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Energy efficient technology adoption in low-income households in the European Union – What is the evidence?

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ABSTRACT

This paper studies the adoption of high-cost, medium-cost, and low-cost energy efficient technologies (EETs) by income categories in eight European Union countries, relying on demographically representative household surveys carried out simultaneously among about 15,000 households in France, Germany, Italy, Poland, Romania, Spain, Sweden, and the United Kingdom. The statistical-econometric analyses allow the effects of income to differ by income quartiles in each country. For high cost EETs such as retrofit measures, the findings suggest that homeowners falling into the lowest income quartile exhibit lower adoption propensities than those falling into the highest income quartile. These findings provide some support for policies targeting "poor homeowners", particularly in lower-income countries with a high share of owner-occupiers such as Poland and Romania. Further, differences in adoption propensities across income quartiles also exist for medium- and low-cost EETs such as appliances and light bulbs. Finally, analyzing factors related to homeowners receiving financial support for retrofit measures from governments or utilities suggests that differences in implementation rates between the highest and lowest income quartile would likely have been higher without such support schemes in place. For the United Kingdom (but not for other countries) these schemes appeared to have had a progressive effect.

1. Introduction

Household energy poverty has emerged since about a decade ago as a pressing concern for energy policy in the wake of rising energy prices and the economic downturn, and this has disproportionately affected low income households. A recent study commissioned by the European Commission states that nearly 11% of the population of the European Union (EU) cannot afford to properly heat their homes (Pye et al., 2015). Similarly, BPIE (2014) reports that up to a quarter of the EU population is at risk of suffering from energy poverty.[1] Lacking a common definition of energy poverty, estimates for the number of energy-poor people in the EU range between 50 million and 160 million (Stoerring, 2017). The literature agrees that the main reasons for this mounting problem are rising energy prices, low income and poor energy performance of dwellings (e.g. Bouzarovski, 2011; Bouzarovski and Petrova, 2015; Pye et al., 2015; Ugarte et al., 2016; Ordonez et al., 2017; Burlinson et al., 2018). According to Bouzarovski (2011), for example, the most common reasons for fuel poverty in Mediterranean countries include inefficient thermal insulation and heating systems. Energy poverty appears to be particularly prevalent in Central and Eastern European countries but is also a widespread phenomenon in some Southern European countries and even in high-income countries (including the United Kingdom) (e.g. BPIE, 2014; Ugarte et al., 2016; Maxim et al., 2016; Bouzarovski and Tirado Herrero, 2017; Aristondo and Onaindia, 2018, Chaton and Lacroix, 2018). The relation between low-income status and poor energy performance of the dwellings may be described as a vicious cycle (e.g. Ugarte et al., 2016). Low-income households are more likely to reside in low-priced, non-refurbished dwellings, associated with high fuel costs (Grösche, 2010). At the same time, low-income household are less likely to have the financial means to purchase energy-efficient technologies (EETs), which often come with higher upfront costs than less efficient technologies. Similarly, low-income households are more likely to be constrained for credit because they cannot provide adequate collateral. They are also more likely to have an unfavorable debt-service ratio, preventing them from taking out further loans. Since low income households typically spend a higher share of their income on energy services, they tend to

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[1] Energy poverty commonly describes a situation where individuals or households are not able to adequately consume required energy services at affordable cost. In practice, countries apply different criteria to define energy poverty. Most prominently, in the United Kingdom, a household is classified as fuel-poor if it spends more than 10% of its income (before housing costs) on heating services. For an overview of the concepts used in different countries see Thomson and Snell (2013), Ugarte et al. (2016), Bouzarovski (2017), or European Commission (2017).

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benefit in particular from adopting measures to increase energy efficiency (e.g. Schleich and Mills, 2012).

Not least because of the so-called landlord-tenant problem, renters are particularly prone to live in dwellings with poor insulation (e.g. Krishnamurthy and Kriström, 2015). While it is commonly acknowledged that low-income households are often also tenants, it is less recognized that homeowners may be energy-poor, too, even in high-income countries. For example, depending on the criteria applied to be classified as energy poor, Legendre and Ricci (2015) find 32–66% of the homeowners in France to be energy poor.

The EU policy framework including the Electricity and Gas Directives (2009/72/EC and 2009/73/EC) and the Energy Efficiency Directive (EED) (2012/27/EU) stresses the need for member states to address energy poverty and highlights energy efficiency improvements as an effective means to alleviate energy poverty. According to the subsidiary principle, it is up to member states to transpose the provisions of the directives into national law. Pursuant to Article 7 of the EED, domestic energy suppliers in several member states now deliver a certain amount of energy savings through so-called energy efficiency obligation schemes. According to Article 7(7)(a) of the EED, such obligations schemes may require a share of EET to be implemented in households affected by energy poverty or in social housing. Reviewing member states' energy efficiency policies, Ugarte et al. (2016) find only a few policies specifically targeting low-income households. These policies typically combine energy audits with low-interest loans or grants earmarked for retrofit measures or boiler replacements. Not many policies concern appliance replacements.[2]

This paper analyzes adoption rates of high-cost, medium-cost, and low-cost EETs by income groups across eight EU member states. The implementation of retrofit measures (a high-cost measure) is explored for homeowners, thus checking whether adoption rates differ between low- and high income homeowners. Adoption of energy efficient appliances (a medium-cost measure) and of light emitting diodes (LEDs) (a low-cost measure) is explored for tenants and homeowners. The findings help assessing whether policies targeting particular income groups for medium- and low-cost measures might be effective. For retrofit measures, it will also be explored if financial support received for EET adoption varies by income quartiles, thus providing information on whether existing support policies have been progressive or rather regressive.

The methodology involves descriptive statistics focusing on income quartiles, and a multivariate analyses of EET adoption equations and of equations governing whether households had received financial support for EET measures. Unlike previous studies, the multivariate analyses allow the effects of income on EET adoption to differ by income quartiles. In contrast to previous studies relying on multi-country surveys (e.g. Mills and Schleich, 2010a; Ameli and Brandt, 2015; Krishnamurthy and Kriström, 2015), this study estimates separate EET adoption equations for each country, thus allowing the effects of income (and other explanatory variables) to differ between countries.

All analyses rely on demographically representative household surveys carried out simultaneously in 2016 among about 15,000 households in eight EU member states: France, Germany, Italy, Poland, Romania, Spain, Sweden, and the United Kingdom. Thus, this study allows for a comparison of the implications of households falling into a particular income group on EET adoption and on financial support received across EU countries. Heterogeneity in the extent to which households resort to support policies across countries may also help explain observed differences across countries in EET adoption rates for different income groups.

The remainder of the paper is organized as follows. Section 2 describes the data and the statistical-econometric approaches employed. Section 3 presents and discusses the findings. The final Section 4 concludes and offers policy implications.

[2] In addition, almost every EU Member State has social policies in place such as direct payments via housing and heating allowances, reduced energy tariffs, and tolerance for non-payment of energy bills.

2. Methodology and data

The empirical analyses rely on two types of methods. First, adoption shares of typical EETs are calculated at the country level for particular income percentiles. Specifically, quartiles are used. That is, households are ranked according to their income from lowest to highest, and then grouped into four income quartiles (1 being the poorest and 4 being wealthiest). Thus, each quartile Q1 to Q4 contains 25% of the sample.[3] Retrofit measures are used as representative of high-cost EET, appliances as representative of medium-cost EET and light bulbs as being representative of low-cost EET. This allows comparing EET adoption shares across income groups, countries, and technologies using descriptive statistics. For retrofit measures, only homeowners are considered. In addition, for the case of retrofit measures, it will also be explored whether receiving financial support for EET adoption varies by income quartiles.

