Determinants of energy saving investments behaviors. Analysis at the European level.

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1. Introduction

The past decade has witnessed considerable research activity devoted to better understanding the process determining energy conservation behaviors. The factors affecting the rate of diffusion of sustainable technology and the effects of energy policy in encouraging such adoption have important implications for policy-making (Mcdougall, 1981; Rogers, 2003; IEA, 2016; Jeffe and Stavins, 1994). The benefits deriving from home energy efficiency improvement are also an important instrument to combat energy poverty (INSHIGHT_E, 2015; Boardman, 2010; Ürge-Vorsatz and Herrero, 2012).

Energy efficient technologies represent a key driver for the reduction of energy demand (EC, 2012; IEA, 2016). This aspect is particularly relevant in the residential sector that represents 25% of the final energy consumption in EU (Eurostat, 2018). Research and development and robust global market growth have driven significant solar photovoltaic system price and performance improvement and several demand-side incentives have been introduced in the EU. However, even if energy efficient technologies costs have been reduced financial grants introduced, the adoption process has remained gradual. In the literature, potential explanations for understanding the energy-efficiency gap have included non-monetary costs explanation. Environmental problem awareness, technical and bureaucratic barriers may have also had a significant influence on the decision to purchase energy-efficient technologies (Jager, 2006; Rai, 2016). Addressing these barriers requires a better understanding of households decision-making process. Growing agreement over the critical importance of changing human behavior to make progress toward energy sustainability as been address also in the policy filed (World Bank, 2014). Analyze the purchase motives of adopters may disclose to what extent additional factors influence the decision to purchase energy efficient technologies and may contribute to the development of effective strategies in stimulating the diffusion of capital-intensive technologies.

Exploiting the increased availability of large households' surveys, a set of recent papers has provide some quantitative evidence of the main determinants of households energy consumption and the relative importance of socio-demographic and energy related behavioral characteristics (Barr et al. 2005; Sutterlin et al. 2011; Trotta et al. 2018; Martinsson et al. 2011; Han et al. 2013). Drawing insight from environmental psychology literature energy conservation behaviors are conceptually divided into consumption oriented behavior (i.e. investment behavior) and habitual actions (i.e. curtailment behavior) (Stern, 1992). The general results highlight the importance of households energy related attitudes (i.e. specific type of individual behavior) in determining the diversity that exists across the population that helps identifying targeting policy interventions.

Moreover, policies aim at reducing energy consumption do not affect only greenhouse gas emissions but also improve household life standards. Poor residential energy efficiency has been address as one of the principal causes for most of the adverse effect of energy poverty (Bouzarovski, 2011). Strategies to capture residential sector mitigation potential provide the ground for successfully aligning shorter-term social and longer-term environmental priorities (Boardman, 2010, Urge Vorsatz and Herrero, 2012). At the policy level a set measures linking energy poverty and energy efficiency are recognized (Directive 2012/27/EU, Directive 2009/72/EC). However, despite the potential synergies between climate change and fuel poverty shared policy goal have not been addressed.

This paper seeks to contribute to the body of growing literature focusing on the design of policies to speed the diffusion of energy efficient technologies. First, we ask based on available data what are the main trends characterizing household energy saving behaviors. Second, selecting some European countries based on their energy poverty levels, we focus our analysis on countries heterogeneity. Third, we aim at measuring the direct effect of households' characteristics and behaviors on technology adoption. Finally, from a policy perspective, we aim at identifies the links between energy efficiency policy measures and energy poverty.

This paper starts from the analysis of data collected in 2014 from a consumer survey covering all EU member States, Iceland and Norway. We study the survey by selecting the questions regarding household energy demand.? We analyze the types of individuals engaged in energy conservation activities highlighting their energy poverty status. To perform this task we adopt a logit regression model selecting the covariates based on the existing literature.

The paper is divided in 5 sections. Section 2 briefly surveys the available evidence and discussed the novelty of the paper. Section 3 describes the data and the methodology. Section 4 gives the econometrics results. Section 5 concludes.

2. Background and motivations

The gradual technological diffusion process has been extensively studied from an economic perspective (Jeffe and Stavins, 1994, Gararden et al. 2015) and in connection with conservation behaviors (Stern and Gardner, 1981, Stern, 1992). However, there is no agreement on a theoretical model to describe consumer choice or on the empirical evidence on the importance of the determinants of energy saving behaviors. Indeed, the factors underlying the reduction in energy consumption are complex and far reaching.

Even if energy efficiency investment decisions are highly dependent on costs, have been observed a discrepancies between optimal and actual investments.

Table 1: Selected literature

Title	Country	Data	Observations	Analysis	Findings
Factors affecting energy-saving behaviours and energy efficiency investments in British households (Trotta et al. 2018)	UK	Survey		Principal Component Analysis, Probit regression	Age(+) Income(+)
Intervention strategy to stimulate energy-saving behavior of local residents (Han et all. 2013)	Netherland	Survey	256	Choice experiment	Education (+) Ownership(+) Income(+)
Energy saving in Swedish households.The (relative) importance of environmental attitudes (Martisson et al. 2011)	Switzerland	Survey	4000	Logistic regression	Environmental identity(+)
Who puts the most energy into energy conservation?A segmentation of energy consumers based on energy-related behavioral characteristics (Sutterlin et al. 2011)	Switzerland	Survey	1292	Cluster Analysis	Gender(+) Education(+) Income(+)
The household energy gap: examining the divide between habitual- and purchase-related conservation behaviours (Barr et al. 2005)	UK	Survey	1265	Factor Analysis	Gender(+) Education(+) Ownership(+) Income(-)
Diffusion into new markets: Evolving customer segments in the solar photovoltaics market (Sigrin et al. 2015)	California	Survey	2024	Difference in means	Education(+) Income(+) Home size(+) Children(+)
The transformation of southern California's residential photovoltaics market through third-party ownership (Drury et al. 2011)	California	Survey		Linear regression	Age(+) Education(+) Income(+)
Consumer attitudes towards domestic solar power systems (Faiers and Neame, 2006)	UK	Survey	350	Differenec in means	Age(+) Gender(+)
Stimulating the diffusion of photovoltaic systems: A behavioural perspective (Jager, 2006)		Survey	197	Differenec in means	Age(+) Education(+) Income(+) Environmental identity(+)
Energy efficient technology adoption in low-income households in the European Union– What is the evidence? (Schleich, 2019)	EU	Survey	15000	Probit Model	Age(+) Income(+) Environmental identity(+)

