The Economic and Social Review, Vol. 49, No. 2, Summer 2018, pp. 145-172

Householder Preferences for the Design of an Energy Efficiency Retrofit Subsidy in Ireland

Matthew Collins
Economic and Social Research Institute and
Sustainable Energy Authority of Ireland

Seraphim Dempsey
Economic and Social Research Institute

John Curtis[1]
Economic and Social Research Institute and Trinity College Dublin

Abstract: Improving the energy efficiency of residential dwellings generates private benefits to homeowners, including lower energy costs, health benefits, and improved property values, as well as positive externalities associated with reductions in greenhouse gas emissions. Underinvestment in residential energy efficiency has been attributed to market failures and behavioural issues, which provides a basis for public policy intervention in provision of energy efficiency. This paper examines households' preferences for design features of energy efficiency retrofit subsidies and how these preferences vary across the usual respondent attributes. Based on a survey of Irish homeowners we find that cash payment subsidies are strongly preferred compared to other indirect methods of financial support such as tax credits, roughly by a 70:30 ratio. There are two notable areas where preferences differ by respondent attributes; age and whether respondents have previously availed of an energy efficiency retrofit grant. The preferences of older age cohorts differ compared to younger respondents across all the subsidy schemes examined, whereas people who have previously availed of retrofit grants are more likely to favour ex-post cash payments compared to upfront discounts.

Acknowledgements: This research has been financially supported by the Sustainable Energy Authority of Ireland and the ESRI's Energy Policy Research Centre. We would like to thank SEAI for access to their survey data and to two anonymous referees whose useful suggestions have helped us improve the paper.

[1] Corresponding author: John.curtis@esri.ie.

I INTRODUCTION

The residential sector is the third largest energy consuming sector in the EU, accounting for 24.8 per cent of final consumption (Eurostat, 2016). Space and water heating comprise 67 per cent and 14 per cent of residential energy use respectively (European Commission, 2011b). As a result, improving the energy efficiency of residential buildings provides an opportunity for policy to reduce a nation's carbon footprint and for households to save money on their energy bills and improve the comfort of their homes. This is particularly important given the European Union mandate to reduce energy use by 2020 (European Parliament and the Council of the European Union, 2012), and the Paris Agreement's emphasis on the need to reach peak greenhouse gas emissions as soon as possible as a means of helping to achieve the limitation of global warming below 2°C (United Nations, 2015).

There is extensive evidence that there are positive private net benefits from residential energy retrofits (e.g. Cajias and Piazolo, 2013; Galvin, 2010; Suter and Shammin, 2013), as well as for property developers building new energy efficient properties (e.g. Deng *et al*., 2012). There are also positive externalities from energy efficiency retrofits both associated with reductions in greenhouse gas emissions and wider economic benefits in terms of jobs and competitiveness at sector, national and international levels (European Commission, 2011a; Figus *et al*., 2017; Ryan and Campbell, 2012). However, the positive returns to households are not guaranteed, nor are investment decisions always driven by rational economic logic, as many households are willing to invest in retrofit measures despite unfavourable payback periods and investment returns (Collins and Curtis, 2017b; Havas *et al*., 2015). Also, new-build, energy-efficient properties are not always economically efficient (e.g. Deng and Wu, 2014). Due to the positive externalities, as well as positive net costs of some retrofit measures, there is a case for government intervention subsidising energy efficiency retrofits in the residential sector. Kerr *et al*. (2017) examine the rationale for energy efficiency policy across several countries, including Ireland, and find striking differences between the recognition of benefits and ensuing policy rationale across countries, which are due to a complex mix of political, social and economic influences. Examples of subsidy measures include the UK's recently concluded *Green Deal* financing scheme, France's *Crédit d'Impôt Développement Durable* (CIDD), Germany's *KfW-Effizienzhaus* financing scheme, and Ireland's Better Energy Homes scheme. In general, energy efficiency support schemes are intended to encourage private investment but do not cover the full cost. For example, the value of the subsidy in the Better Energy Homes scheme in Ireland is approximately 35 per cent of the cost of certain energy efficiency retrofit measures (Collins and Curtis, 2017b).

Energy efficiency retrofits result in substantial private gains to the household in the form of lower energy bills, increased comfort and environmental improvements (Aravena *et al*., 2016; Clinch and Healy, 2001; Gillingham *et al*.,

2009), alongside improved health outcomes (Curl *et al*., 2015; Maidment *et al*., 2014) and improved property values (Brounen and Kok, 2011; Hyland *et al*., 2013; Fuerst *et al*., 2015). The design of public subsidy schemes, both in energy efficiency retrofits and elsewhere, are known to affect participation and outcomes (Bird and Hernandez, 2012; Hoicka *et al*., 2014). A policy concern is whether public funds, through energy efficiency retrofit subsidies, lead to distributional inequalities across socio-demographic groups. This paper examines the design of energy efficiency subsidy schemes from a different perspective, that of the household. The research question is to identify households' preferences for design features of energy efficiency retrofit subsidies. By modelling household preferences, this paper identifies the variation in preferences for different design structures of energy efficiency retrofit subsidies and how these preferences vary across the usual socio-demographic characteristics.

The empirical analysis is based on households from Ireland where the residential energy efficiency retrofit subsidy is designed as an ex-post cash payment. Households finance the entire cost of the retrofit works and the subsidy is paid after all supporting documentation has been satisfactorily processed. The analysis considers preferences for a number of other subsidy mechanisms. We find that relative to the status quo, there is strong support for an ex-ante cash subsidy, while several indirect subsidy supports – such as tax credits – are less favourable to respondents, though preferences vary by respondents attributes.

The remainder of the paper is outlined as follows. The next section describes the main residential energy efficiency support scheme in Ireland and provides some comparisons with similar schemes elsewhere in Europe. Section II provides a discussion of literature in the area. Section III describes the data and Section IV outlines the methodological approach, while Section V outlines and discusses the results, before Section VI concludes.

II BACKGROUND

In Ireland the Sustainable Energy Authority of Ireland (SEAI) administers the Better Energy Homes (BEH) grant scheme for energy efficiency retrofits of residential properties. The scheme originated as the Home Energy Savings scheme in March 2009. Grants are available for roof/attic insulation, one of three types of wall insulation (cavity insulation, external wall insulation or internal dry-lining), three types of heating system upgrade (oil or gas boiler with heating controls upgrade or heating controls upgrade only) and solar collector (panel or tube) installation. This means that a household may adopt up to a maximum of four measures, as only one type of wall insulation or heating system upgrade may be awarded grant aid. Upgrades must meet SEAI standards for grant applications to be successful. The level of grant aid available has changed over time, as outlined in Table 1. The level

Table 1: Grant Structure

Measure	*Category*	*Scheme 1 Mar-09 €*	*Scheme 2 Jun-10 €*	*Scheme 3 May-11 €*	*Scheme 4 Dec-11 €*	*Scheme 5 Mar-15 €*
Roof	Attic Insulation	250	250	200	200	300
Wall	Cavity Wall Insulation	400	400	320	250	300
	Internal Dry-Lining	2,500	2,500	2,000	.	.
	Apartment or Mid-terrace House	.	.	.	900	1,200
	Semi-detached or End of Terrace	.	.	.	1,350	1,800
	Detached House	.	.	.	1,800	2,400
	External Wall Insulation	4,000	4,000	4,000	.	.
	Apartment or Mid-terrace House	.	.	.	1,800	2,250
	Semi-detached or End of Terrace	.	.	.	2,700	3,400
	Detached House	.	.	.	3,600	4,500
Heating System	High efficiency boiler (oil or gas) upgrade with heating controls	700	700	560	560	700
	Heating Controls upgrade only	500	500	400	400	600
	Solar Heating	.	.	800	800	1,200
BER	Before and After Building Energy Rating	100	.	.	.	.
	After Works Building Energy Rating	.	100	80	50	50
Bonus	Bonus for 3rd measure	.	.	.	.	300
	Bonus for 4th measure	.	.	.	.	100

Source: Source SEAI.

of the subsidy support in Ireland is approximately 35 per cent of the cost of eligible measures (Collins and Curtis, 2017b), which is relatively high compared to elsewhere in Europe. In France tax credit rates for energy efficiency improvements vary between 10-15 per cent of eligible costs; in Italy income tax credit is 55 per cent though distributed over ten years, whereas in Germany the grants are between 10-20 per cent of eligible costs depending on the efficiency level reached (Hilke and Ryan, 2012). In 2008, prior to the establishment of the BEH scheme, Ireland was sixteenth highest in the EU in its rate of energy efficiency improvement compared to the year 2000 at 14.2 per cent, similar to the EU average of 15.2 per cent.[2] By 2015 Ireland had reached third highest in the EU at 37.3 per cent compared to an EU average of 27.3 per cent. This improvement is partly attributable to the BEH scheme, which by October 2015 had applications from over 160,000 homes or approximately 12 per cent of qualifying household stock (Collins and Curtis, 2016).

