 30%. On average across countries around 10% of respondents are engaged in an environmental NGO, but both in Japan and Korea this share is much lower.

Less than one third of respondents (27%) seemed to understand the causes of climate change, although with some country variation. This share is almost 45% of households in Sweden and only around 15% in Israel. At the same time, Swedish households are more likely to make sacrifices in their lifestyle to solve environmental problems. On the other hand, Dutch households are the less likely to sacrifice their lifestyle for the environment, although 32% of them are aware about the causes of climate change. Quite surprisingly, Israel shows the lowest level of awareness regarding the causes of climate change (15%), but at the same time this is the country with the highest percentage of respondents who are environmental "Altruist" (64%).

A variable is constructed to capture a bias, in that a much larger weight is given to initial investment costs than to higher energy prices, although the impact on households' propensity to invest should be the same for investment cost reductions and energy price increases that have an equivalent present value. Households were asked to rate different reasons that would induce them to invest in energy efficiency or change their behaviour to save more energy on a scale of 0 to 10. A variable named "Cost bias" identifies households giving a significantly higher rating to lower initial investment costs than to higher energy prices. When the rating given to initial investment cost exceeds the rating for future energy prices by three points on the scale, respondents are considered as having a bias towards initial investment costs and the dummy variable takes a value of 1. As a sensitivity test, the variable is also constructed considering a difference of 4 points on the scale. On average, 36% of respondents give a rating to initial investment costs that is 3 points higher than the rating for energy prices, 30% give a rating to initial investment costs that is 4 points higher. The highest rate is observed for Chile, which is also the country with the lowest average annual income. This could suggest that financial constraints might partly explain why households give a stronger weight to investment costs than to future energy prices. However, a high percentage of biased consumers is also observed in Switzerland, the country with the highest level of average annual income.

The data also capture households' knowledge about their energy spending and use. A large majority of respondents, 91% on average across countries, stated that their energy consumption is metered. It is not very common for households to be informed about their energy bills and use, though. Respondents were asked to get hold of their energy bills before answering the survey, but only about 55% were able to provide information about their energy spending on average across countries. Even fewer households were able to provide information about their energy consumption, less than 19% on average across countries. The data show an unusual result for Korean households, who seem better informed about their energy consumption in volumes than about their energy spending.

Regarding energy use, the "behaviour index" variable captures whether respondents perform certain energy conservation actions regularly, such as turning off the lights when leaving the room, cutting down on heating/air conditioning to limit energy consumption, running full loads when using the washing machines, washing clothes using cold rather than warm/hot water, switching off the standby mode of appliances and air dry laundry rather than using a clothes dryer. The behaviour index ranges from 0 to 10, where higher values indicate that households perform several of these actions regularly. The data suggest that households perform quite regularly energy conservation actions and on average across countries the behaviour index takes values around 7. Lower values of the index are observed in Sweden (5.55) and Switzerland (6.82), while higher values are observed in Chile (8.32) and Spain (8.39). Table 5 summarises the variables related to household's knowledge about their energy spending and use.

Table 5. Households' knowledge about their energy spending and use

Country	Metered*	Ebill_known*	KWatt_known*	Behaviour Index	
	Mean	Mean	Mean	Mean	St. Dev.
Australia	0.91	0.66	0.14	7.91	1.66
Canada	0.81	0.53	0.12	7.10	1.77
Chile	0.91	0.71	0.18	8.32	1.63
France	0.94	0.66	0.15	7.95	1.59
Israel	0.89	0.65	0.13	7.64	1.69
Japan	0.97	0.58	0.21	7.08	1.86
Korea	0.96	0.12	0.26	7.80	1.70
Netherlands	0.91	0.38	0.26	7.06	1.75
Spain	0.93	0.63	0.13	8.39	1.45
Sweden	0.90	0.56	0.37	5.55	1.84
Switzerland	0.90	0.63	0.15	6.82	1.77
Total	0.91	0.55	0.19	7.43	1.86

