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Determinants of Households' Investment in Energy Efficiency and Renewables: Evidence from the OECD Survey on Household Environmental Behaviour and Attitudes

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DETERMINANTS OF HOUSEHOLDS' INVESTMENT IN ENERGY EFFICIENCY AND RENEWABLES – EVIDENCE FROM THE OECD SURVEY ON HOUSEHOLD ENVIRONMENTAL BEHAVIOUR AND ATTITUDES

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By Nadia Ameli and Nicola Brandt

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ABSTRACT/RESUMÉ

Determinants of Households' Investment in Energy Efficiency and Renewables – Evidence from the OECD Survey on Household Environmental Behaviour and Attitudes

Many studies on household energy efficiency investments suggest that a wide range of seemingly profitable investments are not taken up. This paper provides novel evidence on the main factors behind consumer choices 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 households' energy practises. Indeed, home owners and high-income households are more likely to invest than renters and low-income households. On the other hand, social context, such as membership in an environmental non-governmental organisation, and households' energy use and practises may play a relevant role in technology adoption.

JEL Classification codes: D12, O33, Q40, Q20, Q56, R22

Keywords: technology adoption, energy efficiency, consumer behaviour, discrete choice

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ABSTRACT/RESUMÉ

Les déterminants de l'investissement des ménages dans l'efficacité et les énergies renouvelables - la preuve de l'enquête de l'OCDE sur l'environnement et le comportement des ménages attitudes

De nombreuses études sur les investissements des ménages en matière d'efficacité énergétique suggèrent qu'une large gamme d'investissements apparemment rentables n'est pas exploitée. Cette étude fournit de nouveaux éléments de preuve sur les principaux facteurs qui expliquent les choix des consommateurs à l'aide de l'Enquête de l'OCDE sur les comportements et les attitudes des ménages avec l'environnement. L'analyse empirique est basée sur l'estimation des modèles de régression logit binaires. Les résultats empiriques suggèrent que la propension des ménages à investir dans les technologies d'énergie propre dépend principalement de la propriété, du revenu, du contexte social et des pratiques énergétiques des ménages. En effet, les propriétaires de maison et les ménages à revenu élevé sont plus susceptibles d'investir que les locataires et les ménages à faible revenu. D'autre part, le contexte social, tels que l'appartenance à une organisation non gouvernementale pour la protection de l'environnement, l'utilisation et les pratiques d'énergie des ménages peut jouer un rôle important dans l'adoption de la nouvelle technologie.

Classification JEL: D12, O33, Q40, Q20, Q56, R22

Mots-clés: adoption de la technologie, efficacité énergétique, le comportement des consommateurs, choix discret

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Nadia Ameli and Nicola Brandt[1]

Introduction

1. Many studies on household energy efficiency investments suggest that a wide range of seemingly profitable investments are not taken up. Households seem to give a much stronger weight to the initial investment cost – which is often large – than to the present value of future energy savings. This could be explained by costs of searching and adopting the best technology that are often not accounted for in studies estimating the net present value of energy efficiency investments. Other possible explanations include market failures, such as credit constraints or informational asymmetries between buyers and sellers, or principal-agent problems. For energy efficiency investments such principal-agent problems frequently occur when renters pay the energy bill, but have comparatively weak incentives to invest in the energy efficiency of a building, as they are much more likely than owners to leave before the investment pays off (the owner-effect). There may also be limits to households' rationality, for example a limited ability or willingness to collect and process the information that is necessary to assess whether an investment is profitable. Finally, attitudes and beliefs may play an important role as a motivation to invest in addition to pure monetary benefits and costs of an investment.

2. This paper provides novel evidence on the main factors behind consumer choices using the OECD Survey on Household Environmental Behaviour and Attitudes. Previous studies investigated technology adoption controlling mainly for households' socio-economic characteristics, dwelling or spatial characteristics (*e.g.* climate zone, urban/rural area), along with policy and economic variables, such as available subsidies and energy prices (Michelsen *et al*. 2012, Sardianou and Genoudi 2013). Thanks to the richness of the underlying dataset, this study draws on a larger set of variables, including also households' beliefs, attitudes and behaviours regarding the environment and their knowledge about their energy use and spending. Moreover, previous studies usually focus on one or two technologies, such as residential solar thermals (Mills *et al*. 2009) or energy efficiency appliances (Mills *et al*. 2010), while this paper covers seven different technologies, including energy efficiency measures and renewable energy technologies. By demonstrating that a variety of factors determine households' investment decisions, this paper complements and confirms a previous OECD study (OECD, 2013a), which focused mainly on differences in adoption behaviour between tenants and landlords for a variety of energy efficient devices.