III RELEVANT LITERATURE

There is long standing recognition that there is a gap between actual and optimal provision of energy efficiency (e.g. Brown, 2001; Hirst and Brown, 1990; Jaffe and Stavins, 1994b). Optimal provision also varies depending on whether the perspective is economic, technological, hypothetical, or social (Jaffe and Stavins, 1994a). Allcott and Greenstone (2012) suggest that policy debate around the energy efficiency gap often combines two types of market failures: energy use externalities and investment inefficiencies. Energy use externalities primarily comprise harm to human health and damages due to climate change associated with the consumption of fossil fuels. Investment inefficiencies are factors such as imperfect information that cause businesses and households not to undertake investment in energy efficiency from which they could be net beneficiaries. Pigouvian taxes are one approach to internalise environmental externalities and drive consumption to socially optimum levels. Policies to address investment inefficiencies (e.g. provide information to ill-informed consumers) are not always effective and in that instance Allcott and Greenstone (2012) suggest that policies that subsidise or mandate energy efficiency can be welfare enhancing. While recognising that further empirical research is required to understand the nature and extent of the energy efficiency gap, they conclude that the magnitude of the energy efficiency gap is small relative to the assessments from engineering analyses. In a recent literature review, Gerarden *et al*. (2017) examine the issue of the energy efficiency gap around four questions. First, are product offerings and pricing economically efficient? On which they find the empirical evidence is quite limited. Second, are energy

[2] See Key Indicators: Energy Efficiency Gains at http://www.odyssee-mure.eu.

operating costs inefficiently priced and/or understood? They conclude that there may be differences between private and socially optimal diffusion rates for energy saving technologies and consequently that there may be a social energy efficiency gap even if a private gap does not exist. Third, are product choices cost minimising in present value terms? The empirical evidence varies substantially and they find that various market failures and/or behavioural phenomena inhibit cost minimisation. Fourth, do other costs inhibit more energy-efficient decisions? They find that they do and conclude that some difficult to quantify costs are often omitted, for example, citing analysis on the basis of energy efficiency cost curves (Granade *et al*., 2009; Huntington, 2011). Overall, Gerarden *et al*. (2017) conclude that the apparent underinvestment in energy efficiency is due to market failures, behavioural issues, as well as modelling errors, which provides a basis for public policy intervention in provision of energy efficiency.

Among the 29 member countries of the International Energy Agency (IEA) all have at least one economic instrument in place to support energy efficiency in buildings but relatively little effort has been directed toward evaluating how well economic instruments work in achieving their goals (Hilke and Ryan, 2012). Monitoring and evaluation are key to understanding the effectiveness and efficiency of economic instruments, and to making necessary adjustments to improve their impact. Markandya *et al*. (2015) provide a discussion of the types of policy measures which can be used to foster energy efficiency, dividing them into three areas: 'command-and-control' policies mandating minimum levels of energy performance, 'price instruments' encouraging certain decisions through indirect changes to prices, e.g. through taxes or subsidies, and 'information instruments' aiming to redress information asymmetry within the market. This paper is concerned with price instruments, which often turn out to be a high-cost approach for achieving energy efficiency (Jaffe *et al*., 2004; Markandya *et al*., 2015). Evaluations of price instrument policies have also found them to be regressive, leading to distributional inequity and reducing welfare (e.g. Borenstein and Davis, 2016; Distante *et al*., 2016; Neveu and Sherlock, 2016) but such outcomes are usually attributable to policy design. Though the current paper considers energy efficiency price instruments, the focus is not an evaluation of economic efficiency; rather it examines households' stated preferences for different instrument design elements.

With fuel poverty closely linked to socio-economic circumstances and housing quality (Belaïd, 2018; Bouzarovski, 2014), preferences over the structure of economic instruments supporting energy efficiency upgrades are also likely to differ by socio-economic cohort. The inability to co-finance retrofit measures is also likely to affect preferences for instrument design. In an assessment of fuel poverty in Ireland, Healy and Clinch (2004) find that almost one-third of respondents in energy inefficient properties reported an inability to pay for energy efficiency retrofit measures. Camprubí *et al*., (2016) suggest that unless supports are free, vulnerable

groups may be deterred from participating. Additionally, they suggest that support schemes based on loans, tax incentives and long-term return periods are less accessible or less economically advantageous for low-income groups thus reducing their likelihood of participation. Studies across a number of countries have examined various aspects of participation in existing energy efficiency support schemes (e.g. Collins and Curtis, 2017a; Neuhoff *et al*., 2012; Hilke and Ryan, 2012) but there has been substantially less research related to the schemes themselves and their design. Some exceptions include Gilbertson *et al*. (2006) who consider households' views with respect to the retrofit installation process and perceived benefits on health and wellbeing, and Sovacool (2015) who examine households' satisfaction with and challenges of an energy efficiency support scheme.

IV DATA

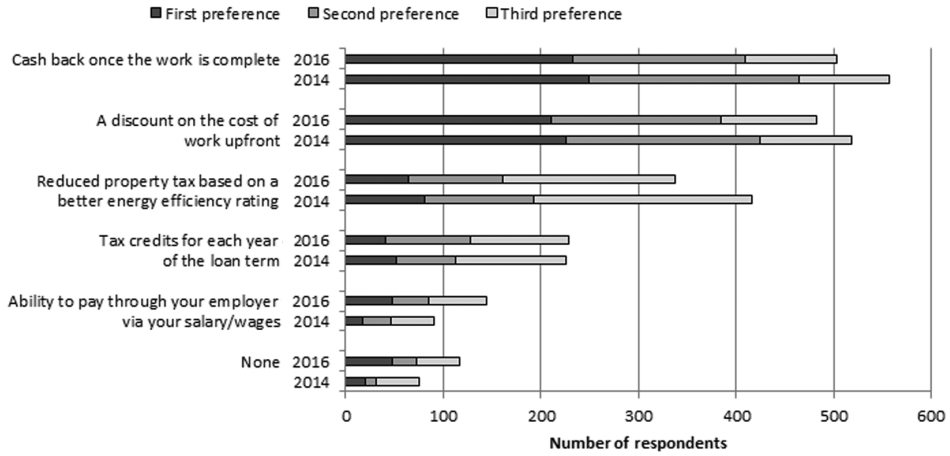
To explore preferences for certain forms of subsidies we analyse stated preference data provided by SEAI from cross-sectional surveys of homeowners in Ireland. The surveys were undertaken by a professional survey company on behalf of SEAI on two occasions in December 2014 and December 2016. Identical methodologies and questionnaires were used in the two surveys. Nationally representative face-to-face surveys were conducted in respondents' own homes using a CAPI (computer aided personal interviewing) approach. The samples were quota controlled in terms of region, socio-economic status and owning a house (i.e. no renters or apartment owners were interviewed). Only persons with responsibility, including joint responsibility, for making decisions about energy usage and energy improvements in the home were interviewed. In total 659 and 650 respondents were interviewed in 2014 and 2016 respectively. Some observations were precluded from the analysis due to item non-responses to questions critical to the analysis undertaken here, leading to a total sample for analysis of 1,290 respondents.