*For dummy variables, standard deviation is not computed

When interpreting these results, it is important to keep in mind that response bias might occur. The wording of questions, the response scale (especially for attitudinal questions), context and data collection techniques can all affect the way responses are provided. In particular, even the slightest suggestion in the way a question regarding opinions and attitudes is formulated can potentially lead the respondent toward a particular answer. For instance, some results concerning households' rationality could reflect the respondents' difficulty to interpret correctly the questions themselves. In addition, self-report bias can occur. Generally, survey participants have the tendency to respond in a way that makes them look as good as possible, or socially desirable, and this could have a bearing on the survey findings (King and Bruner 2000, Donaldson and Grant-Vallone 2002). Another source of bias can be strategic misrepresentation. When respondents expect a possible connection between their response and some economic outcome in which they have an interest, they may have strategic incentives to misrepresent information. For instance, when households are asked whether high energy prices would induce them to invest in energy efficiency, they may understate their reaction to energy prices if they believe that their response could lead to an increase in future energy prices, perhaps because they think that survey results might induce the government to raise energy taxes.

Method

Households' investment in energy efficiency and renewables is investigated within a discrete choice modelling framework. For each investment good i studied in this paper, households' investment is modelled as:

$$y_i^* = x_i \, \beta + \epsilon_i \tag{1}$$

where y_i^* is a latent variable that captures households' preference for technology i, namely the difference between the marginal benefit and the marginal cost of adopting this good. X_i is a vector of explanatory variables (e.g. socio-economic characteristics, dwellings' characteristics, households' attitudes, knowledge and behaviour, and household's energy use), β is the parameter vector to be estimated and ϵ_i is the error term. While preferences cannot be observed directly, the decision to adopt technology i can be observed and it is modelled in line with the following decision rule:

$$y_i = 0 \ \ if \ y_i^* < 0$$
$$y_i = 1 \ \ if \ y_i^* \geq 0 \tag{2}$$

That is, a household invests in good i ($y_i = 1$) if the marginal benefit of adopting this good is larger than or equal to the marginal cost, otherwise it does not invest ($y_i = 0$). The probability of households' investing in good i is modelled as follows:

$$P(y_i = 1|x_i) = \frac{\exp(x_i\beta)}{1 + \exp(x_i\beta\ )}$$

$$= \Lambda(x_i\beta\ ) \tag{3}$$

where Λ denotes the logistic cumulative distribution function.

Given the non-linearity of the logit model, marginal effects have to be calculated from the underlying estimates. For continuous variables, the marginal effect measures the change in the predicted probability of observing that a household invests (y=1) associated with changes in the explanatory variables (X_i) that are infinitesimally small. For dummy variables, the marginal effect measures how the predicted probability of observing that a household invests (y=1) changes as the dummy variables change from 0 to 1. It should be noted that marginal effects do not have a clear interpretation for ordinal variables, such as the behaviour index, as differences between different levels of this variable are not meaningful. Only the sign of the marginal effect can be interpreted in this case.

In this study, marginal effects are evaluated at the sample means of the independent variables. As marginal effects may be very different at data points that are different from the sample mean, it can be useful to examine marginal effects across a range of values for some explanatory variables, such as income. In particular, marginal effects are computed as follows:

$$\frac{\partial \Pr(y_i=1|x_i)}{\partial x} = \Lambda(\ x_i\beta)\ [1 - \ \Lambda(x_i\beta)]\ \beta \tag{4}$$

The logit model is estimated with country-level fixed effects that capture differences in policy and economic context, income levels and other country-specific circumstances. Sweden is the base country.

The Bayesian model averaging (BMA) method is used to determine the best model specification. In absence of a theoretical model, BMA offers a systematic method for analysing specification uncertainty and checking the robustness of results to alternative model specifications (Raftery 1995). For each tested explanatory variable, BMA provides the probability that this variable is included in the true model. This is calculated on the basis of weights assigned to each tested models. The BMA method selects the "best" model (the one with highest posterior probability) based on all possible combinations of the explanatory variables. In this paper, BMA also helps to deal with collinearity issues in the canonical regressions, which include all explanatory variables. In particular, collinearity occurs with attitudinal variables, such as altruists, green growthers and sceptics, while in the model selected with the BMA method those variables are never included all together.