The potential explanation to the "energy efficiency gap" has been argue depends on market failure and behavioral constrains (Gararden et al. 2015; Jeffe and Stavins, 1994). Behavioral factors such as risk aversions, retention of the status quo and heuristics decision-making are other commonly cited barriers preventing household from investing in energy efficiency solutions (Trotta et al. 2018; Rai, 2016).

Investments such solar panel installation and home retrofitting require time and a level of knowledge most consumers do not posses and which is hard to acquire in the short term. The lower temporal discounting increases the uncertainties associated with these technologies, which is amplified by technological and bureaucratic barriers that make these decisions further complex.The quality and quantity of the information about benefits, technical features, and administrative obligations is considered a positive factor encouraging adoption that could overcome these barriers (Drury et al. 2012, Jager, 2006).

The environmental features of energy saving innovations associate these decisions to pro-environmental behaviors. However, in the environmental psychological literature has been shown that these behavior needs not to be motivated only by environmental concerns or values, but other motivations and structural factors often play a greater role (Stern, 2000).

Taking into account the different forces that enable to shape the rate and direction of environmental beneficial innovations in the residential sector, the literature extends the analysis by including several non strictly economic factors. The main determinants of energy saving investments as identified in the literature are synthesized in Table 1.

While we are not able to attribute causality, our findings attribute new insight into how the underlying factors that contributes to energy saving investments adoption at the residential level are changing between countries.

First, we report the main descriptive characterizing the sample. Then we select four representative countries based on the European Commission priorities and use a cluster analysis to validate the countries' selection. The segmentation is based on a proxy representing energy poverty that confirms countries' heterogeneity.

Second, it identifies the main variables affecting energy consumption using evidence drawn from the literature. Following the survey structure, factors related to the electricity market functioning and energy efficient behaviors are dividend into different categories and summarized by indexes.

Thirdly, it focuses on the factors that could potentially affect energy efficiency technology adoption. The decision patterns are accounted by controlling for countries fixed effects to compare individual country results. In order to do so we model the choice of consumers according to a logit regression model. We analyze how predicted probabilities are affected by household specific characteristics highlighting the effect of energy poverty over adoption choices. We expect that the decision to adopt energy saving technologies depends upon a combination of individual and external factors, and that energy poverty level is negatively related to technology adoption.

3. Data and Methodology

3.1. Data

The study exploits the Consumer Survey data from the Second Report consumer market study on the functioning of the retail markets from consumer in the EU conducted in 2015 by Ipsos, London School of Economics and Deloitte. The consumer survey was designed to target members of the general population aged 18 and plus. Younger citizen are less likely to have a responsibility with regard to energy, and are less familiar with purchase decisions. In total 29.119 interviews were conducted across 30 countries (EU28, Iceland and Norway) using a mixed-mode for data collection, involving online, telephone and face-to-face interviewing. Survey questions range from simple yes no questions to those requiring the respondent to assess on a ten-point scale how strongly they engaged in certain practices.

The starting point of this paper is a focus on the sets of variables directly related to household consumption, attitudes and awareness toward energy use. The selected survey's variables are summarized in AppendixA.

Table 2 present variable descriptive statistics for the study sample based on complete observations (i.e. EU 28 plus Norway and Iceland sample size and mean).

Table 2: Descriptive statistics: socio-demographic variables

Individual variables	**N**	**%**	**Households variables**	**N**	**%**
Gender			*Size of municipality*		
Man	14291	49,08	More than 500 inhab/sqkm	12438	43,47
Woman	14828	50,92	Between 100 and 499 inhab/sqkm	8473	29,61
Age			Less than 100 inhab/sqkm	7705	26,93
Working age (18 - 64)	26748	91,86	*Economic resources*		
Retired (>64)	2370	8,14	Very easy	3451	11,85
Education			Fairly easy	11711	40,22
Low	3759	12,92	Not easy	10742	36,89
Medium	13358	45,91	Not easy at all	3215	11,04
High	11978	41,17	*Home dimension*		
Working status			1 bedroom	5011	17,21
Employed full-time	14720	50,55	2 bedrooms	8863	30,44
Employed part-time	2460	8,45	3 bedrooms	9116	31,31
Self-employed full-time	1536	5,27	4 bedrooms	3935	13,51
Self-employed part-time	522	1,79	5 bedrooms	1281	4,40
Unemployed but looking for a job	2155	7,40	More than 5 bedrooms	913	3,14
Unemployed and not looking for a job	299	1,03	*Number of members*		
Long-term sick or disabled	734	2,52	1	4692	16,11
Housewife / Homemaker	1574	5,41	2	9319	32,01
Retired	3421	11,75	3	6611	22,70
Pupil / Student / In full time education	1698	5,83	4	5686	19,53
Landlord / Tenant			5	2009	6,90
Own, with mortgage	8913	30,82	5 +	800	2,75
Own, without mortgage	10625	36,73	*Number of children*		
Rent, private landlord	5482	18,95	0	14420	59,04
Rent, social landlord	2108	7,29	1	5436	22,25
Other	1795	6,21	2	3542	14,50
			3	824	3,37
			4	204	0,84