The survey was primarily about energy efficiency and retrofitting residential properties, whereas the analysis in this paper focuses on stated preferences toward the structure of financial incentives for homeowners to undertake energy efficiency retrofit works. Respondents were verbally provided with the following question and set of response choices, with surveyors asking respondents for their first, second and third preferences:

> "Different incentive options may be considered to encourage investment in energy efficiency measures. For example if you undertook to complete attic insulation or another measure you might receive a financial incentive in one of the following forms. Which of these would you prefer?

1. Reduced property tax based on a better energy efficiency rating
2. Tax credits for each year of the loan term
3. Cash back once the work is complete
4. Ability to pay through your employer via your salary/wages (along the lines of the bike to work scheme[3] where you save on the purchase price with tax relief
5. A discount on the cost of work upfront
6. None."

Figure 1: Ranking of Preferences for Suggested Incentive Structures



The order of preferences for each survey is presented in Figure 1. The total number of preferences varies as some respondents did not express a second and/or third preference. As can be seen, a similar pattern in preferences can be seen in both surveys, with the order of the popularity of preferences remaining the same. Cash back once the work is complete is expressed most often as the most preferred form of financial incentive. This is followed closely by an upfront discount on the cost of work. This is perhaps surprising as, although both options are quite similar, the former requires a larger degree of liquidity in order to first cover total costs, relative to the liquidity required to cover a partial cost. Reduced property tax is the third-most popular choice, followed by tax credits for each year of a loan term and, finally, the ability to make repayments through an employer is the least popular choice. Across the two-year samples the order of popularity of each choice is the same.

[3] This scheme entails a salary sacrifice arrangement to save up to 51 per cent of the retail price of a bicycle and safety equipment, worth up to €1,000. See https://www.biketowork.ie.

Table 2: Descriptive Statistics

	2014			2016			2016 Census
	Obs.	*Prop.*	*Std. Dev.*	*Obs.*	*Prop.*	*Std. Dev.*	*Prop.*
Reduced property tax based on a better energy efficiency rating	81	0.13	1.43	64	0.10	1.43	
Tax credits for each year of the loan term	52	0.08	1.43	41	0.06	1.43	
Cash back once the work is complete	249	0.39	1.43	233	0.36	1.43	
Ability to pay through your employer via your salary/wages	17	0.03	1.43	48	0.07	1.43	
A discount on the cost of work upfront	226	0.35	1.43	211	0.33	1.43	
None	20	0.03	1.43	48	0.07	1.43	
Gender*							
Male	304	0.47	0.5	311	0.48	0.50	0.49
Female	341	0.53	0.5	334	0.52	0.50	0.51
Age*							
18 – 35	140	0.22	1.38	89	0.14	1.34	0.32
36 – 45	157	0.24	1.38	163	0.25	1.34	0.21
46 – 55	137	0.21	1.38	134	0.21	1.34	0.17
56 – 65	103	0.16	1.38	129	0.20	1.34	0.13
65+	108	0.17	1.38	130	0.20	1.34	0.18
Location*							
Urban	380	0.59	0.49	391	0.61	0.49	0.56
Rural	265	0.41	0.49	254	0.39	0.49	0.44

Table 2: Descriptive Statistics (contd.)

	2014			2016			2016 Census
	Obs.	*Prop.*	*Std. Dev.*	*Obs.*	*Prop.*	*Std. Dev.*	*Prop.*
Social Class							
AB – Employers, managers' and higher professionals	98	0.15	0.64	92	0.14	0.62	0.09
C – Lower professionals	370	0.57	0.64	385	0.60	0.62	0.35
DEF – Non-manual, manual skilled, semi-skilled and farmers	177	0.27	0.64	168	0.26	0.62	0.56
Ownership							
Own outright	224	0.35	0.48	269	0.42	0.49	0.53
Own with mortgage	421	0.65	0.48	376	0.58	0.49	0.47
Property Type							
Detached	299	0.46	0.72	260	0.40	0.72	0.56
Semi-detached	248	0.38	0.72	279	0.43	0.72	0.29
Terraced	98	0.15	0.72	106	0.16	0.72	0.16
Availed of current grant in the past							
No	544	0.84	0.36	547	0.85	0.36	
Yes	101	0.16	0.36	98	0.15	0.36	
Total Observations	645			645			

Source: Source Authors' calculations.

Notes: *Census statistics refer to proportions of total adult population in all tenure types. Census statistics relate to population of adults while the surveys count one adult per property

Other information collected about respondents includes socio-demographic characteristics, property type, ownership, location and whether they have availed of a grant for retrofitting in the past. Socio-demographic information comprises gender, age category and social class. As discussed in Section III, preferences may vary due to variation in impacts of policies across these characteristics. Social class is categorised according to the Central Statistics Office socio-economic groupings, where 'A' comprises "Employers and managers'', 'B' is described as "Higher professional'' and 'C' as "Lower professional''. 'D' is described as "Non-manual'', 'E' as "Manual skilled'' and 'F' as "semi-skilled'' and in this case also includes Farmers. Property type is divided into detached, semi-detached and terraced houses, while location is divided between urban and rural dwellings. These characteristics may affect preferences as property values may affect preferences for incentives related to property tax. Ownership is categorised as those who own their homes with a mortgage and those who own their homes outright and may affect preferences due to the ability and/or appetite to take on credit. Descriptive statistics for the two surveys are presented in Table 2. Across most of the variables the two survey samples are quite similar, though there are proportionately more 18-35 year olds in the 2014 survey and proportionately more aged 56 and above in the 2016 sample, which in turn potentially explains the slight differences between samples relating to property tenure. Ex-post cash payment, which is the status quo, is the most popular option across the surveys, followed closely by 'a discount on the cost of the work upfront'. The primary difference in these two subsidy schemes is that the subsidy is paid in one before the retrofit work commences and in the other after completion of the retrofit. The other subsidy scheme options are substantially less popular.

V METHODOLOGY

This research concerns the identification of homeowners' preferences toward different structures of financial incentive to retrofit. We use a multiple regression framework to gain an understanding of how preferences vary across characteristics of the population. The dependent variable in the analysis is the stated first preference for a specific structure of financial support from the six options discussed in Section IV. We use a multinomial logit as our regression model, similar to a number of papers modelling choice of space heating (Braun, 2010; Couture *et al*., 2012; Michelsen and Madlener, 2012).

The multinomial logit model estimates the probability that a respondent will choose one of the six alternative incentive structures in the survey. The multinomial logit model assumes that errors are independently and identically distributed according to the type I extreme value distribution, commonly referred to as the Gumbel distribution. In the case of the multinomial logit, the probability that homeowner i chooses option j ($j = 1,2,...,J$) is specified as follows:

$$P(IS_j) = P_{i,j} = \frac{\exp(\beta_j x_i)}{1 + \Sigma_{k=1}^{J} \exp(\beta_k x_i)} \quad (1)$$

where IS_j represents incentive structure j and $P_{i,j}$ the choice probability. The vector x_i represents the characteristics of respondent i, while β represents the vector of estimated coefficients. To interpret the results of the analysis, relative risk ratios are calculated. Relative risk ratios are calculated as the exponent of the coefficient and represent the relative probability of an outcome, relative to the base outcome, corresponding to a unit change in the predictor, holding all else constant.)