The remainder of this section describes the model, the data, and the dependent and explanatory variables used in the multivariate analyses.

2.1. Econometric model

Regression analyses are employed to analyze the relation of income and EET adoption in a multivariate framework, thereby specifically allowing the effects of income on adoption to vary by income quartile. To do so, standard binary response models are run for each country to estimate the adoption of the three types of EETs. The subsequent equations describe the formal model:

$$y_{ik} = \begin{cases} 1 & \text{if } y_{ik}^* > 0 \\ 0 & \text{otherwise} \end{cases} \tag{1}$$

$$y_{ik}^* = \beta_k X_{ik} + \varepsilon_{ik}, \tag{2}$$

where i denotes the individual household, k stands for the technology type, β_k is a vector of coefficients, y_{ik}^* is the latent variable, X_{ik} is a vector of explanatory variables containing income quartiles and control variables. The error term ε_{ik} is assumed to be normally distributed, giving rise to the Probit model. In addition, similar Probit models are employed to explore in a multivariate analyses whether household income is related to receiving financial support for implementing retrofit measures.

2.2. Data

The empirical analyses employ data collected through an online survey among ca. 15,000 participants from France (FR; N = 2000), Germany (DE; N = 2002), Italy (IT; N = 2000), Poland (PL; N = 2008), Romania (RO; N = 1529), Spain (ES; N = 2001), Sweden (SE; N = 1515), and the United Kingdom (UK; N = 2000). This survey was carried out by Ipsos GmbH via computer-assisted web interviews (CAWI) using existing household panels. The survey participants were selected via quota sampling to be demographically representative of each country in terms of gender, age (between 18 and 65 years), and regional population distribution. To qualify for the survey, participants had to be involved in their household's decisions for utilities, heating, and household appliances. Interviews were conducted between July and August of 2016. The original survey was drafted in English and then professionally translated to the target language of each country. For quality control, and to eliminate differences between countries that could be attributed to language, the translated versions were also back-translated into English.

The survey included items on EET adoption, use of EET support

[3] Income is a crucial indicator in the criteria typically applied to define energy poverty (see Moore, 2012; Thomson and Snell, 2013; Ugarte et al., 2016). It is also the key indicator used by Eurostat (2018) to calculate the share of the population at risk of poverty in EU member states.

policies, dwelling characteristics, personality traits and attitudes. Some socio-demographic information was gathered at the beginning of the questionnaire (to ensure that the quota requirements were met). More extensive socio-demographic information (including education, income, and household size) was collected at the end of the questionnaire.

2.3. Variables

The descriptive analyses link participants' responses to the survey questions on household adoption of EETs and support received for implementing retrofit measures with income quartiles. The multivariate analyses regress adoption of EET and support received for retrofit measures on income (by quartiles) and other explanatory variables.

2.3.1. Dependent variables

The dependent variables for the adoption equations are constructed from participants' stated adoption decisions on retrofit measures, appliances and light bulbs, representing high-cost, medium-cost, and low-cost EETs, respectively.

First, if homeowners had adopted at least one retrofit measure (insulation of roof or ceiling, insulation of exterior walls, insulation of basement, installation of double-glazed windows, or installation of triple-glazed windows) in the ten years preceding the survey.

Second, if participants (homeowners and renters) had acquired a new appliance (refrigerator or fridge/freezer combination, freezer, dishwasher, washing machine) in the five years preceding the survey, they were asked whether their most recent purchase was, to the best of their knowledge, a top-rated energy-efficient appliance.[4]

Third, if participants had bought a new light bulb in the two years preceding the survey, they were asked to report the type of the bulb they had most recently purchased. To help identify the new bulb type, participants were shown pictures of a compact fluorescent light bulb, a light emitting diode (LED), a halogen bulb, and an incandescent light bulb. The purchase of an LED was considered as the energy-efficient choice.

Finally, the dependent variable for the support equation is derived from homeowners' responses to the question whether and for which retrofit measures their household had benefitted from government or utility company financial support (e.g. rebates, grants, low-interest loans).[5] This question was only presented to homeowners who indicated that they had carried out a retrofit measure in the ten years preceding the survey.[6]

2.3.2. Explanatory variables

The variables employed as explanatory variables in the multivariate analyses have typically been included in empirical studies of household adoption of EETs and reflect household characteristics, dwelling characteristics, and individual attitudes towards energy costs and towards the environment. Existing studies tend to find higher-income households to be more likely to have adopted EETs than lower-income households (e.g. Michelsen and Madlener, 2012; Mills and Schleich, 2010a, 2010b, 2014; Ramos et al., 2015; Trotta, 2018). For example, richer households are less prone to suffer from capital constraints. In contrast to previous studies, this study allows the effects of income on EET adoption to differ by income class. While previous studies relying on multi-country surveys (e.g. Mills and Schleich, 2010a, 2012; Ameli and Brandt, 2015; Krishnamurthy and Kriström, 2015; Schleich et al., 2018) employ country dummies to capture general differences across countries, this study estimates separate adoption equations for each country. This allows the parameter estimates associated with income (and other explanatory variables) to differ between countries. For these reasons, the set of explanatory variables included three dummy variables (*DQ1, DQ2, DQ3*) indicating whether a household belongs to the first, second, or third income quartile. To prevent perfect collinearity, no dummy is included for the fourth income quartile. Therefore, the quartile for the highest income households serves as the baseline and the coefficients associated with the three income dummies have to be interpreted relative to the fourth income quartile.

In addition, the set of covariates includes respondent *age*. Previous research suggests that older people have a lower level of knowledge about EETs and weaker preferences for state-of-the-art technologies than younger people (e.g. Carlsson-Kanyama et al., 2005). In addition, older people face higher uncertainty about whether their investments in energy efficiency will be recovered during their lifetime. This would suggest a negative relation between age and EET adoption, especially for capital-intensive investments. On the other hand, older people have been shown to be more patient (e.g. Tanaka et al., 2010). Thus, older people discount future energy cost savings of EET less and accept longer payback times, therefore implying a positive relation between EET adoption and age. The empirical literature provides mixed results on the association of age and EET adoption. For example, Ameli and Brandt (2015) found that age is positively related with the adoption of light bulbs, heat thermostats, thermal insulation and energy-efficient windows, but negatively related with the adoption of heat pumps. Michelsen and Madlener (2012) found older household heads to be less likely to invest in pellet-fired boilers. Similarly, the propensity to invest in low-energy ovens, double-glazing and light bulbs decreases when a household contains a greater number of senior citizens (Ramos et al., 2015). In Mills and Schleich (2014), younger households are more likely to have switched from incandescent bulbs to energy-efficient bulbs than middle aged households.

There is substantial evidence that households' decisions to invest in EETs is positively related to energy costs (e.g. Nair et al., 2010; Houde, 2018; Cohen et al., 2017). To measure the role of participants' attitudes towards energy costs when investing in a particular technology, the set of explanatory variables includes *Energycosts*. To facilitate the interpretation, the z-score is used in the econometric estimations. Thus, a change in the transformed variable by one unit corresponds to a change by one standard deviation.

Most empirical analyses of EET adoption find pro-environmental attitudes to be positively related with EET adoption (e.g. Di Maria et al., 2010; Mills and Schleich, 2014), but less relevant for predicting high-cost investments such as thermal retrofit (e.g. Ramos et al., 2015; Whitmarsh and O'Neill, 2010). *Env_ID* is used to reflect environmental attitudes. It is measured via four items that were adapted from Whitmarsh and O'Neill (2010). More precisely, *Env_ID* was calculated as the average of the 4 items and then transformed into the z-score before entering the econometric analyses.