3. The results suggest that households' propensity to invest in clean energy technologies depends mainly on home ownership, income, social context and households' information. Indeed, home owners and high-income households are more likely to invest than renters and low-income households. On the other hand, social context, such as membership in an environmental non-governmental organisation, and households' knowledge about their energy spending and use may play a relevant role in technology adoption.

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

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1. Nadia Ameli and Nicola Brandt are members of the Economics Department of the OECD. The research leading to these results has received funding from the People Programme (Marie Curie Actions) of the European Union's Seventh Framework Programme (FP7/2007-2013) under REA grant agreement PIEF-GA-2012-331154 – project PACE (Property Assessed Clean Energy). The authors would like to thank Walid Oueslati, Giuseppe Nicoletti, Ysé Serret, Nick Johnstone, Jérôme Silva, Daniel Kammen and various participants of OECD seminars for their valuable comments and suggestions and Veronica Humi for technical preparation.

Data description

5. The Survey data were collected through an online questionnaire. Households were asked to answer a similar questionnaire in five thematic areas: energy use, water consumption, waste generation and recycling, food consumption and personal transport choices. This survey is the second of its kind and 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).

6. For representativeness, the sample was stratified in each country according to different parameters: age, gender, region and socio-economic groups. The target respondent was between 18 and 70 years of age and had influence on household purchasing decision and expenditures. More details on the questionnaire design, respondent targeting and quota sampling are provided in OECD (2013a), annex B.

7. 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 2005 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 (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. Technology adoption across countries

Country	Appl	Bulb	Pump	Solar	Thrm	Heat	Windows
	Mean	Mean	Mean	Mean	Mean	Mean	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

8. 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 implementation. However, technology adoption varies significantly across countries. Israel is the only country showing a high rate of adoption for solar panels (66%), probably due to the favourable supporting scheme for solar thermal introduced in 1983. Moreover, in 2008, Israel implemented also feed-in tariffs for solar photovoltaic (PV) energy and the country experienced further PV market boost (EPIA 2012). 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.

9. Factors that might influence the decision to invest can be 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' exposure to energy prices and their knowledge about their own energy use.

10. 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 (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). Studies suggest that individuals with higher income and education tend to be more likely to adopt energy efficient technologies, while the influence of age and gender is less clear (Hines et al. 1987). Income might be a relevant variable considering that investment cost seems to be one of the major barriers to investing in energy efficiency. It is important to note that income would only be expected to influence investment decisions if lower-income households are credit-constrained or if their ability to assess the profitability of investments is less well developed than for higher income households. Otherwise, lower-income households would be able to identify profitable investments like higher-income households and they would be able to obtain a credit to invest. At the same time, a variable that captures the respondent's education should capture any difference in the ability to assess the profitability of investments across households better than an income variable. Thus, controlling for education should help to identify credit constraints with an income variable. Descriptive statistics are shown in Table 2.

Table 2. Socio-economic characteristics of households

Country	Age		Education		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.

11. Households' average annual net income is approximately 37 868 USD with considerable differences in means across countries. Households living in Chile declared the lowest average annual income (13 585 USD), while households resident in Switzerland declared the highest level of annual average income (62 278 USD). Thirty-six per cent 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 results (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.

12. The survey includes some characteristics of dwellings, such as home-ownership versus rental (Owner), dwelling type (House), number of years lived in the primary residence (Tenure) and whether households live in a rural area (Rural). Controlling for home ownership provides evidence on the frequently cited owner-effect. In most countries, investment incentives for owners who rent out their apartments are weak, since in general it would be the tenant who benefits from any energy savings. At the same time, tenants may not be allowed to invest, but even if they are, their incentives to do so are probably weaker than those of owners who live in their home, as tenants are more likely to move before their investment pays off. The presence of an owner-effect was confirmed in OECD (2013a). The number of years that households have already spent in their house may also matter. Some investments may be more likely to be made as a household moves into a dwelling, since this is usually a good moment for home improvements. In other cases, the length of time that households have already spent in their home may be indicative of their attachment to it and hence a longer tenure may increase the likelihood to invest. Finally, whether households live in a rural area and/or have a detached house may be indicators of space availability (Michelsen and Madlener 2012), as living in larger homes may be relevant for investing in energy technologies requiring more space. Table 3 lists the variables used, along with descriptive statistics.