Results and Discussion

This section discusses results from the preferred model selected with the BMA method (Tables 6 and 7). Some variables which have been never included in the preferred model are not reported in the Tables. These variables include the occupation of the household head and an index variable for those respondents who rated the environment or economy as the most pressing concern. Results from the second and third best model, along with canonical regressions that contain all available explanatory variables, can be made available upon request.

Results suggest that socio-economic characteristics of households partly explain investment in energy efficiency and renewables. The age of the respondent appears to be a relevant variable for most of the technologies analysed. Investments in light bulbs, heat thermostats, thermal insulation and energy-efficient windows depend positively on age, while the probability to choose heat pumps decreases with age. Earlier studies confirm that the probability of investing declines with age for innovative heating systems, such as heat pumps, (Mahaptra and Gustavsson 2008, Michelsen and Madlener 2012), while it increases with age for energy-efficient light bulbs (Mills and Schleich 2012 and 2014). As in Mills and Schleich (2009), age did not seem to be a relevant variable for investments in solar panels. Sardianou and Genoudi (2013) find that middle-aged people are more likely to invest in RES than younger people and Willis et al. (2011) suggest that households with members older than 65 years are less likely to adopt solar technologies compared to the rest of the population. Overall, the impact of age on the probability of investing in clean technologies seems to be technology specific and perhaps sometimes driven by age groups.

Family size is positively related to the probability to invest in solar panels and light bulbs, while it is not included in the preferred model specification for the other technologies. These results are in line with previous studies which also find that the propensity to adopt solar technologies and light bulbs increases with family size and children (Mills and Schleich 2009, Mills and Schleich 2012). Mills and Schleich (2010a), and Mills and Schleich (2012) suggest that a positive relationship between family size and technology adoption holds also for energy-efficient appliances.

We find evidence for credit constraints for some technologies, as investment depends positively on income, except for light bulbs, solar panels and heat pumps, for which income was not included in the preferred model specification or was not a significant variable. This is in line with previous studies, many of which find a positive correlation between income and the probability to invest in energy conservation measures or renewable energy technologies (Long 1993, Mills and Schleich 2010b, Sardianou and Genoudi, 2013), while similar to our study Michelsen and Madlener (2012) did not find any correlation between income and investment in heat pumps. Our findings could suggest that public subsidies for solar panels and heat pumps or other policies have helped to overcome credit constraints.

To better understand the extent of credit constraints, we examined marginal effects across a range of income values. The marginal effect of higher income on the probability to invest is decreasing, pointing to financing constraints that are particularly relevant for lower-income households. This can be seen in Figure 1 for energy-efficient appliances, which shows how the predicted probability to invest evolves with income for a representative individual, whose characteristics are described in more detail in Table 10. In essence, binary variables take the value that is most frequently observed in the sample, while continuous variables are evaluated at the sample mean. An increase in income leads to a big increase in the probability to invest for low-income levels, but this marginal effect decreases and finally levels off for high income levels. In the case of energy-efficient appliances, increasing income from 15 000 $ to 45 000 $ would lead to an increase of about 10 percentage points in the probability to invest, while the same increase in income would lead to an increase of only 3 percentage points in the probability to invest for an individual that starts with 60 000 $. The same pattern emerges for investments in thermal insulation. Those results provide clear evidence for financing constraints. Low-income households are much more likely to lack both savings to cover the initial investment costs for clean energy technologies and access to credit. But this barrier is likely to be much less relevant for higher-income individuals. This would explain why income increases have a large effect on the probability to invest for lower-income households, but much less so for higher-income households.

The representative individual that was used to generate Figure 1 has the characteristics listed in the Table 9. For investment in energy-efficient appliances, the representative individual owns his house/apartment and he is engaged in a non-governmental organisation. He meters his energy consumption, but he is not aware about his energy consumption. He also performs quite regularly energy conservation actions.