The final set of explanatory variables refers to the dwelling. *Detached* controls for potential differences in household propensity to adopt EETs being implemented in detached versus non-detached houses. Retrofit measures, in particular, may be easier to realize in detached houses because of lower transaction costs, since fewer parties are involved in the decision-making. Lastly, *Buildage* is supposed to capture the impact of building age on EET investment. For example, younger buildings (corresponding to a larger value for *Buildage*) may require less retrofit measures because of lower replacement needs (e.g. for windows).

Table 1 provides more detailed information about each explanatory variable. Country-specific descriptive statistics for the variables used to estimate the retrofit, appliances and LED adoption equations appear in Tables A1-A3 in the Appendix.

[4] The findings presented in Section 3 also hold if the sample is limited to appliance purchase decisions that were made from 2014 forward (i.e. in the two years preceding the survey). Thus, these results do not appear to suffer from recall bias.

[5] The survey did not include items eliciting whether adopters of energy-efficient appliances or LEDs had received financial support. In practice, such support measures are far less common than support measures for retrofit. Also, the survey did not ask for further details of the retrofit support program such as eligibility criteria pertaining to recipients or the measures, or to financial amount received etc.

[6] All monetary amounts (e.g. for income categories) were presented in the national currency of the country the survey was conducted. To keep the relative value of monetary amounts similar between countries in terms of purchasing power the following exchange rates were used to convert Euro amounts into the national currency (e.g. when reporting descriptive statistics and Tables A1-A3): Poland 1€ = 3 PLN; Romania 1€ = 3 RON, Sweden 1€ = 10 SEK, and UK 1€ = 1 GBP.

Table 1
Description of explanatory variables.

Label	Description
DQ1, DQ2, DQ3, DQ4	Dummies representing income quartiles. In the survey, household annual income (after taxes) was measured in 1000 EUR per year (via eleven income categories, which differed by countries to reflect general differences in income levels across countries).
Age	Respondent age in years.
Energycosts	Score calculated from participant stated importance of energy costs when investing in insulation measures or heating systems/appliances/light bulbs (1 = played no role to 5 = very important).
Env_ID	Score reflecting environmental identity. Constructed using the equally weighted responses to the subsequent scale items (1 = strongly disagree to 5 = strongly agree): “Please rate how much you agree with the following statements (i) To save energy is an important part of who I am. (ii) I think of myself as an energy conscious person. (iii) I think of myself as someone who is very concerned with environmental issues. (iv) Being environmentally friendly is an important part of who I am.”
Detached	Dummy = 1 if house was detached.
Buildage	Age of the building based on the following nine age categories: < 1920, 1921–1944, 1945–1959, 1960–1969, 1970–1979, 1980–1989, 1990–1999, 2000–2009, > 2009; Age takes on the value of 1 for the first category, 2 for the second, …, and 9 for the last category.
Windows[a]	Dummy = 1 if financial support for retrofit measures was received for the installation of windows rather than thermal insulation of building components.

[a] Only enters the regression equation modelling if households had received financial support for retrofit measures.

3. Results and discussion

First, results based on descriptive statistics of household adoption of EET measures and of financial support received are shown by income quartiles. Then, the findings of the multivariate adoption models are presented and discussed.

3.1.1. Results for adopting energy-efficient technologies

Fig. 1 displays the findings for retrofit measures implemented by homeowners.[7] The retrofit implementation shares are highest in Romania and Poland. In these and other Central and Eastern European post-socialist countries, mass privatization of the building stock in the 1990es led to high homeownership rates and generally poor housing conditions (Cirman et al., 2013). Thus, retrofit needs were particularly high in Romania and Poland.

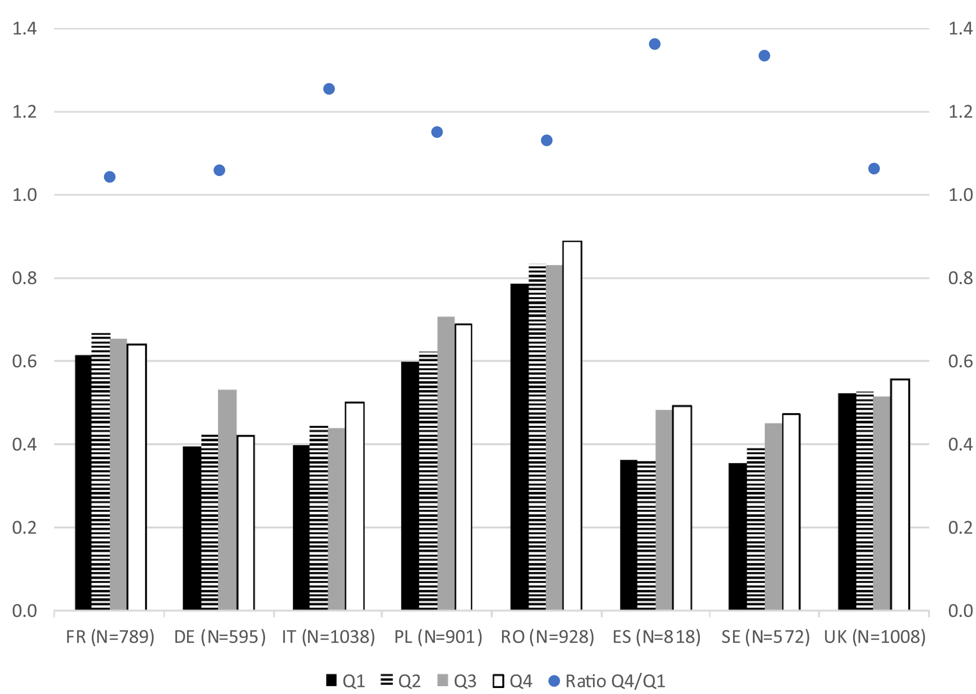

Fig. 1. Rate of retrofit measures implemented by income quartiles across countries.

3.1. Descriptive statistics

Fig. 1, Fig. 2 and Fig. 3 show the rates of EET adoption per income quartile Q1 to Q4 for each country. In addition, Fig. 4 reports the shares of households having received financial support from the implementation of retrofit measures. Q1 refers to the first quartile, that is, to the 25% of the households with the lowest reported household incomes. Similarly, Q2 refers to the 25–50 percentile, Q3 to the 50–75 percentile, and Q4 to the 25% of the households with the highest incomes. To calculate the descriptive statistics underlying Figs. 1–4, the sampling weights provided by Ipsos GmbH were employed. This ensures that the findings are representative for the respective country population.

In all the countries studied, higher income groups tend to have higher retrofit adoption shares. This trend is most pronounced in Spain, Sweden, and Italy. In contrast, in France, Germany, and the United Kingdom, differences across income quartiles appear rather small. As an indicator measuring the degree of inequality, Fig. 1 also shows the ratio of adoption

[7] The shares of households that owned their primary residences (i.e. the house or apartment they primarily lived in) varied substantially across countries. They were highest for Poland (84%), Italy (80%), Romania (79%) and Spain (77%), and lowest for Germany (44%), the United Kingdom (47%), Sweden (53%), and France (64%).