In a multinomial logit model the ratio of two probabilities, for example $(P_{i,j=1})/(P_{i,j=2})$, is assumed not to depend on any alternatives other than $j = 1$ and $j = 2$, irrespective of the other alternatives available. As such, the model assumes what is termed independence from irrelevant alternatives (IIA). McFadden (1973) advises that multinomial logit models "should be limited to situations where the alternatives can plausibly be assumed to be distinct and weighed independently in the eyes of each decision maker". For our empirical application it is not unreasonable to assume that households possess a clear distinction in preferences between potential structures of financial incentives for retrofitting measures.

A further methodological issue relates to the nature of the data collection. The two surveys had identical questionnaires and followed the same sampling approach but the surveys were administered two years apart. Pooling the survey responses assumes that underlying preferences are consistent and stable, which has been an issue of concern in the environmental valuation literature (Brouwer, 2006; Brouwer *et al*., 2017; Whitehead and Hoban, 1999). However, a broad range of test-retest studies finds that underlying preference parameters in the estimated random utility models appear to be stable over a time period up to at least two years (Bateman *et al*., 1995; Brouwer *et al*., 2017). The analysis here initially considers the two surveys separately before deciding whether it is reasonable to pool the samples.

VI RESULTS AND DISCUSSION

The model estimates for the years 2014 and 2016 are presented in Tables 3 and 4. The parameter estimates are presented as relative risk ratios to facilitate interpretation. Relative risk ratios are calculated as the exponent of the coefficient $e^{\beta j}$, and represent the probability of an outcome relative to the base outcome (i.e. an ex-post cash payment), corresponding to a unit change in the predictor, holding all else constant. Examining the estimates across the two survey years we can see that there are broad similarities, but also substantial differences between the estimates. The largest differences in the multinomial parameters occur in the coefficients on the age and social class variables, as well as whether the respondent previously availed of a grant in the case of the no subsidy option (i.e. 'None').

When comparing the relative risk ratios across the two tables in many instances the ratio is greater than 1 in one year and less than 1 in the other. It would be convenient to pool the samples for the discussion but there are sufficient differences across the estimates that make it more appropriate to consider them separately.

As the econometric model is comprised solely of categorical independent variables, the estimated constants reflect the preferences of those in our reference categories. In this case, the reference category is comprised of males in the '18-35' age category, those living in detached houses in urban areas who own their house outright, those in the 'AB' social class and who have not availed of a grant for retrofitting works in the past. We know from Table 2 that the two almost equally popular subsidy scheme structures are the baseline or status quo category of an ex-post cash payment and an ex-ante discount, i.e. up-front cash payment. This is reflected in the relative risk ratios (RRR) associated with the constant, where in both samples the RRR value is close to unity. For the reference category the upfront discount was 1.21 times more likely to be selected in 2016 compared to the status quo, versus 1.013 times compared to the status quo in 2014, and neither are statistically different from 1. The other subsidy schemes are significantly less likely to be selected versus the status quo. The RRRs across the other variables indicate how preferences toward the structure of the subsidy vary by household attributes.

6.1 Socio-demographic Attributes

Comparing females to males, they are more likely to select an upfront discount scheme compared to the status quo in 2014, and similarly for the no subsidy support (i.e. 'None'). In 2016 their stated preferences are the opposite, being less likely than males to prefer such subsidy schemes. However, in neither sample year are the estimates significantly different from 1, so females' preferences are not significantly different from males. Only in the 2016 sample and for just two subsidy schemes, 'reduced property tax' and 'via employer' are female preferences different from males.

There is no significant difference in preferences across age cohorts with only a few exceptions and primarily in the 2014 sample. Those in the older age cohorts, '56-65' and '65+', are significantly less likely to prefer incentive structures involving tax credits or making repayments through an employer, relative to the '18-35' cohort. This likely reflects the fact that members of this age cohort are more likely to be out of the workforce due to retirement and therefore unable to avail of the scheme. Across both sample years people in older age cohorts are substantially more likely to state a preference in favour of the 'None' option, though the estimates are not significantly different from 1.

6.2 Tenure and Retrofitting Attributes

With one exception there is no statistical difference in preferences across the subsidy scheme depending on whether respondents had a mortgage on their

Table 3: Homeowners' Likelihood of Possessing a Preference for Incentive Structures 2014, Reported Using Relative Risk Ratios
Base category = Status quo ("Cash back once work is complete")

	"Reduced property tax based on a better energy efficiency rating"	*"Tax credits for each year of the loan term"*	*"Ability to pay through your employer via your salary/wages"*	*"A discount on the cost of work upfront"*	*"None"*
Constant	0.531	0.505	0.146***	1.013	0.0537***
	(0.309)	(0.336)	(0.157)	(0.444)	(0.0568)
Gender (ref = Male)					
Female	0.749	0.935	0.662	1.257	1.735
	(0.196)	(0.289)	(0.346)	(0.239)	(0.905)
Age (ref = 18 – 35)					
36 – 45	1.289	1.350	2.854	1.329	0.689
	(0.498)	(0.557)	(1.772)	(0.375)	(0.643)
46 – 55	1.122	0.908	0.897	1.090	1.581
	(0.446)	(0.406)	(0.679)	(0.323)	(1.365)
56 – 65	1.217	0.414**	$8.74e^{-07}$***	0.787	1.653
	(0.545)	(0.231)	($5.26e^{-07}$)	(0.271)	(1.457)
65 +	0.796	0.071***	$9.35e^{-07}$***	1.067	6.256
	(0.419)	(0.075)	(6.26e-07)	(0.380)	(5.444)
Location (ref = Urban)					
Rural	0.833	0.631	0.943	1.033	0.492*
	(0.233)	(0.241)	(0.587)	(0.213)	(0.279)
Social Class (ref = AB)					
C	0.694	0.969	0.425**	0.715	1.052
	(0.244)	(0.436)	(0.253)	(0.201)	(0.760)
DEF	0.641	0.935	0.351*	0.955	0.428
	(0.261)	(0.511)	(0.334)	(0.305)	(0.381)
Ownership (ref = Own outright)					
Own with a mortgage	1.104	0.637	0.996	0.723	1.327
	(0.382)	(0.252)	(0.815)	(0.177)	(0.758)
Property Type (ref = Detached House)					
Semi-detached	0.897	1.117	2.054	1.558*	0.583
	(0.261)	(0.423)	(1.332)	(0.339)	(0.306)
Terraced	0.446***	0.737	0.816	1.160	0.599
	(0.204)	(0.390)	(0.721)	(0.322)	(0.456)
Availed of grant in the past (ref = No)					
Yes	1.218	0.736	0.297**	0.539***	0.793
	(0.386)	(0.343)	(0.298)	(0.145)	(0.527)

Source: Authors' estimations.
Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1 and relate to tests of difference from 1). Relative risk ratios are calculated as the exponents of the estimated coefficients of the multinomial logit model. N=645.