Table 6 Bayesian Model Averaging Estimates. Logit regressions I

Dependent variables: investments in energy-efficient appliances, light bulbs and heat thermostat

Variables	Energy-efficient appliances		Light bulbs		Heat thermostats	
	Coefficients	Marginal effects	Coefficients	Marginal effects	Coefficients	Marginal effects
Age			0.0140***	0.00171***	0.0115***	0.00229***
			(0.00226)	(0.000274)	(0.00234)	(0.000465)
HHsize			0.135***	0.0165***		
			(0.0249)	(0.00302)		
Education						
Log_Income	0.362***	0.0833***			0.0154***	0.00306***
	(0.0425)	(0.00978)			(0.0027)	(0.000538)
NoCope						
Owner	0.336***	0.0783***	0.151**	0.0186**	0.372***	0.0714***
	(0.0518)	(0.0122)	(0.0628)	(0.00789)	(0.073)	(0.0134)
House			0.295***	0.0363***	0.167**	0.0330**
			(0.0656)	(0.00814)	(0.0694)	(0.0136)
Tenure			-0.0502**	-0.00611**	-0.0908***	-0.0181***
			(0.0247)	(0.00301)	(0.0258)	(0.00513)
Rural			0.0206	0.00250	0.150**	0.0301**
			(0.0651)	(0.00789)	(0.0654)	(0.0133)
Green_Growther						
Altruist						
Sceptics			-0.200***	-0.0248***		
			(0.0566)	(0.00719)		
NGO	0.345***	0.0797***	0.416***	0.0511***	0.270***	0.0535***
	(0.0485)	(0.0112)	(0.0563)	(0.00696)	(0.0584)	(0.0115)
ENV_NGO						
Understand_CC						
Behaviour Index	0.140***	0.0322***	0.161***	0.0196***	0.0916***	0.0182***
	(0.0139)	(0.00319)	(0.0154)	(0.00186)	(0.0167)	(0.00332)
KWatt_know	0.316***	0.0708***			-0.00762	-0.00151
	(0.0604)	(0.0131)			(0.0743)	(0.0148)
Ebill_know			0.189***	0.0232***	-0.0938	-0.0188
			(0.0592)	(0.00734)	(0.0655)	(0.0132)
Metered	0.354***	0.0845***				
	(0.0939)	(0.023)				
Cost_Bias					-0.125**	-0.0247**
					(0.0599)	(0.0117)
AUS	0.0831	0.0189	-0.0286	-0.00351	-1.214***	-0.185***
	(0.121)	(0.0273)	(0.165)	(0.0205)	(0.153)	(0.0165)
CAN	0.158	0.0357	-0.283**	-0.0374*	1.157***	0.266***
	(0.117)	(0.0259)	(0.141)	(0.0202)	(0.129)	(0.0316)
CHE	-0.109	-0.0255	-0.755***	-0.114***	0.263*	0.0550*
	(0.12)	(0.0283)	(0.132)	(0.0237)	(0.136)	(0.0296)
CHL	-0.690***	-0.167***	0.365**	0.0400**	-1.765***	-0.241***
	(0.128)	(0.0317)	(0.186)	(0.0180)	(0.196)	(0.0158)
ESP	0.405***	0.0882***	-0.0947	-0.0118	0.492***	0.106***
	(0.124)	(0.0253)	(0.155)	(0.0200)	(0.135)	(0.0309)
FRA	0.491***	0.106***	-0.527***	-0.0742***	0.287**	0.0601**
	(0.119)	(0.0236)	(0.138)	(0.0221)	(0.13)	-0.0284
ISR	-0.0576	-0.0133	-0.594***	-0.0856***	-1.371***	-0.205***
	(0.117)	(0.0273)	(0.142)	(0.0236)	(0.16)	(0.0164)
JPN	-0.656***	-0.159***	-2.254***	-0.443***	-1.985***	-0.256***
	(0.111)	(0.0274)	(0.126)	(0.0291)	(0.176)	(0.0124)
KOR	0.311***	0.0688***	-1.672***	-0.308***	1.187***	0.273***
	(0.117)	(0.0247)	(0.135)	(0.0313)	(0.138)	(0.0337)
NLD	-0.0129	-0.00296	-0.115	-0.0145	0.532***	0.116***
	(0.116)	(0.0269)	(0.142)	(0.0185)	(0.129)	(0.03)
Constant	-5.000***		-0.276		-3.774***	
	(0.466)		(0.168)		(0.346)	
Observations	8,605	8,605	10,951	10,951	7,334	7,334