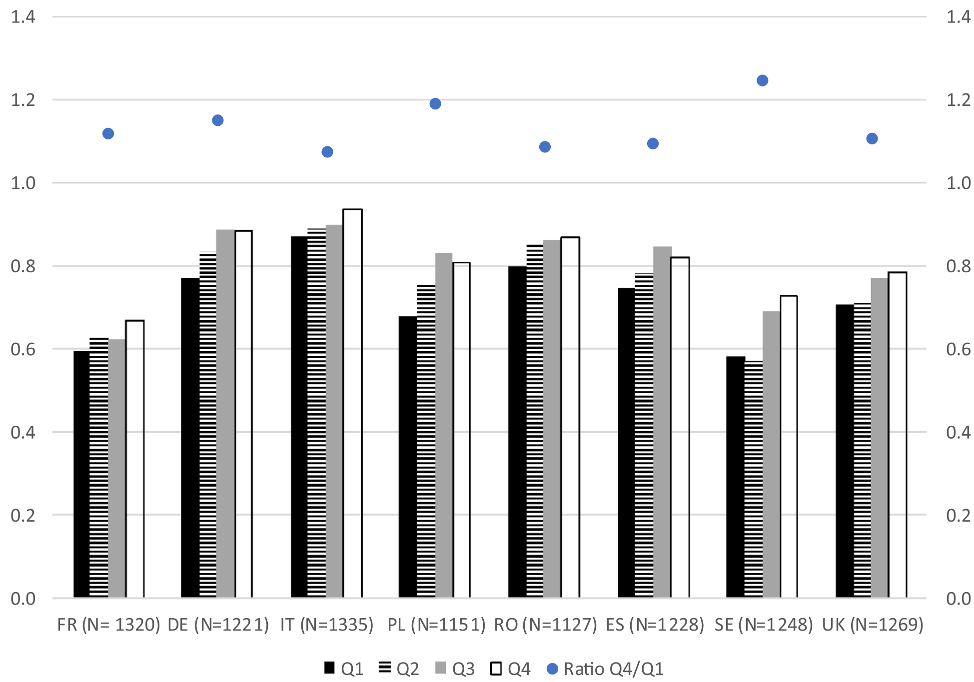

Fig. 2. Rate of adoption of energy efficient appliances by income quartiles across countries.

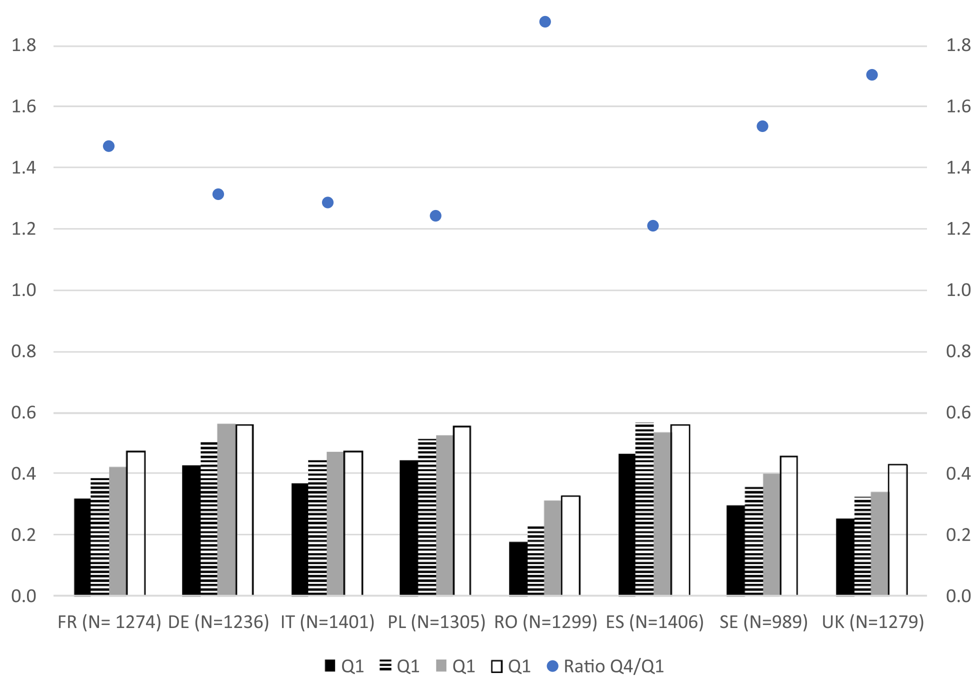

Fig. 3. Rate of LEDs purchased by income quartiles across countries.

shares for the highest income quartile relative to the lowest income quartile.

In comparison, Fig. 2 and Fig. 3 display the findings for energy-efficient appliances and LEDs. In contrast to retrofit measures, these adoption rates refer to both homeowners and renters. Similar to the findings for retrofit measures, for all countries in the sample, Fig. 2 and Fig. 3 suggest that adoption of energy-efficient appliances and LEDs tends to be higher for higher income quartiles than for lower income quartiles. Comparing the ratios of adoption shares of Q4 versus Q1 suggests that for appliances, this inequality is highest for Spain and Sweden. In general, though, differences in this measure of inequality across countries is rather small. In contrast, for LEDs the ratio of adoption shares for the highest to the lowest income quartile varies substantially across countries. This ratio is particularly high for Romania, the United Kingdom, Sweden and Germany.[8] Finally, on average, the ratio of adoption shares of Q4 versus Q1 for LEDs is generally higher than for energy-efficient appliances, and also higher than for retrofit measures (although for a different population, i.e. for homeowners). Thus, the descriptive statistics provide large-sample evidence that differences in adoption shares across income groups not only exist for high-cost EETs like

[8] Results from standard *t*-tests indicate that the differences in the shares of retrofit measures implemented by households in Q4 compared to Q1 are statistically significant ($p < 0.10$) for Italy, Poland, Romania, Spain, and Sweden. For appliances and LEDs, the differences in adoption shares between Q4 and Q1 were statistically significant different for all countries.

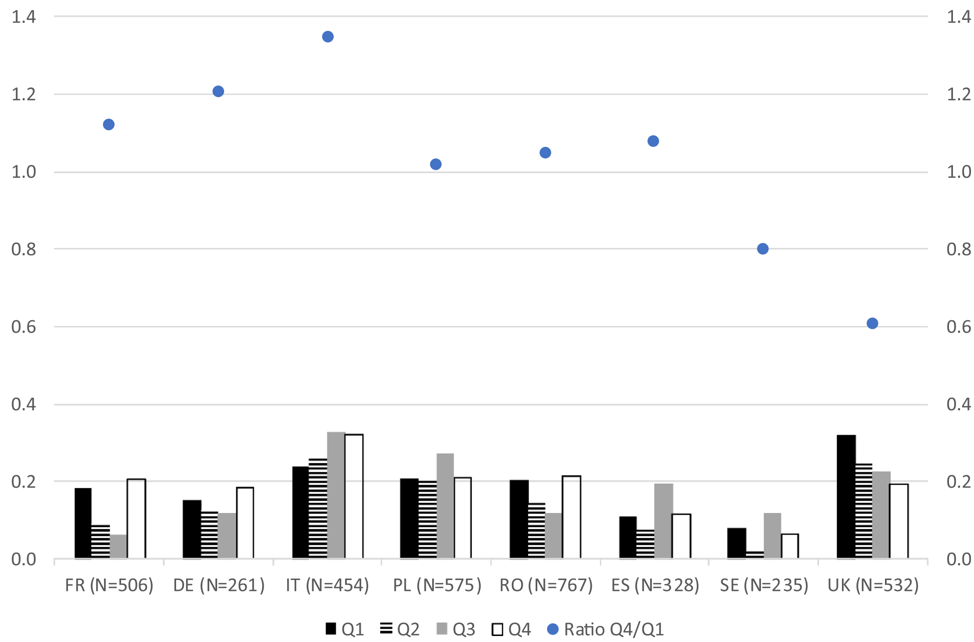

Fig. 4. Rate of homeowners receiving support for retrofit measures by income quartiles across countries (adopters only).

retrofit measures, but also for medium- and low-cost EETs like appliances and light bulbs.