Table 4: Homeowners' Likelihood of Possessing a Preference for Incentive Structures 2016, Reported Using Relative Risk Ratios
Base category = Status quo ("Cash back once work is complete")

	"Reduced property tax based on a better energy efficiency rating"	*"Tax credits for each year of the loan term"*	*"Ability to pay through your employer via your salary/wages"*	*"A discount on the cost of work upfront"*	*"None"*
Constant	0.552	0.071***	0.209***	1.210	0.023***
	(0.331)	(0.064)	(0.144)	(0.519)	(0.034)
Gender (ref = Male)					
Female	0.391***	0.779	0.639*	0.966	0.824
	(0.118)	(0.275)	(0.206)	(0.190)	(0.289)
Age (ref = 18 – 35)					
36 – 45	1.223	1.871	1.532	0.667	2.379
	(0.657)	(1.116)	(0.775)	(0.210)	(2.694)
46 – 55	0.970	1.582	1.341	0.748	3.112
	(0.557)	(0.994)	(0.731)	(0.247)	(3.618)
56 – 65	1.446	1.933	0.637	1.504	8.166
	(0.807)	(1.275)	(0.446)	(0.531)	(9.714)
65 +	1.557	0.608	0.263***	0.853	14.630
	(0.906)	(0.519)	(0.248)	(0.316)	(17.640)
Location (ref = Urban)					
Rural	0.548**	1.496	0.799	0.689**	0.469***
	(0.183)	(0.535)	(0.274)	(0.147)	(0.176)
Social Class (ref = AB)					
C	1.063	1.888	1.519	0.831	2.789
	(0.458)	(1.084)	(0.740)	(0.226)	(2.251)
DEF	1.134	0.821	0.632	1.221	6.341
	(0.592)	(0.631)	(0.458)	(0.400)	(5.213)
Ownership (ref = Own outright)					
Own with a mortgage	0.812	0.770	0.962	1.835*	1.367
	(0.251)	(0.284)	(0.388)	(0.444)	(0.585)
Property Type (ref = Detached House)					
Semi-detached	0.571**	1.214	1.249	0.741	0.554**
	(0.192)	(0.463)	(0.479)	(0.164)	(0.206)
Terraced	0.474**	1.225	0.984	0.475***	0.267***
	(0.219)	(0.603)	(0.498)	(0.138)	(0.158)
Availed of grant in the past (ref = No)					
Yes	1.692	1.604	0.797	0.583**	0.190***
	(0.576)	(0.690)	(0.402)	(0.166)	(0.147)

Source: Authors' estimations.
Notes: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1 and relate to tests of difference from 1). Relative risk ratios are calculated as the exponents of the estimated coefficients of the multinomial logit model. N=645.

property or not. In the 2016 sample respondents with a mortgage had a higher preference for the upfront discount scheme versus the ex-post cash payment.

Respondents who have previously availed of the retrofit subsidy are familiar with the ex-post cash payment status quo subsidy scheme. Across the two sample years such respondents are no more likely to express a preference for no subsidy support than those who have not availed of a retrofit subsidy. Such respondents stated preferences, as reflected in the RRRs (0.793 and 0.190), are consistent with their revealed preferences in the sense that having availed of the existing subsidy are not in favour of no subsidy support. Respondents who already availed of the retrofit subsidy are less likely to favour the upfront discount across both sample years with an RRR significantly different from 1. While the RRRs for some of other subsidy schemes are greater than 1, none are statistically so.

6.3 Location and Dwelling Attributes

In the 2014 sample there was no practical difference between preferences of urban and rural dwellers for subsidy schemes except in the case of no subsidy support, in which case rural respondents favoured more than urban dwellers. In the 2016 sample there are more differences between preferences of urban and rural respondents. When compared to urban dwellers, rural dwellers are less in favour of subsidy support via either property taxes or upfront discounts versus the status quo ex-post cash payment.

There were only small differences in preferences based on respondents' dwelling types. Those living in terraced properties had less support for a subsidy implemented via property taxes compared to detached house dwellers in both sample years. Respondents living in semi-detached or terraced properties expressed less support than detached house residents for an upfront discount subsidy scheme compared to the ex-post cash rebate, though only in one sample year each.

6.4 Sensitivity

A number of issues potentially arise regarding the regression samples. The samples are intended to be nationally representative of homeowners who make energy related decisions within the family. Approximately 15 per cent of the sample respondents have previously availed of an energy efficiency retrofit grant. While experience of the grant application process may affect preferences for retrofit subsidy schemes, it is important to understand if application for the grant is correlated with other respondent attribute covariates included in the models. Research on SEAI's retrofit subsidy scheme has indicated that building attributes (e.g. dwelling type and location) are associated with different levels of scheme engagement, such as retrofit depth and application abandonment (Collins and Curtis, 2016; 2017a), while the motivation for grant application varies by socio-demographic characteristics (Aravena *et al*., 2016) but there are no published studies profiling applicants versus non-applicants. We consider whether there are

differences between respondents who are either grant applicants or not across the respondent attributes within our datasets by means of a logit regression. The model estimates are presented in Table 5 for both sample years. Excluding the constant terms, only the odds ratios for three variables are significantly different from one across the two model estimates. In 2014 terraced property compared to detached

Table 5: Logit Regression: Dependent Variable "Availed of a Grant in the Past"

	2014	*2016*
Constant	0.126***	0.095***
	(0.067)	(0.052)
Gender (ref = Male)		
Female	0.966	0.867
	(0.216)	(0.197)
Age (ref = 18 – 35)		
36 – 45	2.235	1.172
	(0.899)	(0.572)
46 – 55	2.852	3.598
	(1.147)	(1.652)
56 – 65	2.520	3.584
	(1.142)	(1.71)
Location (ref = Urban)		
Rural	1.338	1.189
	(0.327)	(0.292)
Social Class (ref = AB)		
C	0.763	0.635*
	(0.239)	(0.198)
DEF	0.805	0.520**
	(0.284)	(0.194)
Ownership (ref = Own outright)		
Own with a mortgage	0.722	0.933
	(0.197)	(0.243)
Property Type (ref = Detached House)		
Semi-detached	0.964	1.423
	(0.242)	(0.37)
Terraced	0.485**	1.794
	(0.201)	(0.592)
Observations	645	645

Source: Authors' estimations.
Note: Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1 and relate to tests of difference from 1). Coefficients estimates are reported as odds ratios.

house residents were less likely to be grant applicants, while in 2016 respondents in social classes C-F were less likely to be applicants compared to respondents in classes A and B. Arguably income is potentially correlated with grant applicants, as the retrofit works have to be self-financed and the grant accounts for approximately 35 per cent of the cost. If income were driving the significance of the coefficients on social class we would expect that the social class odds ratios in the 2014 sample to be also significant, which they are not. Overall, there is little evidence to suggest that within the two samples that there is any substantial difference in respondent attributes between grant applicants and those who have yet to apply.

As noted above, prior experience of the grant application process may affect preferences for retrofit subsidy schemes. One way preferences might be affected is that respondents who have previously availed of a retrofit grant have a bias toward the status quo ex-post cash payment. Or more generally, preferences of such respondents might be fundamentally different to homeowners who have not invested in an energy efficiency retrofit. One way to consider this is to estimate the model with data just on respondents who have yet to invest in a retrofit, which we report in Tables 6 and 7 for the two sample years. We have insufficient data to estimate a separate model for grant applicants only. Invariably there are differences in the reported RRRs compared to Tables 3 and 4 but the magnitude and number of differences are not such that one can easily argue that preferences of non-grant applicants are substantially different from the entire population. Across all the reported RRRs in Tables 6 and 7, including those that are not statistically different from 1, approximately 25 per cent have a magnitude difference in RRR compared to the equivalent value in Tables 3 and 4 of 0.2 or less. Of the 15 RRRs that are statistically different from 1 in Table 4, thirteen are also statistically different from 1 in Table 7. The two exceptions have RRRs of comparable magnitude. We formally tested equality of each RRR estimate in Tables 3 and 4 with the equivalent point values in Tables 6 and 7 for a total of 60 t-tests and failed to reject equality in any instance. We also performed the tests in reverse, testing equality of each RRR estimate in Tables 6 and 7 with the equivalent point values in Tables 3 and 4. We failed to reject equality in just three instances, which are on the '65+' variable in the tax credit and via an employer scheme options, and the '56-65' variable in the "via an employer scheme" option. Overall, we conclude that there is little evidence to suggest that we should consider respondents who have previously availed of a grant separately from all other respondents.