Table 7 Bayesian Model Averaging Estimates. Logit regressions II

Dependent variables: investments in solar panels, heat pumps, thermal insulation and energy-efficient windows

Variables	Solar panels		Heat pumps		Thermal Insulation		Energy-efficient windows	
	Coefficients	Marginal effects	Coefficients	Marginal effects	Coefficients	Marginal effects	Coefficients	Marginal effects
Age			-0.0223***	-0.000510***	0.00930***	0.00204***	0.0149***	0.00335***
			(0.00449)	(0.000105)	(0.00221)	(0.000484)	(0.00225)	(0.000506)
HHsize	0.213***	0.0135***						
	(0.0369)	(0.00234)						
Education								
Log_Income			0.136	0.00311	0.232***	0.0508***	0.211***	0.0474***
			(0.126)	(0.00288)	(0.0490)	(0.0107)	(0.0512)	(0.0115)
NoCope								
Owner			0.420***	0.00884***	0.687***	0.141***	0.612***	0.131***
			(0.155)	(0.00302)	(0.0715)	(0.0136)	(0.0707)	(0.0143)
House	0.330***	0.0204***			0.557***	0.119***	0.109	0.0245
	(0.11)	(0.00661)			(0.0657)	(0.0137)	(0.0671)	(0.015)
Tenure					-0.122***	-0.0267***	-0.105***	-0.0236***
					(0.0246)	(0.00538)	(0.0247)	(0.00556)
Rural	-0.249**	-0.0153**	0.0884	0.00204			0.00845	0.0019
	(0.109)	(0.0065)	(0.132)	(0.00310)			(0.0646)	(0.0145)
Green_Growther			-0.531***	-0.0104***				
			(0.185)	(0.00314)				
Altruist			-0.986***	-0.0225***				
			(0.139)	(0.00329)				
Sceptics					0.131**	0.0289**		
					(0.0578)	(0.0128)		
NGO					0.292***	0.0638***	0.244***	0.0546***
					(0.0567)	(0.0123)	(0.0566)	(0.0126)
ENV_NGO	0.672***	0.0536***	0.694***	0.0209***				
	(0.125)	(0.0122)	(0.170)	(0.00659)				
Understand_CC	-0.099	-0.00617						
	(0.106)	(0.00646)						
Behaviour Index	0.0998***	0.00634***			0.141***	0.0309***	0.103***	0.0232***
	(0.0265)	(0.00167)			(0.0164)	(0.00358)	(0.0162)	(0.00364)
KWatt_know								
Ebill_know	-0.0274	-0.00174					0.0555	0.0125
	(0.0941)	(0.006)					(0.0626)	(0.014)
Metered							0.113	0.0249
							(0.117)	(0.0255)
Cost_Bias	-0.389***	-0.0236***						
	(0.096)	(0.00554)						
AUS	1.214***	0.120***	-2.071***	-0.0242***	0.776***	0.184***	-1.829***	-0.290***
	(0.24)	(0.0337)	(0.264)	(0.00240)	(0.138)	(0.0341)	(0.156)	(0.0149)
CAN	-0.567*	-0.0296**	-1.881***	-0.0234***	0.111	0.0246	0.347***	0.0810***
	(0.291)	(0.0123)	(0.243)	(0.00240)	(0.133)	(0.0300)	(0.123)	(0.0298)
CHE	-0.0449	-0.0028	-1.002***	-0.0158***	0.451***	0.104***	0.386***	0.0907***
	(0.273)	(0.0168)	(0.208)	(0.00252)	(0.142)	(0.0342)	(0.131)	(0.0317)
CHL	-1.327***	-0.0562***	-3.553***	-0.0323***	0.127	0.0283	-1.203***	-0.221***
	(0.312)	(0.0084)	(0.547)	(0.00270)	(0.152)	(0.0343)	(0.16)	(0.0222)
ESP	-0.0819	-0.00506	-2.284***	-0.0262***	-0.531***	-0.107***	0.460***	0.108***
	(0.266)	(0.016)	(0.274)	(0.00252)	(0.148)	(0.0269)	(0.131)	(0.032)
FRA	0.0435	0.0028	-1.285***	-0.0189***	0.459***	0.106***	0.715***	0.171***
	(0.259)	(0.0169)	(0.202)	(0.00238)	(0.135)	(0.0326)	(0.127)	(0.0313)
ISR	3.441***	0.577***	-2.121***	-0.0252***	-0.462***	-0.0940***	-1.481***	-0.257***
	(0.233)	(0.0499)	(0.283)	(0.00256)	(0.146)	(0.0272)	(0.15)	(0.0179)
JPN	-0.321	-0.0181	-3.443***	-0.0308***	-0.590***	-0.117***	-1.097***	-0.204***
	(0.297)	(0.0148)	(0.465)	(0.00259)	(0.144)	(0.0253)	(0.138)	(0.0199)
KOR	0.0451	0.00291	-1.854***	-0.0232***	0.523***	0.122***	0.415***	0.0976***
	(0.268)	(0.0176)	(0.261)	(0.00249)	(0.137)	(0.0333)	(0.133)	(0.0324)
NLD	-0.405	-0.0225*	-2.454***	-0.0261***	0.680***	0.161***	1.350***	0.325***
	(0.272)	(0.0131)	(0.304)	(0.00246)	(0.139)	(0.0343)	(0.141)	(0.0321)
Constant	-4.142***		-2.022		-5.454***		-4.536***	
	(0.296)		(1.331)		(0.545)		(0.563)	
Observations	6,485	6,485	7,645	7,645	6,807	6,807	7,269	7,269