The EU is committed to reducing the greenhouse gas emission from at least 80 % (from the 1990 baseline) by 2050 and to improve the energy efficiency of residential building stocks (EC, 2012). To achieve the EU's 2050 decarbonisation objectives a sets of policy studies states the priority of energy efficiency improvement in the residential sector (Directive 2012/27/EU, IEA, 2016).Overall final energy consumption in the EU-28 have not shown a stable decreasing

Table 3: Descriptive statistics: energy related variables

Electricity variables	**N**	**%**
Satisfaction with services provided		
Very satisfied	12167	41,78
Satisfied	12550	43,10
Unsatisfied	4402	15,12
Satisfaction with market functioning		
Very satisfied	7196	24,71
Satisfied	15268	52,43
Unsatisfied	6655	22,85
Energy efficiency investments		
Home reinsulated	9363	32,15
Solar panels/heat pump	3391	11,65
Applied for public founding		
Yes	1883	6,47
No	27236	93,53
Public advice on energy saving		
Yes	3030	10,41
No	26089	89,59
External advice energy saving		
Yes	1686	5,79
No	27433	94,21
Energy poverty		
Social tariff	1358	4,66
Government assistance	1681	5,77
Government assistance bills	960	3,30
Payment restriction	816	2,80
Late payment fee	2256	7,75

trend (Eurostat, 2018). European progress on energy intensity is still too slow. In particular the final consumption of the residential sector that accounts for 25.4 % and lack of and 64.7 % of this energy is used by households to heating their homes.

This figures seems to testify a difficult take-off of the European energy markets. The first issue to address this datum is consumers energy efficiency adoption rate. In the dataset almost 33 % of households have reinsulated their home and only 11 % have installed solar panel or heat pumps (see Table 3). Inertia is in part caused by lower financial policy incentives to up take energy efficiency investments. Household that benefit fro tax allowance or grant to found energy saving investments are only 6 % of the sample. However financial incentive are not the only way to encourage consumers. Policy analysis should simultaneously address technical and infrastructural investments as well as occupant energy habits and daily practices to effectively reduce energy consumption. This critical issue is further complicated by the uneven geographical distribution of the observed variables. Discussion of the differences between European countries is the scope of this paper. Figures 1 and 2 show quite differentiated scenarios on the issue of interest, suggesting that caution is necessary when making general claims.

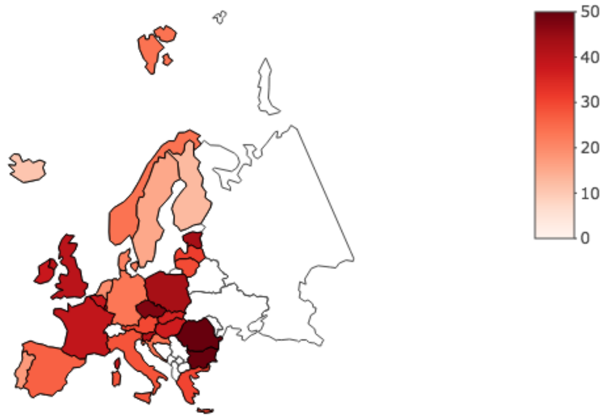

Figure 1: Had your home (re-)insulated.% by country. Base: all respondent

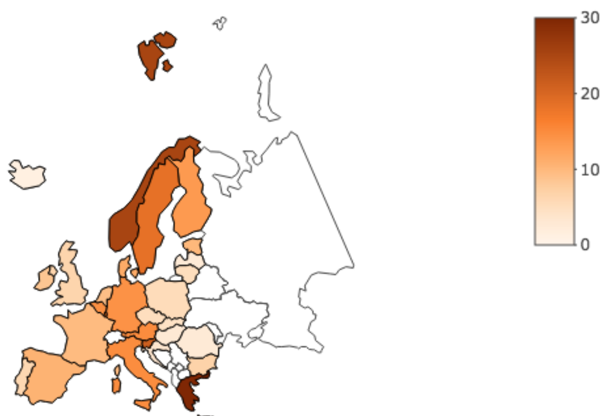

Figure 2: Installed solar panels or a heat pump. % by country. Base: all respondent

The poor energy performance of dwelling could have also negative effect on energy poverty. The literature agrees that the main reasons for this mounting problem are the rising energy prices, low income and energy performance of dwelling (Bouzarovski, 2011, Ugartes, 2016, Bouzarovski and Petrova, 2015). As show in Figure 3, the energy poverty measure constructed based on the variables in Table 3, is a problem across many countries. Even though it appears to be particularly prevalent in Southern and Easter Europe countries, the issue concerns also the remaining Member States.

Under the Third Energy Package Member States are required to identify vulnerable consumers and put measures in place to address energy poverty. However, policy specifically addressing fuel poverty has been limited, despite the potential tension between climate change and fuel poverty policy objectives. This paper contribute to recognize the interaction between the policy goals of reduce fuel poverty and carbon emission.

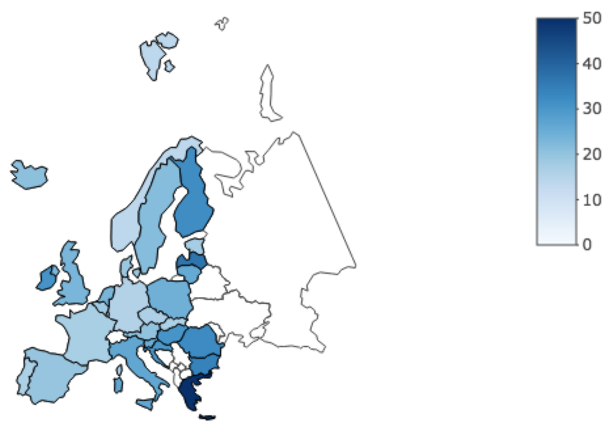

Figure 3: Energy poverty Index.