6.5 Discussion

We proceed with the results as presented in Tables 3 and 4, which indicate that public preferences for retrofit subsidy schemes are complex and nuanced. It is difficult to immediately draw clear conclusions on preferences associated with particular socio-demographic or other attributes. This is accentuated by the fact that

Table 6: Homeowners' Likelihood of Possessing a Preference for Incentive Structures 2014, Excl. Grant Recipients

	"Reduced property tax based on a better energy efficiency rating"	*"Tax credits for each year of the loan term"*	*"Ability to pay through your employer via your salary/wages"*	*"A discount on the cost of work upfront"*	*"None"*
Constant	0.414**	0.550	0.086***	0.900	0.058***
	(0.269)	(0.385)	(0.121)	(0.419)	(0.062)
Gender (ref = Male)					
Female	0.927	0.946	0.618	1.367	2.034
	(0.272)	(0.322)	(0.337)	(0.280)	(1.209)
Age (ref = 18 – 35)					
36 – 45	1.070	1.304	2.763	1.307	0.775
	(0.460)	(0.570)	(1.718)	(0.388)	(0.720)
46 – 55	1.128	0.900	0.609	0.986	1.708
	(0.481)	(0.431)	(0.527)	(0.310)	(1.487)
56 – 65	1.479	0.416**	$3.22e^{-07}$***	0.862	1.403
	(0.719)	(0.239)	($2.05e^{-07}$)	(0.317)	(1.394)
65 +	0.834	$1.36e^{-07}$***	$3.68e^{-07}$***	1.049	5.142
	(0.504)	(6.39e-$^{-08}$)	($2.83e^{-07}$)	(0.401)	(4.870)
Location (ref = Urban)					
Rural	0.831	0.404***	0.641	0.908	0.495
	(0.280)	(0.185)	(0.412)	(0.208)	(0.328)
Social Class (ref = AB)					
C	0.699	1.370	0.598	0.834	0.904
	(0.278)	(0.707)	(0.384)	(0.253)	(0.672)
DEF	0.644	1.131	0.577	1.107	0.389
	(0.303)	(0.760)	(0.558)	(0.387)	(0.407)
Ownership (ref = Own outright)					
Own with a mortgage	1.324	0.624	2.087	0.793	1.337
	(0.551)	(0.264)	(2.307)	(0.210)	(0.869)
Property Type (ref = Detached House)					
Semi-detached	0.904	0.835	1.524	1.415	0.681
	(0.315)	(0.342)	(0.972)	(0.346)	(0.390)
Terraced	0.502**	0.520	0.604	1.056	0.454
	(0.243)	(0.293)	(0.511)	(0.313)	(0.427)

Source: Authors' estimations.

Note: Base category = Status quo ("Cash back once work is complete"). Coefficients are relative risk ratios. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1 and relate to tests of difference from 1). Relative risk ratios are calculated as the exponents of the estimated coefficients of the multinomial logit model. N=544.

Table 7: Homeowners' Likelihood of Possessing a Preference for Incentive Structures 2016, Excl. Grant Recipients)

	"Reduced property tax based on a better energy efficiency rating"	*"Tax credits for each year of the loan term"*	*"Ability to pay through your employer via your salary/wages"*	*"A discount on the cost of work upfront"*	*"None"*
Constant	0.657	0.144***	0.290***	1.301	0.027***
	(0.467)	(0.137)	(0.203)	(0.604)	(0.041)
Gender (ref = Male)					
Female	0.484***	0.629	0.673	1.037	0.853
	(0.167)	(0.253)	(0.231)	(0.220)	(0.309)
Age (ref = 18 – 35)					
36 – 45	1.517	1.058	1.104	0.601**	2.149
	(0.929)	(0.668)	(0.574)	(0.195)	(2.442)
46 – 55	0.936	1.549	1.322	0.720	2.548
	(0.651)	(1.024)	(0.766)	(0.253)	(3.028)
56 – 65	1.474	1.599	0.820	1.573	7.769
	(0.985)	(1.130)	(0.586)	(0.596)	(9.475)
65 +	1.578	0.687	0.298**	0.761	14.590
	(1.060)	(0.577)	(0.286)	(0.302)	(17.790)
Location (ref = Urban)					
Rural	0.450***	1.610	0.720	0.652**	0.437***
	(0.178)	(0.659)	(0.268)	(0.149)	(0.171)
Social Class (ref = AB)					
C	1.081	1.646	1.184	0.831	2.626
	(0.565)	(1.094)	(0.592)	(0.250)	(2.193)
DEF	1.106	0.406	0.376**	1.097	5.620
	(0.685)	(0.381)	(0.295)	(0.397)	(4.766)
Ownership (ref = Own outright)					
Own with a mortgage	0.581**	0.556*	0.933	1.548	1.215
	(0.212)	(0.228)	(0.416)	(0.402)	(0.545)
Property Type (ref = Detached House)					
Semi-detached	0.440***	1.033	1.383	0.838	0.594*
	(0.177)	(0.470)	(0.576)	(0.200)	(0.230)
Terraced	0.450**	1.531	0.944	0.607**	0.237***
	(0.235)	(0.807)	(0.533)	(0.188)	(0.157)

Source: Authors' estimations.

Note: Base category = Status quo ("Cash back once work is complete"). Coefficients are relative risk ratios. Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1 and relate to tests of difference from 1). Relative risk ratios are calculated as the exponents of the estimated coefficients of the multinomial logit model. N=547.

stated preferences across the two-year samples are not stable. The differences in preferences across samples could reflect changing preferences through time, or alternatively that the structure of subsidy schemes is not a particularly salient issue for respondents. Either explanation is problematic for the design of effective subsidy schemes. What is clear across the two samples is the strong preference in favour of the upfront discount and ex-post cash rebate compared to the other schemes considered in the survey; this is reflected in the response rates from Table 2. There is an apparent dichotomy in preferences for type of subsidy scheme with cash payments (either ex-ante or ex-post) on one side and more indirect subsidy supports (e.g. tax credits, reduced property tax, etc.) on the other. We consider to what extent preferences across respondent attributes are similar between these two types of subsidy scheme. We do this by testing for a number of parameter restrictions. In the case of the cash payments subsidy schemes, we test for equality of the multinomial coefficient vector, H_{o1}: $\beta_j = \beta_k$, where the β parameters are from Equation (1) and the subscripts j and k refer to the two cash payment subsidies: 'Cash back once the work is complete' and 'A discount on the cost of work upfront'. Inability to reject the null hypothesis H_{o1} in favour of an alternative in which the parameters are not equal would suggest that preferences for cash payment subsidy schemes do not vary by respondent attributes. The test results are reported in the first row of Table 8 for both survey samples. We fail to reject equality of parameters for the 2014 sample but reject for the 2016 sample. The remaining rows in Table 8 test for equality of parameters for individual respondent attributes, H_{o2}: $\beta_{jxai} = \beta_{kxai}$ where x_{ai} refers to attribute a within the vector of respondent attributes x_i from Equation (1). While we perform these tests on both year samples, we are particularly interested in the results for the 2016 sample as they will give insight on which respondent attributes are associated with difference in preferences across the two cash payment subsidy schemes. We fail to reject H_{o2} in the case of the gender variable but reject for the four age cohort variables together. We re-test subsets of the age parameters and find that some of the differences in preferences across the two cash payment subsidies in the 2016 sample are associated with the age cohorts aged 56 and above relative to the '18-35' reference category. There are also differences associated with respondents with a mortgage, from rural areas, living in terraced properties and those that have previously availed of a retrofit grant. Where in the 2014 sample we could conclude that preferences for the two cash payment subsidy scheme types did not differ across respondent attributes, the opposite is the case for the 2016 sample.