Heterogeneity in the extent to which households resort to support policies may also help explain differences in adoption rates within countries.[9] For each country, Fig. 4 shows the share of households per income quartile that reported to have received financial support for a retrofit measure they had implemented. For all countries except Italy and Poland, Fig. 4 suggests that support programs targeting low-income groups were effective, i.e. the support rates for Q1 are higher than for Q2. Looking at the ratio of support received by Q4 versus Q1 suggests that support programs in particular in Italy are regressive. In contrast, they appear to be progressive in the United Kingdom and – to a smaller extent – also in Sweden.[10] This aspect will be pursued more formally in Section 3.2.4 which employs multivariate methods to explain whether households had received support for implementing retrofit measures.

3.2. Results from multivariate analyses

For each EET in each country, a separate Probit model was estimated using robust standard errors. To allow for a more meaningful interpretation of the results, the average marginal effects of the explanatory variables were calculated. For dichotomous variables the discrete probability effects are shown in the results tables.[11]

3.2.1. Results for implementing retrofit measures

Table 2 reports the findings for the implementation of retrofit measures. First, the results for the quartile dummies will be discussed. The findings for *DQ1* suggest that in five of the eight countries in the sample, that is in Italy, Poland, Romania, Spain, and Sweden, homeowners belonging to the lowest homeowner income quartile Q1 are associated with statistically significantly lower retrofit adoption propensity than homeowners belonging to the highest income quartile Q4. For example, the point estimate for the marginal effect of − 0.1099 for Italy means that the probability to have adopted a retrofit measure in the ten years preceding the survey is about 11% points lower for a household in Q1 compared to a household in Q2. None of the coefficients associated with *DQ2* and *DQ3* turns out to be statistically significant (except for *DQ2* in Spain). Thus, for most countries the results provide no evidence that adoption propensities are lower for homeowner households in Q2 and *Q3* compared to homeowner households in Q4.[12]

Next, the results for the remaining explanatory variables will be examined. *Age* is statistically significant in half the countries in the sample, that is. in France, Poland, Romania, and the United Kingdom. Accordingly, older participants exhibit a higher propensity to have adopted at least one retrofit measure. For example, for France, one additional year of *Age* is related with an increase in the take-up of retrofit measures by 0.26% points. In general, the higher households weigh energy costs when investing in insulation measures or heating systems, the more likely they are to have implemented a retrofit measure. This relation is statistically significant in France, Germany, Poland, Romania, and the United Kingdom. Since *Energycosts* enters the regression equation as z-values, an increase in one unit corresponds to an increase in one standard deviation. Hence, if *Energycosts* increases by one standard deviation, the propensity that the average French participant had implemented a retrofit measure rises by about 6.4% points. A higher environmental identity is associated with a statistically significantly higher adoption of retrofit measures in all countries. If *Env_ID* rises by one standard deviation, the propensity that the average French homeowner household had implemented a retrofit measure increases by about 3.8% points. Finally, both building characteristics measures turned out to be statistically significant in some countries. First, the coefficient associated with *Detached* is positive for all countries, and statistically significant at conventional levels in six countries. For France, the propensity to have implemented a retrofit measures is about 15% points higher for a household living in a detached house rather than a non-detached house. Second, the findings for *BuildAge* suggest that newer dwellings are correlated with lower retrofit rates. This relation is statistically

[9] Since information on whether households benefitted from support policies is, naturally, only available for adoptions, it cannot be included as an explanatory variable in the multivariate analysis in 3.2.

[10] Results from standard *t*-tests imply though that the differences in the shares of support received by households in Q4 compared to Q1 are statistically significant at $p < 0.10$ only for the United Kingdom.

[11] To test for collinearity variance-inflation factors (VIFs) were calculated for all EETs and for all countries. All average VIFs and all VIFs of individual variables were below 3, and thus below the critical value of 10, which is often used as a benchmark in empirical analyses. Thus, the explanatory variables are not highly inter-correlated.

[12] Robustness checks show that this finding also holds if the income quartiles are calculated using the entire population rather than homeowners.

Table 2
Probit model results (average marginal effects) for implementing retrofit measures.

	FR	DE	IT	PL	RO	ES	SE	UK
DQ1	− 0.0397	− 0.0745	**− 0.1099**[***]	**− 0.0944**[*]	**− 0.1185**[**]	**− 0.1463**[***]	**− 0.1050**[**]	− 0.0321
	(0.400)	(0.150)	(0.006)	(0.089)	(0.021)	(0.001)	(0.047)	(0.494)
DQ2	0.0218	− 0.0144	− 0.0529	− 0.0820	− 0.0616	**− 0.1464**[***]	− 0.0594	− 0.0218
	(0.664)	(0.815)	(0.228)	(0.111)	(0.211)	(0.002)	(0.288)	(0.623)
DQ3	0.0090	0.0826	− 0.0514	0.0061	− 0.0745	− 0.0262	− 0.0263	− 0.0332
	(0.851)	(0.139)	(0.323)	(0.916)	(0.120)	(0.654)	(0.651)	(0.484)
Age	**0.0026**[**]	− 0.0011	− 0.0002	**0.0030**[**]	**0.0022**[*]	0.0002	− 0.0021	**0.0026**[**]
	(0.030)	(0.474)	(0.830)	(0.024)	(0.059)	(0.908)	(0.175)	(0.025)
Energycosts[a]	**0.0643**[***]	**0.0612**[**]	0.0087	**0.0426**[**]	**0.0306**[**]	0.0233	0.0040	**0.0457**[***]
	(0.002)	(0.020)	(0.682)	(0.027)	(0.047)	(0.149)	(0.849)	(0.007)
Env_ID[a]	**0.0376**[*]	**0.0433**[**]	**0.0970**[***]	**0.0650**[***]	**0.0437**[***]	**0.0917**[***]	**0.0749**[***]	**0.0689**[***]
	(0.060)	(0.042)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Detached	**0.1523**[***]	**0.0771**[**]	**0.0635**[*]	0.0278	0.0162	**0.1116**[***]	**0.1349**[***]	**0.1071**[***]
	(0.000)	(0.048)	(0.050)	(0.402)	(0.540)	(0.002)	(0.001)	(0.002)
Buildage	**− 0.0356**[***]	**− 0.0605**[***]	− 0.0122	0.0013	0.0152	− 0.0057	**− 0.0282**[**]	0.0058
	(0.000)	(0.000)	(0.163)	(0.883)	(0.127)	(0.600)	(0.016)	(0.482)
Pseudo R^2 (McFadden)	0.0605	0.0800	0.0313	0.0385	0.0447	0.0492	0.0512	0.0399
N	789	595	1038	901	928	818	572	1008

p-values (robust) in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
[a] z-score of the variable was used.

significant in France, Germany, and Sweden. For example, in France, one additional year of building age raises the retrofit rate by about 3.6% points for the average homeowner household. Arguably, newer dwellings have lower retrofit needs, because they are already equipped with good insulation and windows.

3.2.2. Results for adopting appliances

Table 3 presents the estimation results for the regressions modelling the adoption of appliances. In general, the findings for the quartile dummies suggest that the tendency for households to adopt an energy efficient appliance is lower for households belonging to Q1 compared to households belonging to Q4. The coefficient associated with *DQ1* is statistically significant in all countries but Romania, where the coefficient is just shy of being statistically significant at conventional levels. Similarly, households in Q2 are found to exhibit a lower propensity to adopt energy-efficient appliances than households in Q4. This finding is statistically significant in half of the countries in the sample. In comparison, the coefficient associated with *DQ3* is negative in most countries, but statistically significant for France only.