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.

13. The majority of respondents (63%) own their residence and more than half of the investigated 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.

14. A number of variables reflect households' 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). Some authors suggest that the social context is important for environmental behaviour, as social participation correlates positively with responsible environmental behaviour (Olli *et al*. 2001). 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).

15. 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[2]: 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

2.. 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).

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.

16. 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 the existence of 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.

17. 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.

18. 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%).

19. Among variables reflecting households' beliefs and attitudes, a dummy is constructed to capture whether households give higher weight to investment costs than to future energy savings. 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 dummy variable "Cost bias" is meant to capture a bias, in that a larger weight is given to initial investment costs. It identifies households giving a significantly higher rating to lower initial investment costs than to higher energy prices which result in higher energy bills. In principle, individuals should be indifferent between lower investment costs and higher energy prices, since these factors have an equivalent impact on the net present value of energy saving investments, the sum of forecasted discounted energy savings minus the upfront investment cost. 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 robustness check the variable was 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 at least three points higher than that of higher energy prices and 30% give it a rating that is at least 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 for biased decisions is observed also in Switzerland that showed the highest level of average annual income.

20. When interpreting these results, it is important to keep in mind that response bias might occur. Choices made about question wording, response scale (especially for attitudinal questions), question

context, and data collection techniques can all affect the way responses are provided. In particular, opinion and attitude questions constitute perhaps the most challenging type of questions. Since opinions and attitudes, rather than facts, are solicited, even the slightest suggestion in the way a question 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 the questions correctly rather than irrational behaviour.

Table 4. 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.

Box 1. Why do people give more weight to initial investment costs than to future energy savings?

An excessive weight on initial investment cost could be related to the way people process information. Consumers tend to perceive the upfront investment cost relatively easily. On the other hand, assessing the total present value of energy savings over the life of an investment good could be a difficult task given the uncertainty surrounding energy savings and fluctuations in energy prices (Anderson and Newell 2004, Jaffe and Stavins 1995, Hassett and Metcalf 1995). 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 1993). This salience effect might partially explain why many households give initial costs a higher weight than energy savings.

Another phenomenon that might explain consumers' stronger emphasis on initial costs than future energy savings 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 profitable investments, as they weigh the certain initial costs (the loss) much more strongly than future uncertain benefits, even if these are in principle of an equivalent value.

Box 1 (cont.)

Loewenstein and Prelec (1992) hypothesize that people weigh events according to the magnitude of the outcome. That means that high discount rates apply to small outcomes and lower discount rates apply to large outcomes. This behavioural bias can explain the high implicit discount rates observed for energy efficiency investments as energy savings per period are small, while initial costs are large.

Another explanation for a bias towards initial investment costs could be that individuals use hyperbolic rather than fixed discount rates. That would mean that they discount events in the immediate future more strongly than those in the more distant future (Harris and Laibson 2001, Della Vigna 2009). It also means that the discount rate for the same event changes over time, namely it increases as the event approaches. When consumers have to choose between technologies, implying an assessment of costs and benefits over time, their decisions might not be very farsighted. Indeed, people prefer short-term gains or immediate consumption, even if this implies relatively large negative effects in the long term (Gintis 2000). This can translate into procrastination and oversensitivity to immediate costs and benefits. Procrastination can be relevant for many energy related decisions. For instance, a person may postpone installing insulation, replacing inefficient light bulbs, or buying a new refrigerator (GHK 2010), because costs are endured immediately, while net gains take a long time to materialise.

On the other hand, the fact that some households put more weight on initial costs than on later energy savings according to their responses in this survey may also be partly explained by 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. 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.

21. The last category contains data regarding households' knowledge about their energy spending, use and their exposure to prices. 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 use in volumes, less than 19% on average across countries. The data shows an unusual result for Korean households, who seem better informed about their energy consumption in volumes than about their energy spending.

22. 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, as 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 households' knowledge about their energy spending, use and their exposure to prices.

Table 5. Households' knowledge about their energy spending, use and their exposure to prices

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.