We next consider the same tests for the four indirect subsidy scheme options: 'Reduced property tax based on a better energy efficiency rating', 'Tax credits for each year of the loan term', 'Ability to pay through your employer via your salary/wages', and 'None'. The test results are reported in Table 9. The null hypothesis H_{o1} is rejected for both year samples, though this is not unexpected as it is quite a restrictive test. We fail to reject the null hypothesis H_{o2} in many

Table 8: Chi Square Tests on Equality of Parameters across Cash Payment* Subsidy Scheme Types

		2014			*2016*	
Variable	*df*	$X^2_{(df)}$	*p-value*	*df*	$X^2_{(df)}$	*p-value*
All parameters	12	15.63	0.21	12	23.21	0.03
Female	1	1.45	0.23	1	0.03	0.86
All age variables	4	2.77	0.60	4	8.05	0.09
Age 36-55	2	1.07	0.59	2	1.68	0.43
Age 56+	2	1.00	0.61	2	3.51	0.17
Rural	1	0.02	0.88	1	3.05	0.08
All social classes	2	2.46	0.29	2	2.51	0.28
Own with a mortgage	1	1.76	0.18	1	6.29	0.01
All dwelling types	2	4.23	0.12	2	6.67	0.04
Semi-detached	1	4.14	0.04	1	1.83	0.18
Terraced	1	0.28	0.59	1	6.60	0.01
Availed of grant in the past	1	5.26	0.02	1	3.60	0.06

Source: Authors' estimations.
Note: df: degrees of freedom. * Refers to the following two subsidy scheme options: (1) Cash back once the work is complete; (2) A discount on the cost of work upfront.

instances, though there are some differences between the two sample years. In the 2014 sample year the differences in preferences are largely associated with age, with older age cohorts differing in their preferences across the four subsidy schemes relative to the '18-35' reference category. There are similar findings in the 2016 sample and additionally we reject H_{o2} in the case of rural respondents and those who availed of a retrofit grant in the past. With the results from the two-year samples we can say that differences in preferences across respondent attributes for the four indirect subsidy scheme options (including no subsidy) are primarily attributable to age and to a lesser extent on location and whether respondents previously availed of a grant. For respondents with those attributes the nature of their preferences differs across the four subsidy scheme options.

Preferences for the subsidy scheme options differed depending on whether people had availed of a retrofit grant in the past. Even for the two cash subsidy schemes (ex-ante and ex-post), respondents who had availed of a retrofit grant in the past were significantly less likely to express a preference for the upfront discount option across both sample years. This specific finding suggests satisfaction with receiving the subsidy payment after all retrofit works have been satisfactorily completed. Respondents who have already availed of the retrofit subsidy have the means to afford the retrofit works and self-finance the retrofit installation until the subsidy is paid. Some of the respondents who have not previously availed of a grant are likely to be liquidity constrained and this may underlie expressed

differences in preferences associated with this variable. For respondents who cannot afford energy efficiency investments the survey choice between subsidy schemes is moot.

Table 9: Chi Square Tests on Equality of Parameters Across Indirect* Subsidy Scheme Types

		2014			*2016*	
Variable	*df*	$X^2_{(df)}$	*p-value*	*df*	$X^2_{(df)}$	*p-value*
All parameters	36	2,241.62	0	36	73.16	0
Female	3	2.65	0.45	3	4.23	0.24
All age variables	12	885.25	0	12	20.76	0.05
Age 36-55	6	4.52	0.61	6	1.23	0.98
Age 56+	6	503.12	0	6	11.40	0.08
Age 56-65	3	492.94	0	3	4.04	0.26
Age 65+	3	377.29	0	3	8.18	0.04
Rural	3	1.17	0.76	3	6.92	0.07
All social classes	6	3.12	0.79	6	12.98	0.04
C	3	1.76	0.62	3	1.64	0.65
DEF	3	1.24	0.74	3	5.42	0.14
Own with a mortgage	3	1.92	0.59	3	1.51	0.68
All dwelling types	6	3.33	0.77	6	7.88	0.25
Availed of grant in the past	3	2.66	0.45	3	8.86	0.03

Source: Authors' estimations.
Note: df: degrees of freedom. * Refers to the following four subsidy scheme options: 1. Reduced property tax based on a better energy efficiency rating; 2. Tax credits for each year of the loan term; 3. Ability to pay through your employer via your salary/wages; 4. None.

VII CONCLUSION AND POLICY IMPLICATIONS

Improving the energy efficiency of the residential building stock leads to multiple potential private benefits to homeowners, including lower energy costs, health benefits, and improved property values. There are also positive externalities associated with reductions in greenhouse gas emissions and wider economic benefits in terms of jobs and competitiveness at sector, national and international levels. Underinvestment in residential energy efficiency has been attributed to market failures and behavioural issues, which provides a basis for public policy intervention in provision of energy efficiency. This paper considers homeowners' preferences across different types of potential subsidy schemes, a better understanding of which should aid the design of residential energy retrofit subsidy schemes.

The clear message from the survey is that respondents strongly prefer cash payment subsidies versus other indirect methods of financial support, roughly by a 70:30 ratio. When modelling the survey responses within a multinomial choice framework it is also clear that the variability of preferences across respondent attributes is not stable across the two survey year samples. A simple explanation might be that preferences have evolved through time, which if true makes the design of subsidy schemes more difficult as preferences evolve so rapidly. An alternative explanation is that the structure of subsidy schemes is not a particularly salient issue for respondents, which is also problematic for the design of effective subsidy schemes. What makes the latter explanation possibly more likely is that subsidy support schemes are only relevant to households with the resources and ability to invest in energy efficiency, *ceteris paribus*. Consequently, respondents for which the survey options are not particularly relevant, perhaps due to budget constraints, may not have given due consideration to their responses, which is reflected in the differences in model estimates between years.

When looking across the six subsidy schemes considered in the survey it is difficult to draw obvious conclusions on preferences associated with particular respondent attributes and each of the subsidy schemes considered. However, when focusing on just two categories of subsidy scheme, cash payment or indirect support options, we see a clearer picture of how preferences differ with respondent attributes. One clear finding is that preferences on type of subsidy scheme differ depending on whether respondents have previously availed of an energy efficiency retrofit grant. People who have experience availing of retrofit grants are more likely to have preferences in favour of ex-post cash payments compared to upfront discounts, for example. Second, though the results from the two sample years are not identical we can also say that preferences vary by respondents' property type, tenure, location and age. Age appears to be particularly important in distinguishing preferences across subsidy schemes with the older age cohorts more likely to differ in their preferences across schemes compared to younger respondents both in the cash payment and indirect subsidy schemes (including no subsidy).

In an Irish context and from the perspective of the grant provider the fact that the ex-post cash payment is one of the two more popular support scheme designs preferred by homeowners validates the existing scheme design and approach taken to encourage energy efficiency retrofits. However, the findings with respect to age and whether respondents previously availed of a grant, in particular, suggest support schemes need to cater for a greater heterogeneity of preferences and circumstances. Incentives to encourage older age cohorts to invest in energy efficiency may need to be tailored to their particular circumstances. Expressed choices differ depending on whether homeowners previously availed of a grant but this research does not provide any evidence of the underlying drivers for such preferences. We surmise that it may be associated with budget or credit constraints. Irrespective of the underlying driver, it is clear that those who have availed of the existing subsidy

scheme have a higher preference for the ex-post cash payment than those who have not accessed the grant. It suggests that there is a bias associated with those who access the existing grant scheme and therefore consideration is required to address that bias. The SEAI's 'Better Energy Warmer Homes' scheme already provides energy efficient retrofit support to vulnerable people in, or at risk of, energy poverty. A policy question is whether there are homeowners who are not eligible for the 'Better Energy Warmer Homes' scheme but their circumstances preclude them from participating in the more general 'Better Energy Homes' scheme.

REFERENCES

Allcott, H. and M. Greenstone, 2012. "Is There an Energy Efficiency Gap?", *The Journal of Economic Perspectives*, Vol. 26, No. 1, pp. 3-28. https://doi.org/10.1257/jep.26.1.3.

Aravena, C., A. Riquelme and E. Denny, 2016. "Money, Comfort or Environment? Priorities and Determinants of Energy Efficiency Investments in Irish Households", *Journal of Consumer Policy*, Vol. 39, pp. 159-186. https://doi.org/10.1007/s10603-016-9311-2.