The analysis of the determinants of households has been restricted to four representative countries, namely Estonia, Greece, Portugal and The Netherlands. Countries of interest have been selected based on European priorities to address energy poverty. In order to validate countries heterogeneity a cluster analysis was performed based on the energy poverty measure constructed from the available variables in the dataset (see Table 3). The analysis confirmed the policy driven choice. The result (see Table 4) shown a clusterization of EU countries in four segment.

Table 4: Cluster results of EU cuontries

Country	Cluster	Country	Cluster
Austria	1	Italy	3
Belgium	2	Latvia	1
Bulgaria	3	Lithuania	1
Croatia	3	Luxembourg	2
Cyprus	2	Malta	1
Czech Republic	2	Norway	2
Denmark	2	Poland	3
Estonia	2	**Portugal**	3
Finland	1	Romania	3
France	2	Slovakia	2
Germany	2	Slovenia	2
Greece	4	Spain	2
Hungary	3	Sweden	2
Iceland	2	**The Netherlands**	1
Ireland	1	Uk	1

Figure 5 show that Estonia has higher rensulation investment rate then the EU, while Greece is very similar to the EU, and Portugal and The Netherlands have lower rates. Contrarily, investments in solar panel or heat pump are higher in Greece compared to the rest of the countries and EU. This datum could be explained by the higher rate of public found received by the Greek households (see Table 6). However, also The Netherlands shows a relative high share of households that applied for tax allowances or grant to finance energy saving investments, but the investments rate in renewable energy is significantly lower compared to Greece.

Further investigation are needed to assess what are the drivers of energy saving investments in the selected countries.

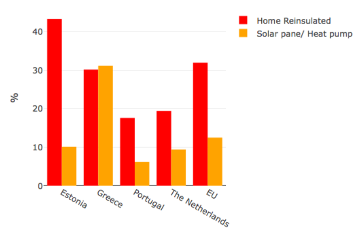

Table 5

Country	Founding
Estonia	2,90
Greece	6,37
Portugal	2,29
The Netherlands	5,90

3.2. Methodology

To establish the empirical relationship between household decision variables and households characteristics, we economically estimate reduced form of regression model. In order to define a relationship between household choice and their socio-demographic and behavioral characteristics we use a logit regression model (Train, 2003). A discrete choice model allows the estimation of predicted probabilities of energy saving choices. The dependent variables are household adoption of energy efficient technologies. In order to derive some insights on the components affecting reinsulation and renewable energy investments the results of the two models will be compared.

Influencing factors of energy saving behavior were identified according to the literature, and to perform a parsimonious model indexes were constructed to account to similar questions (see Table 6.

Energy literacy relates to households knowledge of electricity consumption and production. In general terms, an energy literate individual has a sound conceptual knowledge and understanding on how energy is used in every day life, of the impact that energy production and consumption have on the environment and society, is sympathetic to the need for energy conservation and the need to develop alternatives to fossil-fuel based energy resources, is cognizant of the impact that personal energy related decisions and actions have on the global community. Most importantly, an energy literate individual strives to make choice and exhibit behaviors that reflect those attitudes. The underlying hypothesis is that an informed energy literate public will be better equipped to make thoughtful, and responsible energy related decisions and actions (De Waters and Powers, 2011).

Electricity use summarizes frequency of electricity usage for heating, and cooking. Higher electricity usage is a proxy for higher electricity costs. We hypothesize a positive relation between this measure and energy saving investments. Electricity service quality refers to service reliability and overall quality. We expect that higher household satisfaction with the quality of the service, lower their need to switch to auto produced form of energy.

The variable construct to represent energy poverty is a proxy to measure domestic energy deprivation. In the literature there is no standard qualitative definition of energy/fuel poverty. More commonly the term fuel poverty is referred to households inability to heat adequately its leaving space. However, the emphasis on heating affordability downplays the importance of other domestic end-use of energy (Urge Vorsatz and Herrero, 2012). Following the varied definitions of the concept, there are also varied approaches to measure it across the EU (INSHIGHT_E, 2015). In order to compare Member States .. we rely on the energy poverty measure define through the variables in our dataset. It is composed of a set of direct measures of energy poverty, as delays in paying energy bills and disconnection due to debt, and indirect measures that support vulnerable consumer through financial assistance. The underlying hypothesis is that there is a negative relation between the rate of investments and the energy poverty measure.

The variables under green identity refer to household perception of energy saving importance. Green identity is generally understood to mean the label used to describe oneself. Assertions of identity are an attempt to establish consistency in our attitudes and actions (Whitmarsh and O'Neill, 2010). Self-identity has been found to be a significant prediction of behavior including in relation to pro-environmental actions. People who see themselves as typical energy savers are more likely to engage in energy saving actions than those who do not perceived themselves as paying attention to energy efficiency.

Energy conservation behaviors include investment and curtailment practices (Stern and Gardner, 1981; Stern, 1992). The former are often long-term alterations to the structure of the dwelling and include internal changes that require financial and technical resources. Curtailments behaviors instead are defined as everyday reduction energy usage that require either no or minimal structural adjustments. These behaviors undertake daily activities related to habitual element of an individual lifestyle. To test the theoretical assumption that environmental actions are sectored into certain traditional categories (i.e. curtailments and investments) we perform a factor analysis of conservation activities related variables (i.e. Grid_Q16 in AppendixA). Results provided a good check of the grouping variables, assessing their empirical link, and justified our decision to divide environmental actions in two groups.

4. Results

The estimated models are conceived so as to include demographic, social, attitudinal and institutional factors assumed to impact on investment behavior (see Table 6). Energy saving investment probability is estimate under a logistic regression model with household variables (Table 7 and 8). To compare European and countries result we include a country fixed effect in the EU model. The model adds several explanatory elements to the variable that are traditionally used to explain energy saving investments behavior (see Table 3). At the individual level, in addition to geographical and economic variables we account for electricity market perception, environmental attitude and policy effect. At the family level, we consider home size as a proxy for the relevance of electricity bill, and a self-declared satisfaction with economic resources as a proxy for income.