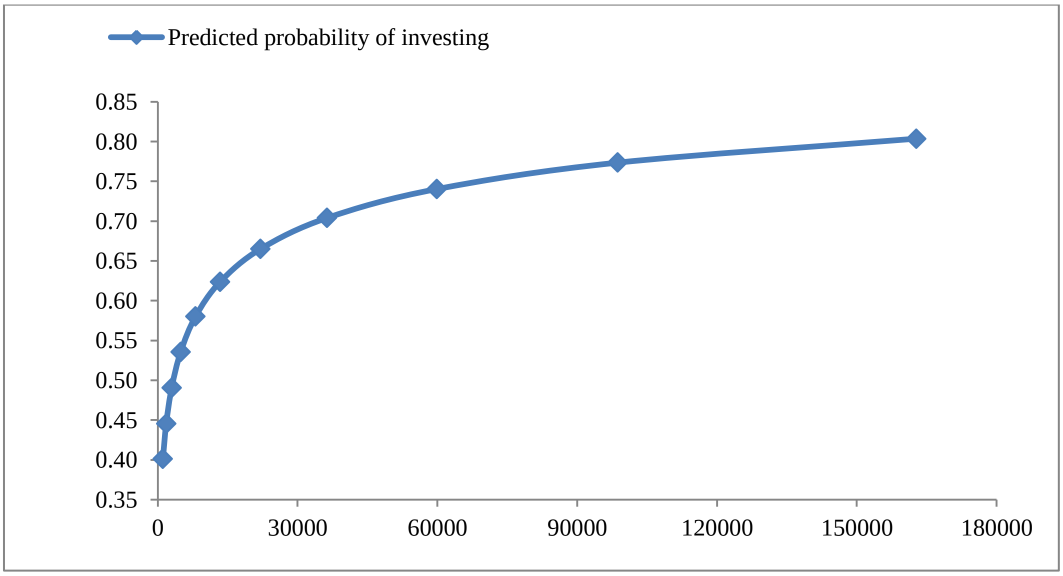
Notes:

Standard errors are reported in parentheses.

Marginal effects at means of dependent variables, superscripts ***, ** and * indicate statistical significance at the 1%, 5% and 10% level, respectively. For dummy variables, the marginal effect shows how the predicted probability of observing that a household invests (y=1) changes as the dummy variables change from 0 to 1. For instance, owners were 7.8 percentage points more likely than renters to own energy-efficient appliances. For continuous variables, the marginal effect measures the instantaneous rate of change. In other words, it measures the change in the predicted probability of observing that a household invests (y=1) associated with changes in the explanatory variables (X_i), when this change is infinitesimally small. For instance, an infinitesimal change of income raises the probability to own energy-efficient appliances by 8.3 percentage points.