Age tends to be positively correlated with the stated take up of energy efficient appliances. Likewise, higher *Energycosts* and higher *Env_ID* render adoption of energy efficient appliances more likely, and almost all the related coefficients are statistically significant. Households living in detached houses tend to be more likely to have adopted energy efficient appliances. The coefficient linked with *Detached* is statistically significant for three countries (France, Romania and Sweden). In comparison, with the exception of France, building age does not appear to be related with energy-efficient appliance adoption.

3.2.3. Results for purchasing LEDs

The econometric results for LED adoption appear in Table 4 Similar to the findings for retrofit measures and appliance adoption, households in

Table 3
Probit model results (average marginal effects) for adopting energy efficient appliances.

	FR	DE	IT	PL	RO	ES	SE	UK
DQ1	**− 0.0759**[**]	**− 0.1119**[***]	**− 0.0594**[**]	**− 0.0938**[**]	− 0.0578	**− 0.0608**[*]	**− 0.1058**[*]	**− 0.0645**[*]
	(0.041)	(0.001)	(0.020)	(0.030)	(0.141)	(0.058)	(0.055)	(0.086)
DQ2	− 0.0551	**− 0.0541**[*]	**− 0.0577**[*]	− 0.0496	− 0.0131	− 0.0458	**− 0.1327**[**]	**− 0.0644**[*]
	(0.198)	(0.079)	(0.062)	(0.193)	(0.725)	(0.225)	(0.013)	(0.078)
DQ3	**− 0.0701**[*]	− 0.0028	− 0.0537	0.0442	0.0020	0.02499	− 0.0257	− 0.0079
	(0.082)	(0.934)	(0.158)	(0.287)	(0.957)	(0.530)	(0.617)	(0.838)
Age	0.0007	**0.0016**[**]	0.0004	− 0.0010	0.0002	0.0012	**0.0024**[*]	**0.0023**[***]
	(0.421)	(0.022)	(0.546)	(0.373)	(0.874)	(0.163)	(0.058)	(0.008)
Energycosts[a]	**0.1708**[***]	**0.1104**[***]	**0.0842**[***]	**0.0736**[***]	**0.0461**[***]	**0.1141**[***]	**0.1110**[***]	**0.1205**[***]
	(0.000)	(0.000)	(0.010)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Env_ID[a]	**0.0534**[***]	0.0165	**0.0238**[***]	**0.0597**[***]	**0.0407**[***]	0.0179	0.0273	**0.0337**[***]
	(0.000)	(0.141)	(0.010)	(0.000)	(0.000)	(0.155)	(0.104)	(0.004)
Detached	**0.0554**[**]	− 0.0335	− 0.0107	0.0100	**0.0418**[**]	0.0324	**0.0887**[**]	0.0039
	(0.027)	(0.104)	(0.523)	(0.692)	(0.045)	(0.167)	(0.013)	(0.883)
Buildage	**0.0123**[***]	− 0.0007	0.0009	0.0062	− 0.0001	0.0080	− 0.0024	− 0.0053
	(0.009)	(0.861)	(0.805)	(0.249)	(0.987)	(0.146)	(0.774)	(0.273)
Pseudo R^2 (McFadden)	0.1322	0.1866	0.1419	0.0833	0.0634	0.1219	0.1037	0.1309
N	1320	1221	1335	1151	1127	1228	695	1269

p-values (robust) in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
[a] z-score of the variable was used.

Table 4
Probit model results (average marginal effects) for purchasing LEDs.

	FR	DE	IT	PL	RO	ES	SE	UK
DQ1	**− 0.1409*****	**− 0.1208*****	**− 0.1066*****	**− 0.0839***	**− 0.1276*****	**− 0.1175*****	**− 0.1469*****	**− 0.1559*****
	(0.000)	(0.003)	(0.002)	(0.059)	(0.000)	(0.002)	(0.001)	(0.000)
DQ2	**− 0.0835****	− 0.0452	− 0.0293	− 0.0310	**− 0.0804****	− 0.0182	**− 0.0886****	**− 0.0954*****
	(0.036)	(0.260)	(0.444)	(0.455)	(0.019)	(0.661)	(0.035)	(0.006)
DQ3	− 0.0564	0.0166	− 0.0100	− 0.0171	− 0.0142	− 0.0516	− 0.0478	**− 0.0711***
	(0.152)	(0.708)	(0.829)	(0.716)	(0.694)	(0.276)	(0.276)	(0.055)
Age	**− 0.0018***	**− 0.0018***	− 0.0015	**− 0.0029****	0.0004	− 0.0010	**− 0.0029****	0.0008
	(0.066)	(0.095)	(0.147)	(0.014)	(0.738)	(0.355)	(0.010)	(0.421)
Energycosts[a]	**0.1213*****	**0.1442*****	**0.0947*****	**0.1319*****	**0.1028*****	**0.1475*****	**0.0921*****	**0.0795*****
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Env_ID[a]	0.0150	− 0.0014	− 0.0029	0.0144	0.0026	− 0.0150	0.0049	− 0.0215
	(0.338)	(0.926)	(0.853)	(0.351)	(0.847)	(0.319)	(0.742)	(0.100)
Detached	**0.0836*****	0.0086	0.0405	− 0.0316	0.0056	0.0005	**0.0922*****	0.0297
	(0.002)	(0.769)	(0.155)	(0.267)	(0.816)	(0.985)	(0.005)	(0.337)
Buildage	0.0061	0.0071	0.0098	**0.0159*****	**0.0118***	**0.0178*****	0.0118	**0.0105***
	(0.241)	(0.245)	(0.117)	(0.009)	(0.092)	(0.008)	(0.101)	(0.051)
Pseudo R^2 (McFadden)	0.0604	0.0717	0.0253	0.0618	0.0720	0.0625	0.0562	0.0427
N	1274	1236	1401	1305	1299	1406	989	1279

p-values (robust) in parentheses.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.
[a] z-score of the variable was used.

Q1 are less likely to have purchased an LED as their last light bulb than households in Q4. The coefficient associated with *DQ1* is statistically significant in all countries. For France, Romania, Sweden and the United Kingdom, households in Q2 are found to exhibit a statistically significant lower tendency to have purchased an LED compared to households in Q4. In comparison, and similar to the findings for appliances, the coefficient associated with *DQ3* is negative in most countries, but statistically significant in one country only, i.e. in the United Kingdom.

In contrast to the findings for retrofit measures and appliances, *Age* tends to be negatively linked with the LED purchase. The associated parameter estimate is statistically significant for France, Germany, Poland, and Sweden. As for the adoption of retrofit measures and appliances, *Energycosts* also turns out to be positively related with the adoption of LEDs. The coefficient linked with *Energycosts* is statistically significant in all countries (as was also the case for appliances). Unlike for retrofit and appliances, though, Table 4 provides no evidence that LED adoption is driven by environmental preferences. For two countries, France and Sweden, LED adoption is positively and statistically significantly related with households living in detached rather than non-detached houses. Finally, households residing in younger buildings are generally less likely to have purchased an LED. This finding is statistically significant at conventional levels in four of the eight sample countries, i.e. in Poland, Romania, Spain and the United Kingdom.