Econometric Model

23. 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:

$$y_i^* = x_i\,\beta + \epsilon_i \qquad (1)$$

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:

$$\begin{aligned} y_i &= 0 \;\; if\; y_i^* < 0 \\ y_i &= 1 \;\; if\; y_i^* \geq 0 \end{aligned} \qquad (2)$$

24. 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:

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

$$= \Lambda(x_i\beta\,) \qquad (3)$$

where Λ denotes the logistic cumulative distribution function.

25. 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 shows how the predicted probability of observing that a household invests (y=1) changes as the dummy variables change from 0 to 1. 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:

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

The logit model is estimated with country-level fixed effects.

26. 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

27. 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.

Table 6. Bayesian Model Averaging Estimates. Logit regressions – preferred estimates 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*** (0.00226)	0.00171*** (0.000274)	0.0115*** (0.00234)	0.00229*** (0.000465)
HHsize			0.135*** (0.0249)	0.0165*** (0.00302)		
Education						
Log_Income	0.362*** (0.0425)	0.0833*** (0.00978)			0.0154*** (0.0027)	0.00306*** (0.000538)
NoCope						
Owner	0.336*** (0.0518)	0.0783*** (0.0122)	0.151** (0.0628)	0.0186** (0.00789)	0.372*** (0.073)	0.0714*** (0.0134)
House			0.295*** (0.0656)	0.0363*** (0.00814)	0.167** (0.0694)	0.0330** (0.0136)
Tenure			-0.0502** (0.0247)	-0.00611** (0.00301)	-0.0908*** (0.0258)	-0.0181*** (0.00513)
Rural			0.0206 (0.0651)	0.00250 (0.00789)	0.150** (0.0654)	0.0301** (0.0133)
Green_Growther						
Altruist						
Sceptics			-0.200*** (0.0566)	-0.0248*** (0.00719)		
NGO	0.345*** (0.0485)	0.0797*** (0.0112)	0.416*** (0.0563)	0.0511*** (0.00696)	0.270*** (0.0584)	0.0535*** (0.0115)
ENV_NGO						
Understand_CC						
Behaviour Index	0.140*** (0.0139)	0.0322*** (0.00319)	0.161*** (0.0154)	0.0196*** (0.00186)	0.0916*** (0.0167)	0.0182*** (0.00332)
KWatt_know	0.316*** (0.0604)	0.0708*** (0.0131)			-0.00762 (0.0743)	-0.00151 (0.0148)
Ebill_know			0.189*** (0.0592)	0.0232*** (0.00734)	-0.0938 (0.0655)	-0.0188 (0.0132)
Metered	0.354*** (0.0939)	0.0845*** (0.023)				
Cost_Bias					-0.125** (0.0599)	-0.0247** (0.0117)
AUS	0.0831 (0.121)	0.0189 (0.0273)	-0.0286 (0.165)	-0.00351 (0.0205)	-1.214*** (0.153)	-0.185*** (0.0165)
CAN	0.158 (0.117)	0.0357 (0.0259)	-0.283** (0.141)	-0.0374* (0.0202)	1.157*** (0.129)	0.266*** (0.0316)

Table 6. (cont.)

Variables	Energy-efficient appliances		Light bulbs		Heat thermostats	
	Coefficients	Marginal effects	Coefficients	Marginal effects	Coefficients	Marginal effects
CHE	-0.109 (0.12)	-0.0255 (0.0283)	-0.755*** (0.132)	-0.114*** (0.0237)	0.263* (0.136)	0.0550* (0.0296)
CHL	-0.690*** (0.128)	-0.167*** (0.0317)	0.365** (0.186)	0.0400** (0.0180)	-1.765*** (0.196)	-0.241*** (0.0158)
ESP	0.405*** (0.124)	0.0882*** (0.0253)	-0.0947 (0.155)	-0.0118 (0.0200)	0.492*** (0.135)	0.106*** (0.0309)
FRA	0.491*** (0.119)	0.106*** (0.0236)	-0.527*** (0.138)	-0.0742*** (0.0221)	0.287** (0.13)	0.0601** -0.0284
ISR	-0.0576 (0.117)	-0.0133 (0.0273)	-0.594*** (0.142)	-0.0856*** (0.0236)	-1.371*** (0.16)	-0.205*** (0.0164)
JPN	-0.656*** (0.111)	-0.159*** (0.0274)	-2.254*** (0.126)	-0.443*** (0.0291)	-1.985*** (0.176)	-0.256*** (0.0124)
KOR	0.311*** (0.117)	0.0688*** (0.0247)	-1.672*** (0.135)	-0.308*** (0.0313)	1.187*** (0.138)	0.273*** (0.0337)
NLD	-0.0129 (0.116)	-0.00296 (0.0269)	-0.115 (0.142)	-0.0145 (0.0185)	0.532*** (0.129)	0.116*** (0.03)
Constant	-5.000*** (0.466)		-0.276 (0.168)		-3.774*** (0.346)	
Observations	8,605	8,605	10,951	10,951	7,334	7,334