Figure 1. Predicted probability of investing in energy efficient appliances depending on changes in income

Values for a representative individual



Source: Values as in table 9

Table 9 Characteristics of the representative individual for energy-efficient appliances

Specified characteristics	Characteristics at mean
Owner=1 NGO=1 KWatt_know=0 Metered=1	Energy Behaviour Index

Other socio-economic characteristics were not included in the preferred model. In particular, empirical results from this study have never shown education as a key explanatory variable for technology adoption, in contrast with many studies in the literature (Mills and Schleich 2009, Di Maria et al. 2010, Mills and Schleich 2010a, Michelsen and Madlener 2012, Mills and Schleich 2012, Sardianou and Genoudi 2013). Only in a recent study do Mills and Schleich (2014) find that education has no significant impact on light bulb replacement choices.

There is clear evidence supporting the idea that renters may have much weaker incentives to invest than owners. Owners are more likely to invest than renters in energy-efficient appliances, light bulbs, heat thermostats, heat pumps, thermal insulation and energy-efficient windows, with a substantially larger magnitude of the effect for relatively immobile investments (such as windows and thermal insulation). Nevertheless, renters do invest frequently in more mobile technologies with a shorter life cycle, such as energy-efficient appliances and light bulbs as shown in Table 8. These results confirm the analysis conducted in OECD (2013a). The owner-effect is also well documented in the literature (Davis 2010, Gillingham et al. 2012).

Table 8 Share of renters and owners adopting energy efficiency measures and renewables

	Energy-efficient appliances	Light bulbs	Heat pumps	Solar panels	Thermal insulation	Heat thermostat	Energy-efficient windows
Renters	0.54	0.78	0.03	0.09	0.23	0.25	0.28
Owners	0.66	0.84	0.04	0.12	0.39	0.37	0.42

The characteristics of dwellings seem to be relevant for technology adoption. The investment probability for light bulbs, heat thermostats, thermal insulation and energy-efficient windows depends negatively on the time that households have already spent in their place. That could indicate that households are more likely to invest in energy upgrades when they first move into their home. To our knowledge, previous studies did not investigate this aspect, focusing more on other characteristics of dwellings, such as when the house was built (Mills and Schleich 2009, Michelsen and Madlener 2012) or spatial aspects, such as rural or urban area and climate zone (Michelsen and Madlener 2012). Our results also suggest that owning a detached house, which might be seen as an indicator of space availability, increases the probability of investing in light bulbs, heat thermostats, thermal insulation and solar panels. For investment in light bulbs, Di Maria et al. (2010) and Mills and Schleich 2010 provide similar results.

Having to pay in line with energy consumption and information about this, play a role for investment in some technologies. Metered households are more likely to invest in energy-efficient appliances than those, who are not. Households who were able to provide information about their energy bill or energy consumption are more likely to invest in light bulbs and energy-efficient appliances. For instance, in the case of energy-efficient appliances, households that are aware of their kilowatt hours consumed are 7 percentage points more likely to own these devices than other households. This lends support to the idea that imperfect information of households limits the uptake of these clean energy technologies, suggesting that bounded rationality can contribute to explaining underinvestment in such technologies.

There is strong evidence that households who regularly perform low-cost energy conservation measures are also more likely to spend money to conserve energy or use renewables. The investment probability for all technologies, except heat pumps, depends positively on the energy behaviour index.

Estimation results suggest that the role of social context is important for investment decisions. Households who are engaged in a NGO are more likely to invest, in particular when the NGO is environmental. Such social participation correlates positively with technology adoption for energy-efficient appliances, light bulbs, heat thermostats, thermal insulation and energy-efficient windows. When households are involved in environmental associations, they are even more likely to invest than others, who are engaged in non-environmental NGOs. This holds for solar panels and thermal insulation. Social participation is not only a significant variable for all technologies, but the corresponding marginal effects are also quite high. For instance, households involved in NGOs are about 8 percentage points more likely to invest in energy-efficient appliances than households who are not in a NGO. Work by Olli et al. (2001) and Khan (2007), as well, finds social context to be an important predictor of environmental behaviour.