Table 6: Variables description

	Dependent variables
Reinsulation investments	Dummy variable: 1 for families that reinsulated their home
Solar panel Heat pump investments	Dummy variable: 1 for families that installed solar panel/heat pump
	Explanatory variables
Female	Dummy variable: 1 for female
Inhab	Categorical variable: municipality size, with levels > 500 inhabitants, 499 - 100 inhabitants, < 100 inhabitants
Education	Categorical variable with levels low, medium, and high
Employed	Dummy variable: 1 for employment work status
Landlord	Dummy variable: 1 for home ownership
Home size	Categorical variable: number of bedrooms with levels1,2,3,4,5,5+
Children	Categorical variable: number of children with levels 1,2,3,4+
Economic resource low	Dummy variable: 1 for unsatisfactory level of economic resources
Electricity use	Index from dummy variables: 1 for home heating, water heating, and cooking
Energy literacy	Index from categorical variables: factor analysis of awareness electricity consumption, expenditure, price, tariff characteristics, energy source
Service quality	Index from categorical variables: factor analysis from reliability of service, information quality, overall service quality
Energy poverty	Index from dummy variables: 1 for electricity restriction due to non-payment of bills and late payment
Poverty measures	Index from dummy variables: 1 for family benefit from social tariff, governmental assistance bill, and governmental assistance
Green identity	Index from categorical variables: factor analysis from importance efficient consumption, efficient appliances, smart-meter, saving for environmental reasons
Monetary concern	Dummy variable: 1 for importance saving for financial reasons
Curtailments behavior	Index from dummy variables: 1 for switching off lights and efficient use of appliances
Investments behavior	Index from dummy variables: 1 for installed night/day electricity meter,bought energy saving light bulbs and appliances
Pro activity	Index from dummy variables: 1 for sought public advice on energy savings, and home energy audit
Public founding	Dummy variable: 1 for applied for public founding
Institution trust	Index from categorical variables: factor analysis from market malfunctioning, market improvement for consumers, role of national energy regulator for market functioning and consumer

The results confirm considerable heterogeneity between countries and among energy efficiency technological investments. As expected, the age of the contact person negatively affects renewable energy investments: elderly people are less prone to risk and to adopt new technologies. However, this effect is not confirmed looking at single country regression. Contrarily, regarding reinsulation investments, age has a positive but close to zero effect in EU and is not significant in the rest of the countries. Only in Greece age is associated with statistically significant higher retrofit adoption. Elderly people generally spent more time at home and are more prone to retrofit measure that increase the house comfort. Gender positively affects solar panel investment in EU and Greece but is not significant for reinsulation investment except in The Netherlands. It confirms the mixed effect found in the literature (see Table 1). The introduction of local variables such as municipality size is intended to preserve dwelling type heterogeneity within the same geographical area. People living in less densely populated areas are more likely to live in detached house, compared to households in the city that generally living in flats. Larger house consume more energy, especially space heating consumption, thus people in detached dwelling have more incentive to reduce energy consumption. This result is confirmed in our analysis. In Estonia and the Netherlands households living in less populated areas are more likely to invest in retrofit measure, while in Portugal and Greece in solar panel or heat pump. In Portugal and Estonia this result is further support by the positive effect of dwelling size on investment likelihood.The coefficient can be interpreted as an attempt to save on electricity bills. Similarly, the amount of electricity has a significant effect in both models.

The general assumption that more educated people tend to be more environmental friendly is not support by our results. Higher of education positively affect reinsulation investment only at the EU level, highlighting the differences observed between aggregate and specific country data. The same results apply for employment status, probably because it is not directly correlated with income levels. Our results confirm the hypothesis that own occupied households show a higher probability to invest in behaviors that have long term effects on the energy consumed. Ownership may engender a sense of belonging and a personal control that motivates the individual to invest in saving energy. The underlying hypothesis is that landlord have higher economic inventive compared to tenants. The coefficient is significant and positive in all countries regarding solar panel installation, while in Estonia and the Netherlands appears irrelevant in affecting reinsulation measures. Number of children does not appear to be a relevant factor, contradicting the hypothesis that future oriented behavior may increase the likelihood to save energy. Finally, income effects significantly diverge comparing aggregate and single country results. In our sample only in Greece our proxy for low-income households have a negative effect on renewable energy installation.

Service quality seems to confirm the hypotheses that lower the quality of the service offered by the electricity retailers higher the propensity to not rely on it. Similarly, lower levels of trust in the market functioning and in the role of the energy regulator in monitoring and enforce them, higher the likelihood to independently produce energy. However, the results apply only at the European level, underlying the heterogeneity among energy markets across Member States. Only in Portugal and the Netherlands a poor quality of the service has a significant effect on renewable energy investment. Awareness about household energy consumption and sources of energy production are not statistically significant in explaining solar panel or heat pump investment. Even though at the EU level the coefficient is positive and significant, looking at the country estimates green identity affects solar panel investments only in the Netherlands, and reinsulation Greece and Estonia for reinsulation. Investment in solar panels enables to be independent from external production sources, and this could be an incentive independently on how the electricity is produced by the retailer.

Environmental attitude it has been argue to be an important factor explaining energy saving investments. However, it appears to be significantly less relevant for high cost energy efficient investment, suggesting the existence of a trade-off between environmental friendly behavior and costs as confirmed by our analysis. A positive impact of environmental related motivation is observed for resinsulation investments, which are lower cost measures compared to solar panel installation. The results confirm the hypothesis that the lower the pressure of cost in a situation, the easier is for actors to transform the attitude in corresponding behaviors. Whereas, if investments costs are high, environmental concern does not help overcome investment related reservation, and there will be few or no effects of environmental attitudes. Monetary concern is not significant in both models and for all countries. This result can be understood if taken in relation to the income effect.