To sum up, the empirical findings from econometrically estimating adoption equation for retrofit measures, appliances and light bulbs in eight EU countries provide strong evidence that households in the lowest income quartile are less likely to have adopted EETs than households in the highest income quartile. Thus, while belonging to the lowest income quartile of homeowners appears to impede implementing retrofit measures, a similar finding holds for the population at large when it comes to adopting medium- and low-cost measures such as appliances and light bulbs. These findings from the multivariate analyses therefore corroborate the conclusions drawn from the descriptive statistics. While the results on the role of income for EET adoption are consistent with the existing empirical literature, they also suggest that this relation with income levels is nonlinear.

The findings for the remaining explanatory variables are generally in line with previous findings in the literature. In particular, adoption of EET is higher in households that attach a higher weight to energy costs when investing in energy technologies. Environmental preferences are positively related with the adoption of retrofit measures and energy-efficient appliances. Somewhat surprisingly though, LED adoption was not statistically significantly related to the variable capturing environmental preferences. Thus, for LED adoption, financial rather than environmental motives appear to matter. Finally, the findings for building characteristics, i.e. detached houses and building age, are intuitive.

3.2.4. Results for receiving financial support for retrofit measures

In addition to the income quartile dummies, the set of explanatory variables in the multivariate analyses includes participant *Age*, *Detached* and *Buildage* to control for buildings characteristics, and *Windows* to control for the type of retrofit measure. The dummy variable *Windows* indicates whether the financial support for retrofit measures was received for the installation of windows rather than thermal insulation of building components. Results of estimating a Probit model for homeowner households which stated to have implemented retrofit measures appear in Table 5 for each country.

First of all, the findings for the coefficient of *DQ1* provide no evidence that homeowner households in Q1 are less likely to receive support from the government or utilities than households in Q4. For the United Kingdom, homeowner households falling into Q1 are even found to be more likely to have received financial support for implementing retrofit measures than households in Q4. Thus, for the United Kingdom the multivariate analyses corroborate the findings from descriptive statistics analyses, which find the support programs for retrofit measures to be progressive for these countries. For Italy, *DQ1* is statistically significant at $p < 0.15$, thus providing some weak support for the finding from the descriptive statistics analyses that support programs might be regressive in this country.

In comparison, the results for *DQ2* and *DQ3* for France and Romania suggest that in these countries, homeowner households in Q2 and *Q3* are less likely to have received financial support for implementing retrofit measures than households in Q4. For Sweden, households in Q2 were less likely to have benefited from such support relative to households in Q4.

Interestingly, older homeowners who had implemented a retrofit measure in Spain and Sweden were less likely to have benefitted from financial support than younger homeowners. The results for *Windows* suggest that in about half of the countries retrofit measures related to the installation of windows were more likely to have received financial support than thermal insulation measures. Finally, *Detached* was also statistically significantly correlated with receiving financial support in four countries, but results are mixed. Finally, and somewhat unexpectedly, the coefficient associated with *Buildage* was positive and statistically significant in two countries, Poland and the United Kingdom.

Table 5
Probit model results (average marginal effects) for receiving financial support for retrofit measures.

	FR	DE	IT	PL	RO	ES	SE	UK
DQ1	− 0.0039	− 0.0357	− 0.0748	0.0092	− 0.0154	− 0.0262	− 0.0005	**0.1201***
	(0.915)	(0.518)	(0.148)	(0.876)	(0.663)	(0.562)	(0.990)	(0.056)
DQ2	**− 0.0839****	− 0.0487	− 0.0503	0.0139	**− 0.0586***	− 0.0673	**− 0.0617****	0.0556
	(0.013)	(0.398)	(0.357)	(0.795)	(0.076)	(0.122)	(0.040)	(0.322)
DQ3	**− 0.1151*****	− 0.0564	0.0039	0.0740	**− 0.0804****	0.0820	0.0340	0.0344
	(0.000)	(0.281)	(0.955)	(0.249)	(0.014)	(0.225)	(0.468)	(0.572)
Age	− 0.0017	− 0.0022	− 0.0010	0.0010	− 0.0013	**− 0.0043*****	**− 0.0034*****	0.0002
	(0.111)	(0.193)	(0.525)	(0.473)	(0.265)	(0.002)	(0.008)	(0.871)
Windows	**0.0586****	**0.1524*****	0.0036	**0.1437*****	**0.3263*****	− 0.0183	− 0.0131	0.0598
	(0.046)	(0.008)	(0.931)	(0.001)	(0.000)	(0.670)	(0.753)	(0.462)
Detached	0.0016	**− 0.0957****	**0.1790*****	**− 0.0978*****	− 0.0242	**0.0673***	− 0.0520	− 0.0386
	(0.960)	(0.031)	(0.000)	(0.003)	(0.338)	(0.088)	(0.153)	(0.341)
Buildage	0.0004	− 0.0021	0.0094	**0.0186***	0.0151	− 0.0093	− 0.0026	**0.0249*****
	(0.953)	(0.853)	(0.446)	(0.063)	(0.115)	(0.384)	(0.767)	(0.009)
Pseudo R^2 (McFadden)	0.0573	0.0816	0.0376	0.0467	0.1869	0.0763	0.1330	0.0196
N	506	261	454	575	767	328	235	532

p-values (robust) in parentheses.
† z-score of the variable was used.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

In light of the objective of this paper, the most important result in Table 5 pertains to the (non-)findings for *DQ1*. These imply that the negative effect generally found for *DQ1* in the adoption equation for retrofit measures (in Table 2) are not a consequence of the lowest income quartile receiving less financial support for these measures. In fact, the negative effect of DQ1 in the retrofit adoption equation observed for most countries would most likely have been stronger without the financial support targeting low-income homeowners. Finally, it should be noted that these interpretations implicitly assume that the projects implemented by homeowners falling into different income quartiles are comparable in terms of their eligibility for financial support.

4. Conclusions and policy implications

The academic literature and policy-makers typically link energy poverty to poor energy performance of buildings, yet the empirical evidence on household adoption of EETs or financial support received for EET adoption by income groups appears limited. Similarly, comparisons across countries based on representative samples and on a harmonized methodology are lacking.

Relying on demographically representative household samples in eight EU member states, this paper employs statistical-econometric analyses of household adoption of high-cost (i.e. retrofit), medium-cost (i.e. appliances) and low-cost (i.e. LED) technologies, and of financial support received for implementing retrofit measures, which provide guidance for policy-making.

For retrofit measures implemented by homeowners, the findings for most countries in the sample suggest that homeowners falling into the lowest homeowner income quartile have lower adoption propensities than homeowners falling into the highest income quartile. To support the uptake of retrofit measures, policies could be designed to specifically target “poor homeowners”. That is, low-interest loans or grants for implementing insulation measures could be made more attractive for low-income homeowners than for high-income homeowners.[13] For example, for low-income homeowners, interest rates could be lower, the duration for re-payment of the loan could be longer, or the subsidy could be larger. In addition, countries like France or Italy could turn existing tax credit schemes into premiums to be paid upfront or immediately after the works are finished. This might help households who lack the capital to finance these measures and then wait to receive the tax credits several months later. Also, low-income households are likely to benefit more from direct premiums than income tax exemptions, since tax exemptions are only effective if households actually pay taxes. Since households are normally exempted from paying income taxes if the income is below a certain threshold, tax exemptions may not be an effective measure to speed up EET adoption by low-income households. In addition, tax exemptions tend to have a regressive effect, since the financial benefits depend on a household's marginal tax rate which is typically higher for higher income households. In some countries such as France and the United Kingdom, the energy efficiency obligations (pursuant to Article 7 of the EED) involve direct subsidies for EET adoption, which specifically target retrofit measures in low-income households. Similar schemes could also be introduced in other countries with energy efficiency obligations. Requiring quantifiable targets for the share of energy-efficiency measures to be realized in low-income households may further strengthen the effectiveness of such schemes. Support for low-income homeowners is likely to be particularly effective in lower-income countries with a high share of owner occupiers such as Poland and Romania. In any case, such policy interventions should be subject to cost-benefit analyses.