Only for solar panels and heat thermostats do households seem to attach a much larger weight to initial investment costs than to opportunities to reduce the energy bills later on. This could be indicative of credit constraints or of bounded rationality, whereby consumers use simplified or flawed decision making rules that do not involve a full comparison between the costs and benefits of investments (Yates and Aronson 1993). However, since a bias towards initial investment costs is found only for a few technologies, the data do not seem to provide strong evidence in favour of the idea that there may be bounded rationality.

An understanding of the causes of climate change and attitudes towards the environment do not seem to play an important role for investment decisions. The corresponding variables were not included in the preferred model specification in most cases, but when they were, results were rather counter-intuitive. As an example, households who were grouped in the altruist and green growthers clusters seem to be less likely than others to invest in heat pumps.

Conclusions and Policy implications

By adopting energy efficiency and renewable energy technologies, households can make an important contribution to reducing residential energy demand and CO_2 emissions. Therefore, understanding the determinants of consumers' investment choices is becoming increasingly important.

The aim of this study is to provide evidence regarding the determinants of investment in energy efficiency and renewables that have been put forward in the literature. The data from the OECD Survey on Household Environmental Behaviour and Attitudes provides a rich basis for such an investigation.

Results provide clear evidence supporting the idea that renters may have much weaker incentives to invest than owners. This effect is found for almost all investment goods studied in this paper, with a substantially larger magnitude for relatively immobile investments, such as windows and thermal insulation. Nevertheless, renters show some propensity to invest in lower-cost technologies that are more mobile, such as energy-efficient appliances and light bulbs.

Moreover, investment depends positively on income and this effect is larger for lower income levels. This is indicative of credit constraints. Many energy efficiency and renewable investments have high initial investment costs representing a relevant obstacle, especially for low-income households, who are more likely to be credit-constrained.

Technology adoption is also influenced by households' attitudes and beliefs, as households who are in an environmental group or who are ready to engage in low-cost energy conservation practices are also more likely to invest in energy efficiency or renewables.

These results suggest that targeted policies are required to address specific barriers for different groups of consumers. For instance, credit constraints are more relevant for low-income households and lifting these constraints would likely promote investment for this group. Direct subsidies, tax credits or rebates can also be relevant policy instruments to lower the upfront cost of energy investments. While internalising external costs of emissions by increasing energy prices is thought to be a more efficient instrument in the absence of credit constraints, subsidies to adopt low-emission technologies may be a more effective and less costly than higher energy taxation when credit constraints are present.

The split incentive problem that arises in the rental housing market also requires specific policy actions. If investments in energy-efficient measures were capitalised in the purchase and rental prices of the corresponding property, the owner could recover the investment cost. However, this is often not the case, not least because the effectiveness of energy efficiency measures is difficult to observe. Energy efficiency labels can help in this respect. In addition, explicitly allowing owners to increase the rent after implementing energy efficiency measures might be necessary in some countries, where owners are not allowed to raise the rent as they wish, unless the tenant changes. In Germany, this seems to have helped to diffuse energy efficiency measures in a market with a high share of rental housing.

To promote energy conservation actions and influence individual decision-making, providing households with feedback on their energy use can be helpful along with energy labels. Recent research shows that informing households about their energy or water consumption compared with that of similar households and providing them with conservation tips can lead to important savings (Allcott, 2011; Ferraro and Price 2013). Those programmes can be used to encourage the adoption of new technologies such as energy-efficient appliances and, more generally, encourage households to engage in energy conservation actions and practises. Labels can be also used to provide households with reliable information about the performance of energy conservation measures or renewable energy, encouraging them to conserve energy and invest.

Novel approaches, such as nudging consumers could be another policy option to promote energy conservation. A recent example comes from the United Kingdom. Families are being offered an attic-clearing service as an incentive to insulate their lofts at the same time. Under this scheme, workers clear lofts while installing insulation, and take away any unwanted items to charity shops. Early results show that the system significantly increased the number of households insulating their roofs (The Guardian 2013).

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