Household engagement in daily practices to reduce energy consumption does not affect investments behavior in all countries except Greece. The results is sustained by the assumption that wealthier household tend to save less energy through daily activities. On the other hand, investment behavior is positively correlated with higher costs investments. People that pay attention to energy efficiency when by light bulbs and appliances are more likely to invest in structural home retrofits. Only in Portugal and the Netherlands the result does not apply.

Our result on solar panel adoption goes against our hypothesis that higher levels of energy poverty should be related to lower rate of investments. To disentangle the underlying effects we decomposed the aggregate index: a measure representing households difficulties in paying their energy bills (i.e. energy poverty), and a more general measure of poverty status (i.e. poverty measure), which defines those households that benefit from governmental financial assistance. Both variables still positives and significant in EU and Portugal. To further investigate this unexpected result we run another regression interacting the two variables. Taking the net effect the significance of energy poverty is annulled. It seems that the positive effect of energy poverty on solar panel adoption was mediated by financial assistance received by poor households. For reinsulation the composite index of energy poverty were not significant in the first model, but using the decompose measures we find poverty measure to negatively affect energy efficiency investments at the EU level. The result sustains the assumption that measures in support to poorer households are not generally targeted on preventing energy poverty. The same reasoning applies in the Portugal case for solar panel investments.

The pro activity coefficient demonstrates that information provided to potential adopters positively affects their likelihood to adopt solar panel. The lack of household knowledge about their saving options hinders them from investing in energy efficiency improvements or changing their behaviors to reduce consumption. Moreover, due to perceived technical and bureaucratic barriers, information reduce the complexity of the decision problem experienced by potential adopters (Jager, 2006). The positive effect of gathering information is testified by our results. Only in Greece and Estonia it seem to be insignificant, probably due to lower level of information campaign. This result confirms that a policy measure providing subsides for energy audit in households might effectively increase energy efficiency uptake, especially if targeting those groups less keen to gather information by themselves or that lives in poor energy conditions (Ugartes, 2016). However, for the latter, the investment impact is rated only as slightly positive because low-income households lack the capital to make financially substantial advised investments. Nonetheless smaller investments like energy efficient appliances can still have a significant overall impact.

As expected, tax allowances and grants are positively and highly correlated with both types of energy efficiency investments. The only outlier is Estonia, where the lower level of public funding (only 2.9 % of the household applied) might explain the incentives ineffectiveness. Incentives promoting renewables are particularly effective. The usual targets of this type of policies are homeowners. People with low income in most member states are more likely to be tenant and thus are less likely to benefit from public funding for energy saving home improvements (Ugartes, 2016).In our sample only 0.5% of the household defined as energy poverty are homeowners. It further supports the hypothesis that to sustain the uptake of energy efficiency measures in low-income households, policies should be design to specifically target poor households and to finance energy efficiency improvements.

Overall, the results show a great variability between aggregate (EU level) and country specific outcomes. Relying on multi country surveys do not allow estimating the context specific effect of the explanatory variables and could cause incorrect policy implication. Our analysis is a first attempt to define context specific problem affecting the low up-take of energy efficiency investment. It also tries to shed light on the benefit that policy efficiency incentives could have to alleviate energy poverty issues.

Table 7: Logistic regression at household level

	Dependent variable:				
	Reinsulation investments				
	(EU)	(Estonia)	(Greece)	(Portugal)	(The Netherlands)
Age	0.003**	−0.001	0.020***	−0.009	0.008
	(0.001)	(0.010)	(0.007)	(0.009)	(0.009)
Female	0.009	0.164	−0.036	0.251	−0.415**
	(0.031)	(0.156)	(0.170)	(0.193)	(0.204)
Inhab 100 - 499 sqkm	0.185***	−0.251	−0.004	−0.260	0.620***
	(0.037)	(0.200)	(0.202)	(0.222)	(0.216)
inhab < 100 sqkm	0.210***	0.387**	0.194	0.041	0.698**
	(0.039)	(0.185)	(0.209)	(0.273)	(0.294)
Education medium	0.065	−0.014	0.349	−0.537*	−0.073
	(0.052)	(0.324)	(0.273)	(0.317)	(0.279)
Education high	0.120**	0.060	0.165	−0.347	0.074
	(0.055)	(0.335)	(0.296)	(0.307)	(0.294)
Employed	0.070**	0.0002	−0.020	0.185	0.336
	(0.035)	(0.208)	(0.181)	(0.230)	(0.228)
Landlord	0.707***	0.553***	1.031***	0.513**	0.767***
	(0.038)	(0.181)	(0.236)	(0.229)	(0.251)
Home size	0.147***	0.215***	0.048	0.139	0.106
	(0.014)	(0.073)	(0.110)	(0.098)	(0.109)
Children	0.005	−0.054	−0.137	0.001	−0.169
	(0.017)	(0.072)	(0.103)	(0.128)	(0.130)
Low economic resource	−0.315***	−0.086	−0.036	−0.189	−0.681
	(0.072)	(0.334)	(0.583)	(0.469)	(0.565)
Electricity use	0.133***	0.958***	−0.653**	0.362	0.114
	(0.049)	(0.279)	(0.303)	(0.313)	(0.290)
Energy literacy	0.062***	0.169*	0.230**	0.002	0.015
	(0.017)	(0.095)	(0.102)	(0.112)	(0.124)
Service quality	−0.036**	−0.290***	−0.133	−0.062	−0.152
	(0.017)	(0.087)	(0.088)	(0.110)	(0.138)
Energy poverty	0.168	−0.792	−0.126	0.008	−0.934
	(0.110)	(0.936)	(0.367)	(0.924)	(0.984)
Poverty measures	−0.190*	0.073	−0.867	−0.820	0.425
	(0.115)	(0.643)	(0.542)	(0.821)	(0.879)
Green identity	0.163***	0.162*	0.056	0.389**	0.277*
	(0.020)	(0.096)	(0.129)	(0.170)	(0.145)
Monetary concern	0.030	0.182	−0.024	0.400	−0.269
	(0.039)	(0.176)	(0.322)	(0.369)	(0.228)
Curtailments behavior	0.279***	0.308	0.790**	0.426	−0.292
	(0.057)	(0.261)	(0.332)	(0.373)	(0.385)
Investments behavior	1.103***	0.953***	1.546***	0.704*	1.167***
	(0.068)	(0.301)	(0.345)	(0.406)	(0.403)
Pro activity	0.912***	0.850	1.372***	1.894***	1.809***
	(0.072)	(0.688)	(0.385)	(0.441)	(0.656)
Public founding	0.900***	0.549	0.615*	0.931*	1.323***
	(0.061)	(0.502)	(0.330)	(0.558)	(0.372)
Institution trust	−0.047***	0.034	−0.011	−0.123	0.131
	(0.017)	(0.080)	(0.088)	(0.108)	(0.121)
Constant	−3.275***	−2.865***	−4.283***	−3.228***	−3.257***
	(0.144)	(0.581)	(0.916)	(0.876)	(0.748)
Country fixed effect	Yes	No	No	No	No
Observations	23,808	893	859	894	769
Log Likelihood	−13,456.460	−545.207	−466.573	−381.118	−341.414
Akaike Inf. Crit.	27,022.910	1,144.413	987.147	816.236	736.829
Note:					*p<0.1; **p<0.05; ***p<0.01