Table 7. Bayesian Model Averaging Estimates. Logit regressions – preferred estimates II

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

Variables	Solar panels		Heat pumps		Thermal Insulation		Energy-efficient	
	Coef	Marginal effects	Coef	Marginal effects	Coef	Marginal effects	Coef	Marginal effects
Age			-0.0223*** (0.00449)	-0.00051*** (0.000105)	0.0093*** (0.00221)	0.0020*** (0.00048)	0.0149*** (0.00225)	0.00335*** (0.00051)
HHsize	0.213*** (0.0369)	0.0135*** (0.00234)						
Education								
Log_Income			0.136 (0.126)	0.00311 (0.00288)	0.232*** (0.0490)	0.0508*** (0.0107)	0.211*** (0.0512)	0.0474*** (0.0115)
NoCope								
Owner			0.420*** (0.155)	0.00884*** (0.00302)	0.687*** (0.0715)	0.141*** (0.0136)	0.612*** (0.0707)	0.131*** (0.0143)
House	0.330*** (0.11)	0.0204*** (0.00661)			0.557*** (0.0657)	0.119*** (0.0137)	0.109 (0.0671)	0.0245 (0.015)
Tenure					-0.122*** (0.0246)	-0.0267*** (0.00538)	-0.105*** (0.0247)	-0.024*** (0.00556)
Rural	-0.249** (0.109)	-0.0153** (0.0065)	0.0884 (0.132)	0.00204 (0.00310)			0.00845 (0.0646)	0.0019 (0.0145)
Green_Growther			-0.531*** (0.185)	-0.0104*** (0.00314)				
Altruist			-0.986*** (0.139)	-0.0225*** (0.00329)				
Sceptics					0.131** (0.0578)	0.0289** (0.0128)		
NGO					0.292*** (0.0567)	0.0638*** (0.0123)	0.244*** (0.0566)	0.0546*** (0.0126)
ENV_NGO	0.672*** (0.125)	0.0536*** (0.0122)	0.694*** (0.170)	0.0209*** (0.00659)				
Understand_CC	-0.099 (0.106)	-0.00617 (0.00646)						
Behaviour Index	0.0998*** (0.0265)	0.00634*** (0.00167)			0.141*** (0.0164)	0.0309*** (0.00358)	0.103*** (0.0162)	0.0232*** (0.00364)
KWatt_know								
Ebill_know	-0.0274 (0.0941)	-0.00174 (0.006)					0.0555 (0.0626)	0.0125 (0.014)
Metered							0.113 (0.117)	0.0249 (0.0255)
Cost_Bias	-0.389*** (0.096)	-0.0236*** (0.00554)						
AUS	1.214*** (0.24)	0.120*** (0.0337)	-2.071*** (0.264)	-0.0242*** (0.00240)	0.776*** (0.138)	0.184*** (0.0341)	-1.829*** (0.156)	-0.290*** (0.0149)
CAN	-0.567* (0.291)	-0.0296** (0.0123)	-1.881*** (0.243)	-0.0234*** (0.00240)	0.111 (0.133)	0.0246 (0.0300)	0.347*** (0.123)	0.0810*** (0.0298)

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Table 7. (cont.)