Analyzing factors related to homeowners receiving financial support from governments or utilities for retrofit measures suggests that differences in implementation rates between the highest and lowest income quartile would likely have been higher without such support schemes in place. For the United Kingdom (but not for other countries) these schemes even appeared to have had a progressive effect.

For all countries, the findings further suggest that differences in adoption propensities across income quartiles not only exist for high-cost EETs like retrofit measures, but also for medium- and low-cost EETs such as appliances and light bulbs. Thus, to accelerate the take up of these technologies, countries' support policies could more strongly target households in the lower income quartiles. For example, in Germany, the “Caritas-Stromsparcheck” program offers advice to about 50000 low-income households per year, installs low-cost EETs (like LEDs or connector strips), and offers premiums of up to 150 EUR for the purchase of a refrigerator rated A+ + +. At a smaller scale, similar programs also exists in some regions in France.[14] Such programs are

[13] Thus, the target group differs from programs which in some countries (e.g. France) provide relief on property taxes or value added taxes, or offer direct subsidies and low-interest loans for low-income social housing organizations for implementing retrofit measures.

[14] The “Caritas-Stromsparcheck” program in Germany and ULISSE in France both recruit unemployed people as energy efficiency trainers.

likely to be even more effective in countries where incomes are generally lower such as Romania and Poland, and other Central and Eastern European post-socialist countries.

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Appendix. :Descriptive statistics

see: Tables A1-A3

Table A1
Descriptive statistics (means and standard deviations) for retrofit implementation.

	FR	DE	IT	PL	RO	ES	SE	UK
Retrofit	0.641	0.439	0.437	0.638	0.827	0.401	0.411	0.528
	(0.480)	(0.497)	(0.496)	(0.481)	(0.379)	(0.490)	(0.492)	(0.499)
DQ1	18.1	29.3	18.1	6.556	3.58	18.1	31.585	23.349
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ2	29.3	38.1	29.3	12.362	6.364	29.3	48.941	49.149
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ3	45.4	52.85	38.1	20.011	12	38.1	65.704	68.176
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ4	88.8	88.8	88.8	60.65	58.874	88.8	95.726	114.552
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	45.636	44.847	44.324	39.660	37.904	44.373	45.212	43.730
	(13.421)	(13.145)	(12.945)	(12.192)	(10.376)	(12.671)	(13.093)	(13.280)
Energycosts[a]	0.038	0.089	0.218	0.190	0.377	− 0.129	− 0.139	− 0.033
	(0.822)	(0.089)	(0.776)	(0.859)	(0.800)	(1.108)	(1.023)	(0.942)
Env_ID[a]	0.195	− 0.044	0.346	0.101	0.181	0.260	− 0.439	− 0.157
	(0.869)	(1.012)	(0.876)	(0.944)	(0.954)	(0.940)	(1.038)	(1.021)
Detached	0.602	0.503	0.329	0.343	0.330	0.307	0.575	0.299
	(0.490)	(0.500)	(0.470)	(0.475)	(0.470)	(0.461)	(0.495)	(0.458)
Buildage	4.075	4.398	4.779	4.764	5.088	5.307	3.983	3.502
	(2.106)	(1.976)	(1.711)	(1.778)	(1.315)	(1.543)	(1.733)	(1.957)
N	789	595	1038	901	928	818	572	1008

[a] z-score of the variable was used.

Table A2
Descriptive statistics (means and standard deviations) for adoption of appliances.

	FR	DE	IT	PL	RO	ES	SE	UK
Appliances	0.622	0.836	0.893	0.757	0.842	0.781	0.642	0.736
	(0.485)	(0.370)	(0.309)	(0.429)	(0.365)	(0.414)	(0.480)	(0.441)
DQ1	18.1	18.1	18.1	6.556	3.58	18.1	19.511	23.349
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ2	29.3	38.1	29.3	12.362	6.364	29.3	41.071	49.149
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ3	45.4	52.85	38.1	20.011	12	38.1	65.704	68.176
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ4	88.8	88.8	88.8	60.65	58.874	88.8	95.726	114.552
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	42.020	42.668	43.033	38.831	36.394	42.056	42.378	41.942
	(13.439)	(13.064)	(12.536)	(11.822)	(10.060)	(12.302)	(13.736)	(13.311)
Energycosts[a]	0.041	0.123	0.376	− 0.035	− 0.013	− 0.099	− 0.504	− 0.380
	(0.921)	(0.964)	(0.788)	(1.022)	(1.033)	(1.011)	(1.129)	(1.076)
Env_ID[a]	0.117	− 0.098	0.351	0.103	0.187	0.210	− 0.444	− 0.130
	(0.926)	(0.972)	(0.876)	(0.953)	(0.954)	(0.960)	(1.090)	(1.044)
Detached	0.523	0.350	0.333	0.353	0.402	0.299	0.479	0.266
	(0.500)	(0.477)	(0.471)	(0.478)	(0.491)	(0.458)	(0.500)	(0.442)
Buildage	5.280	4.842	5.444	5.564	5.574	6.209	4.518	4.178
	(2.584)	(2.314)	(2.107)	(2.263)	(1.729)	(1.962)	(2.164)	(2.370)
N	1320	1221	1335	1151	1127	1228	695	1269

[a] z-score of the variable was used.

Table A3
Descriptive statistics (means and standard deviations) for LED adoption.

	FR	DE	IT	PL	RO	ES	SE	UK
Retrofit	0.383	0.502	0.421	0.503	0.252	0.514	0.367	0.326
	(0.486)	(0.500)	(0.494)	(0.500)	(0.434)	(0.500)	(0.482)	(0.469)
DQ1	18.1	18.1	18.1	6.556	3.58	18.1	19.511	23.349
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ2	29.3	38.1	29.3	12.362	6.364	29.3	41.071	49.149
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ3	45.4	52.85	38.1	20.011	12	38.1	65.704	68.176
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
DQ4	88.8	88.8	88.8	60.65	58.874	88.8	95.726	114.552
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Age	42.792	42.964	43.360	38.948	36.645	42.037	43.076	42.181
	(13.317)	(13.096)	(12.515)	(11.809)	(10.187)	(12.276)	(13.445)	(13.182)
Energycosts[a]	0.029	0.010	0.369	0.197	0.042	0.071	− 0.450	− 0.268
	(0.879)	(1.002)	(0.774)	(0.967)	(1.106)	(0.931)	(1.082)	(1.127)
Env_ID[a]	0.146	− 0.081	0.384	0.101	0.170	0.224	− 0.435	− 0.146
	(0.897)	(0.964)	(0.866)	(0.958)	(0.952)	(0.951)	(1.067)	(1.073)
Detached	0.506	0.341	0.312	0.335	0.377	0.282	0.383	0.259
	(0.500)	(0.474)	(0.463)	(0.472)	(0.485)	(0.450)	(0.486)	(0.438)
Buildage	5.207	4.739	5.403	5.596	5.557	6.227	4.492	4.219
	(2.576)	(2.279)	(2.110)	(2.241)	(1.712)	(1.923)	(2.110)	(2.441)
N	1274	1236	1401	1305	1299	1406	989	1279

[a] z-score of the variable was used.

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