Table 8: Logistic regression at the household level

	Dependent variable:				
	Solar panel Heat pump investments				
	(EU)	(Estonia)	(Greece)	(Portugal)	(The Netherlands)
Age	-0.004^{**}	0.011	-0.001	-0.019	0.006
	(0.002)	(0.018)	(0.007)	(0.014)	(0.012)
Female	0.159^{***}	0.297	0.302^{*}	0.545^{*}	-0.370
	(0.046)	(0.275)	(0.165)	(0.314)	(0.288)
Inhab 100 - 499 sqkm	0.321^{***}	-0.412	-0.222	0.074	0.345
	(0.056)	(0.349)	(0.197)	(0.396)	(0.300)
Inhab < 100 sqkm	0.571^{***}	-0.212	0.382^{*}	1.639^{***}	0.078
	(0.057)	(0.306)	(0.202)	(0.378)	(0.440)
Medium education	0.005	-0.630	0.312	-0.171	-0.138
	(0.077)	(0.557)	(0.272)	(0.507)	(0.418)
High education	0.117	0.039	0.152	-0.423	0.249
	(0.080)	(0.557)	(0.290)	(0.511)	(0.426)
Employed	-0.034	0.183	-0.057	-0.461	0.150
	(0.051)	(0.402)	(0.174)	(0.359)	(0.324)
Landlord	0.589^{***}	-0.129	0.875^{***}	1.068^{**}	0.102
	(0.061)	(0.326)	(0.216)	(0.467)	(0.347)
Home size	0.250^{***}	0.169	0.027	0.378^{**}	0.156
	(0.021)	(0.119)	(0.107)	(0.154)	(0.156)
Children	0.044^{*}	0.139	-0.062	0.289	0.181
	(0.024)	(0.116)	(0.098)	(0.191)	(0.169)
Low economic resource	-0.683^{***}	-0.624	-1.190^{**}	-1.209	-2.115^{*}
	(0.111)	(0.630)	(0.540)	(0.738)	(1.084)
Electricity use	0.723^{***}	4.693^{***}	-0.488^{*}	0.116	-0.270
	(0.074)	(0.557)	(0.295)	(0.522)	(0.415)
Energy literacy	0.095^{***}	-0.031	-0.081	0.089	0.660^{***}
	(0.026)	(0.165)	(0.097)	(0.185)	(0.205)
Service quality	-0.060^{**}	-0.035	0.114	-0.331^{*}	-0.359^{*}
	(0.026)	(0.142)	(0.086)	(0.173)	(0.200)
Energy poverty	0.508^{***}	0.675	0.008	2.051^{*}	0.288
	(0.143)	(1.354)	(0.356)	(1.154)	(1.164)
Poverty measures	0.336^{**}	1.314	0.467	-2.372^{*}	-0.306
	(0.158)	(1.075)	(0.486)	(1.280)	(1.225)
Green identity	0.065^{**}	0.283	-0.094	-0.017	0.072
	(0.030)	(0.176)	(0.125)	(0.252)	(0.203)
Monetary concern	-0.074	0.173	0.274	-0.196	0.529^{*}
	(0.057)	(0.314)	(0.304)	(0.467)	(0.318)
Curtailments behavior	-0.380^{***}	-0.532	-0.152	0.453	-0.386
	(0.081)	(0.449)	(0.313)	(0.573)	(0.552)
Investments behavior	1.123^{***}	1.659^{***}	2.290^{***}	0.899	0.927
	(0.101)	(0.589)	(0.351)	(0.642)	(0.574)
Pro activity	1.321^{***}	2.250^{**}	0.252	1.606^{***}	-0.732
	(0.088)	(0.907)	(0.371)	(0.621)	(0.761)
Public founding	1.240^{***}	-1.501^{*}	0.473	1.538^{**}	2.835^{***}
	(0.069)	(0.863)	(0.318)	(0.659)	(0.427)
Institution trust	-0.047^{*}	-0.081	-0.058	-0.096	0.059
	(0.025)	(0.142)	(0.086)	(0.175)	(0.184)
Constant	-3.883^{***}	-7.460^{***}	-2.127^{**}	-4.856^{***}	-3.465^{***}
	(0.198)	(1.114)	(0.845)	(1.373)	(1.036)
Country fixed effect	Yes	No	No	No	No
Observations	23,808	893	859	894	769
Log Likelihood	−7,089.849	−219.534	−490.095	−171.437	−195.918
Akaike Inf. Crit.	14,289.700	493.067	1,034.190	396.873	445.836
Note:					*p<0.1; **p<0.05; ***p<0.01

5. Conclusions

There is no doubt that current energy consumption causes global problems. The great amount of green gas emission deriving from fossil fuel burning can be alleviated in two ways: reducing energy consumption and shifting energy provision toward renewable energy. Promising technological progress has been made in both areas. Energy efficiency of technical devices increases and renewables energy systems improve constantly. However, even though green technologies exist and are affordable consumers stills not adopt its (Jeffe and Stavins, 1994). Ultimately are final users who decide about consumption and about whether or not to adopt new technologies (IEA, 2016).