Variables	Solar panels		Heat pumps		Thermal Insulation		Energy-efficient	
CHE	-0.0449 (0.273)	-0.0028 (0.0168)	-1.002*** (0.208)	-0.0158*** (0.00252)	0.451*** (0.142)	0.104*** (0.0342)	0.386*** (0.131)	0.0907*** (0.0317)
CHL	-1.327*** (0.312)	-0.0562*** (0.0084)	-3.553*** (0.547)	-0.0323*** (0.00270)	0.127 (0.152)	0.0283 (0.0343)	-1.203*** (0.16)	-0.221*** (0.0222)
ESP	-0.0819 (0.266)	-0.00506 (0.016)	-2.284*** (0.274)	-0.0262*** (0.00252)	-0.531*** (0.148)	-0.107*** (0.0269)	0.460*** (0.131)	0.108*** (0.032)
FRA	0.0435 (0.259)	0.0028 (0.0169)	-1.285*** (0.202)	-0.0189*** (0.00238)	0.459*** (0.135)	0.106*** (0.0326)	0.715*** (0.127)	0.171*** (0.0313)
ISR	3.441*** (0.233)	0.577*** (0.0499)	-2.121*** (0.283)	-0.0252*** (0.00256)	-0.462*** (0.146)	-0.094*** (0.0272)	-1.481*** (0.15)	-0.257*** (0.0179)
JPN	-0.321 (0.297)	-0.0181 (0.0148)	-3.443*** (0.465)	-0.0308*** (0.00259)	-0.590*** (0.144)	-0.117*** (0.0253)	-1.097*** (0.138)	-0.204*** (0.0199)
KOR	0.0451 (0.268)	0.00291 (0.0176)	-1.854*** (0.261)	-0.0232*** (0.00249)	0.523*** (0.137)	0.122*** (0.0333)	0.415*** (0.133)	0.0976*** (0.0324)
NLD	-0.405 (0.272)	-0.0225* (0.0131)	-2.454*** (0.304)	-0.0261*** (0.00246)	0.680*** (0.139)	0.161*** (0.0343)	1.350*** (0.141)	0.325*** (0.0321)
Constant	-4.142*** (0.296)		-2.022 (1.331)		-5.454*** (0.545)		-4.536*** (0.563)	
Observations	6,485	6,485	7,645	7,645	6,807	6,807	7,269	7,269

Notes: 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.

28. 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, confirming similar results from earlier studies for innovative heating systems (Mahaptra and Gustavsson 2008, Michelsen and Madlener 2012) and 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, while Willis *et al*. (2011) find that households with members older than 65 years are much 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.

29. The family size is positively related to the probability of investing 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 (2010), and Mills and Schleich (2012) suggest that a positive relationship between family size and technology adoption holds also for energy-efficient appliances.

30. 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 2010, 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.

31. 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 show a propensity to invest 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 coefficients presented here are the same in terms of sign and significance, with slight differences in the size of marginal effects. For instance, in the earlier OECD study, owners are 6.7 percentage points more likely than renters to own an energy-efficient appliance, while in this analysis the size of this effect is 7.8 percentage points. These differences in the size of the effects do not come as a surprise, as the earlier study uses another specification of the estimation equation, "probit" rather than "logit", and it controls for socio-economic variables and country-level fixed effects only, while this study relies on a larger set of controls.

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 thermostats	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

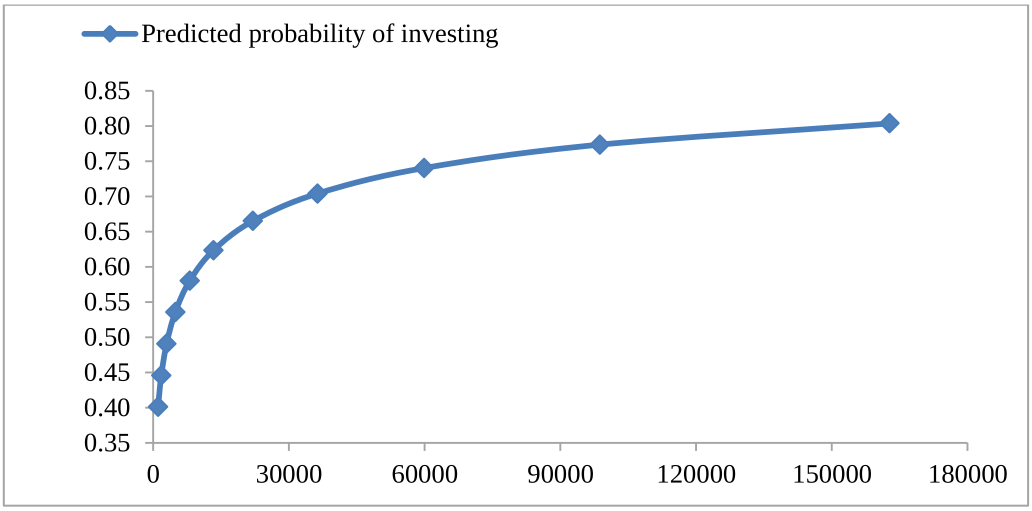
32. The characteristics of dwellings seem to be relevant for technology adoption. The investment probability for light bulbs, heat thermostats, thermal insulation and energy-efficient windows depends negatively on the time that households have already spent in their place. That could indicate that households are more likely to invest in energy upgrades when they first move into their home. 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). Results in this paper suggest that owning a detached house increases the probability of investing in light bulbs, heat thermostats, thermal insulation and solar panels. This might be seen as an indicator of the importance of space availability. For investment in light bulbs, Di Maria *et al.* (2010) and Mills and Schleich 2010 provide similar results.

33. There is also evidence for credit constraints, 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. Many studies find a positive correlation between income and the probability to invest in energy conservation measures as well as renewable energy technologies (Long 1993, Mills and Schleich 2010) instead. Similar results for heating systems were found by Michelsen and Madlener (2012), who did not observe any correlations between income and heat pumps investment, while Sardianou and Genoudi (2013) found that the probability of adopting renewable energies increases with higher levels of income. The findings in this study could suggest that public subsidies for solar panels have helped to overcome credit constraints. At the same time, results have to be interpreted with some caution given the limited sample size of households that could have adopted these technologies (6 485 observations for solar panels and 7 645 observations for heat pumps).

34. 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 the annex (Table A.1). 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 $. This exercise is repeated for thermal insulation and the same pattern emerges. 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.

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

Values for a representative individual3



35. Having to pay in line with energy consumption and being informed about this seems to matter only for a few technologies. Only for energy-efficient appliances are households that are metered more likely to invest than those who are not, while households who are able to provide information about their energy bill or energy consumption are more likely to invest in light bulbs and energy-efficient appliances. This lends some limited support to the idea that imperfect information of households can limit the uptake of these clean energy technologies.

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

37. 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. For solar panels and thermal insulation such an effect is observed only for individuals who are in an environmental NGO. Social participation is not only a significant variable for all technologies, but the corresponding marginal effects are also quite large.

38. 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 proper 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.

3. Characteristic of the representative individual as in the Annex Box.

39. An understanding of the causes of climate change and attitudes towards the environment do not seem to play an important role. The corresponding variables were not included in the preferred model specification in most cases, but when they were, results were rather counter-intuitive. Understanding the causes of climate change seems to impact negatively on the likelihood to invest in solar panels and "altruists" are less likely than others to invest in thermal insulation or heat thermostats.

Conclusions

40. This study provides evidence regarding different hypotheses explaining underinvestment in energy efficiency and renewables that have been put forward in the literature. The data from OECD Survey on Household Environmental Behaviour and Attitudes provides a rich basis for such an investigation.

41. 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 for all investment goods studied in this paper, with a substantially larger magnitude of the effect for relatively immobile investments (such as windows and thermal insulation). This is often referred to as the owner effect. Nevertheless, renters show some propensity to invest in lower-cost technologies that are more mobile, such as energy-efficient appliances and light bulbs.

42. There is also evidence for credit constraints, as investment depends positively on income. The results suggest that the probability to invest in energy efficient appliances increases strongly with income, when income levels are low, but this effect levels off for higher income levels. 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.

43. Technology adoption is also influenced by households' social context and energy practises. Households' social context, such as membership in an environmental non-governmental organisation, and their energy conservation practises, play a role for investment decisions.

44. 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 policy instrument than higher energy taxation, when credit constraints are present.

45. 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 can recover the investment cost. In principle, in a well-functioning market, the rent of a more energy-efficient home should always be higher than a less energy-efficient dwelling, with the difference reflecting the value of discounted energy savings. Yet, it may be difficult for landlords to effectively convey information about the energy efficiency characteristics of the home they offer, as this is difficult to observe. In that case, the landlord might not be able to recover the cost of energy efficiency measures through higher rents, which can lead to underinvestment (Jaffe *et al.* 2004). In addition, in many countries owners are not allowed to raise the rent as they wish, unless the tenant changes. A law allowing owners to increase the rent after implementing energy efficiency measures could solve this issue. In Germany, this seems to have helped to diffuse energy efficiency measures in a market with a high share of rental housing.

ANNEX

Annex Box. Characteristic of the representative individual

The representative individual that was used to generate Figure 1 has the characteristics listed in the Table A.2. 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 A.1. 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

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