Evidence shows that in the residential sector energy demand has not displayed a decreasing trend over the last two decades (Eurostat, 2018). To understand why this is the case, relying only on economic explanation considering cost affordability is not enough (Jeffe and Stavins, 1994). Energy behaviors and energy efficient investments decisions are complex and shaped by many factors, both individual and contextual. There is an urgent need to develop an integrated approach to domestic energy reduction that simultaneously addresses technical and infrastructural energy investments as well as occupant energy habits and daily practice, taking into account heterogeneity of households and dwellings characteristics. In addition, the formulation of effective and well targeted residential energy policies to increase both conservation and technology adoption must be based on a sound understanding of how technology adoption, conservation practices, energy use knowledge, and attitudes toward energy conservation are associated with households characteristics.

Form a policy perspective the EU has stressed the need for member states to address energy poverty highlights energy efficiency improvements as an effective means to alleviate this issue (Directive 2012/27/EU, Directive 2009/72/EC). According to the subsidiary principle, it is up to member states to transpose the provisions of the directives into national law. However, the lack of a prescriptive approach to define vulnerable consumers results in a range of interpretations in the Member States and only in some European countries the energy efficiency obligations involve direct subsides for energy efficiency technologies in low-income households. This overall pictures is confirmed by our results, that highlighted the heterogeneity among countries studied in their up-take of policy measure that mutually address energy efficiency and energy poverty issues.

AppendixA.

Code	Description	Label
D1	Age	[Age]
D2	Gender	[Gender]
D3_recode	Education	[Education]
D4_recode	Urbanisation	[Urbanisation]
D5	Working Status	[Working Status]
D7	Landlord/tenant	[Landlord/tenant]
D8	Economic resources	[Economic resources]
P1	Home dimension (n. of bedrooms)	
P2a	Household numerosity	[Household numerosity]
P2b	Members under age 16	[Num. under age 16]
P4_1_scale	Frequency of elecricticy use for home heating	[Use of electricity]
P4_2_scale	Frequency of elecricticy use for water heating	[Use of electricity]
P4_3_scale	Frequency of elecricticy use for cooking	[Use of electricity]
Q1_1_Scale	Awareness of electricity consumption in kwh	[Aw. consumption]
Q1_2_Scale	Awareness of expenditure for electricity consumption	[Aw. expenditure]
Q1_3_Scale	Awareness of how the electricity price is calculated	[Aw.price composition]
Q1_4_Scale	Awareness of current tariff characteristics	[Aw. tariff characteristics]
Q1_5_Scale	Awareness of energy source (gas, wind, etc.)	[Aw. energy source]
Q13	Awareness of existing measures against energy poverty	[Aw. energy poverty measures]
Grid_Q14_1_Q14	Benefits from social tariff	[Social tariff]
Grid_Q14_2_Q14	Benefits government financial assistance to pay electricity bills	[Gov. assistance bills]
Grid_Q14_3_Q14	Benefits government financial assistance	[Gov. assistance]
Grid_Q14_4_Q14	Experienced restriction in electricity consumptions due to non-payment of bills	[Payments restrict.]
Grid_Q14_5_Q14	Often paid a fee for late payment	[Late payments fee]
Grid_Q15_1_Q15	Importance of better management of energy consumption	[Imp. efficient consumption]
Grid_Q15_2_Q15	Importance of energy efficiency of household appliances	[Imp. efficient appliances]
Grid_Q15_3_Q15	Awareness of smart meter functions	[Aw. smart-meter]
Grid_Q15_4_Q15	Importance of saving energy for financial reasons	[Imp. financial saving]
Grid_Q15_5_Q15	Importance of saving energy forenvironmental reasons	[Imp. environmental saving]
Grid_Q16_1_Q16	Bought energy saving light bulbs	[Light bulbs]
Grid_Q16_2_Q16	Bought energy-efficient appliances	[Efficient appliances]
Grid_Q16_3_Q16	Efficient use of appliances	[Eff. use of appliances]
Grid_Q16_4_Q16	Switching off lights when leaving a room	[Switching off lights]
Grid_Q16_5_Q16	Installed a night/day electricity meter	[Night/day elect. meter]
Grid_Q16_6_Q16	Had home (re-)insulated	[Home (re)insulated]
Grid_Q16_7_Q16	Installed solar panels or a heat pump	[Solar panels - heat pump]
Grid_Q16_8_Q16	Sought public advice on energy savings	[Public advice on energy saving]
Grid_Q16_9_Q16	Applied for public funding for energy saving home improvement	[Applied for public funding]
Grid_Q16_10_Q16	Asked an independent expert to conduct an energy audit	[External advice energy saving]
Q36_1_Scale	Market malfunctioning	[Market - malfunctioning]
Q36_2_Scale	Market conditions for consumers are improving	[Market - improvement for consumers]
Q36_4_Scale	National energy regulator is essential for market functioning	[National energy regulator - market]
Q36_5_Scale	National energy regulator could do better for consumers	[National energy regulator - consumer]

AppendixB. Bibliography

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