Bateman, I. J., I. H. Langford, R. K. Turner, K. G. Willis and G. D. Garrod, 1995. "Elicitation and Truncation Effects in Contingent Valuation Studies", *Ecological Economics*, Vol. 12, No. 2, pp. 161-179. https://doi.org/10.1016/0921-8009(94)00044-V.

Belaïd, F., 2018. "Exposure and Risk to Fuel Poverty in France: Examining The Extent of the Fuel Precariousness and its Salient Determinants", *Energy Policy*, Vol. 114, pp. 189-200. https://doi.org/10.1016/j.enpol.2017.12.005.

Bird, S. and D. Hernandez, 2012. "Policy Options for the Split Incentive: Increasing Energy Efficiency for Low-Income Renters", *Energy Policy*, Vol. 48, pp. 506-514. https://doi.org/10.1016/j.enpol.2012.05.053.

Borenstein, S. and L. W. Davis, 2016. "The Distributional Effects of US Clean Energy Tax Credits", *Tax Policy and the Economy*, Vol. 30, No. 1, pp. 191-234. https://doi.org/10.1086/685597.

Bouzarovski, S., 2014. "Energy Poverty in the European Union: landscapes of Vulnerability", *Wiley Interdisciplinary Reviews: Energy and Environment*, Vol. 3, No. 3, pp. 276-289. https://doi.org/10.1002/wene.89.

Braun, F. G., 2010. "Determinants of Households' Space Heating Type: A Discrete Choice Analysis for German Households", *Energy Policy*, Vol. 38, No. 10, pp. 5493-5503. https://doi.org/10.1016

Brounen, D. and N. Kok, 2011. "On the Economics of Energy Labels in the Housing Market", *Journal of Environmental Economics and Management*, Vol. 62, No. 2, pp. 166-179. http://doi.org/10.1016/j.jeem.2010.11.006.

Brouwer, R., 2006. "Do Stated Preference Methods Stand the Test of Time? A Test of the Stability of Contingent Values and Models for Health Risks When Facing an Extreme Event", *Ecological Economics,* Vol. 60, No. 2, pp. 399-406. https://doi.org/10.1016/j.ecolecon.2006.04.001.

Brouwer, R., I. Logar and O. Sheremet, 2017. "Choice Consistency and Preference Stability in Test-Retests of Discrete Choice Experiment and Open-Ended Willingness to Pay Elicitation Formats", *Environmental and Resource Economics*, Vol. 68, No. 3, pp. 729-751. https://doi.org/10.1007/s10640-016-0045-z.

Brown, M. A., 2001. "Market Failures and Barriers as a Basis For Clean Energy Policies", *Energy Policy*, 29(14):1197-1207. https://doi.org/10.1016/S0301-4215(01)00067-2.

Cajias, M. and D. Piazolo, 2013. "Green Performs Better: Energy Efficiency and Financial Return on Buildings", *Journal of Corporate Real Estate*, 15(1):53-72. http://doi.org/10.1108/JCRE-12-2012-0031.

Camprubí, L., D. Malmusi, R. Mehdipanah, L. Palffencia, A. Molnar, C. Muntaner and C. Borrell, 2016. "Facade Insulation Retrofitting Policy Implementation Process and its Effects on Health Equity Determinants: A Realist Review", *Energy Policy*, Vol. 91, pp. 304-314. https://doi.org/10.1016/j.enpol.2016.01.016.

Clinch, J. P. and J. D. Healy, 2001. "Cost-benefit Analysis of Domestic Energy Efficiency", *Energy Policy*, Vol. 29, No. 2, pp. 113-124. https://doi.org/10.1016/S0301-4215(00)00110-5.

Collins, M. and J. Curtis, 2016. "An Examination of Energy Efficiency Retrofit Depth in Ireland", *Energy and Buildings*, Vol. 127, p. 170-182. http://doi.org/10.1016/j.enbuild.2016.06.012.

Collins, M. and J. Curtis, 2017a. "An Examination of the Abandonment of Applications for Energy Efficiency Retrofit Grants in Ireland", *Energy Policy*, Vol. 100, pp. 260-270. http://doi.org/10.1016/j.enpol.2016.10.030.

Collins, M. and J. Curtis, 2017b. "Value for Money in Energy Efficiency Retrofits in Ireland: Grant Provider and Grant Recipients", *Applied Economics*, Vol. 49, no. 51, pp. 5245-5267. http://doi.org/10.1080/00036846.2017.1302068.

Couture, S., S. Garcia, S. and A. Reynaud, 2012. "Household Energy Choices and Fuelwood Consumption: An Econometric Approach Using French Data", *Energy Economics*, Vol. 34, No. 6, pp. 1972-1981. https://doi.org/10.1016.

Curl, A., A. Kearns, P. Mason, M. Egan, C. Tannahill and A. Ellaway, 2015. "Physical and Mental Health Outcomes Following Housing Improvements: Evidence from the Gowell Study", *Journal of Epidemiology & Community Health*, Vol. 69, No. 1, pp. 12-19. http://dx.doi.org/10.1136/jech-2014-204064.

Deng, Y. and J. Wu, 2014. "Economic Returns to Residential Green Building Investment: The Developers' Perspective", *Regional Science and Urban Economics*, Vol. 47, pp. 35-44. https://doi.org/10.1016/j.regsciurbeco.2013.09.015.

Deng, Y., Z. Li, and J. M. Quigley, 2012. "Economic Returns to Energy-Efficient Investments in the Housing Market: Evidence From Singapore", *Regional Science and Urban Economics*, Vol. 42, No. 3, pp. 506-515. https://doi.org/10.1016/j.regsciurbeco.2011.04.004.

Distante, R., E. Verdolini and M. Tavoni, 2016. "Distributional and Welfare Impacts of Renewable Subsidies in Italy", FEEM Working Paper, No. 36.2016. http://dx.doi.org/10.2139/ssrn.2783675.

European Commission, 2011a. Commission Staff Working Paper "Impact Assessment", Accompanying the document *Directive 2012/27/EU of the European Parliament and of the Council on energy efficiency and amending and subsequently repealing Directives 2004/8/EC and 2006/32/EC*. Number SEC(2011) 779. European Commission. https://ec.europa.eu/energy/sites/ener/ffles/documents/sec 2011 0779 impact assessment.pdf.

European Commission, 2011b. "Energy Efficiency Plan 2011, Communication from the Commission to The European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions", Number COM(2011) 109. European Commission. http://eur-lex.europa.eu/legalcontent/EN/TXT/PDF/?uri=CELEX:52011DC0109&from=EN.

European Parliament and the Council of the European Union, 2012. *Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy Efficiency, Amending Directives 2009/125/EC and 2010/30/EU and Repealing Directives 2004/8/EC and 2006/32/EC*. European Union. http://eurlexeuropa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012 L0027&from=EN.

Eurostat, 2016. "Consumption of energy", http://ec.europa.eu/eurostat/statisticsexplained/index.php/Consumption of energy [accessed 14 Oct 2016].

Figus, G., K. Turner, P. McGregor and A. Katris, 2017. "Making the Case for Supporting Broad Energy Efficiency Programmes: Impacts on Household Incomes and Other Economic Benefits", *Energy Policy,* Vol. 111, pp. 157- 165. https://doi.org/10.1016/j.enpol.2017.09.028.

Fuerst, F., P. McAllister, A. Nanda and P. Wyatt, 2015. "Does Energy Efficiency Matter to Homebuyers? An Investigation of EPC Ratings and Transaction Prices in England", *Energy Economics,* Vol. 48, pp. 145-156. http://doi.org/10.1016/j.eneco.2014.12.012.

Galvin, R., 2010. "Thermal Upgrades of Existing Homes in Germany: The Building Code, Subsidies, and Economic Efficiency", *Energy and Buildings*, Vol. 42, No. 6, pp. 834-844. https://doi.org/10.1016/j.enbuild.2009.12.004.

Gerarden, T. D., R. G. Newell and R. N. Stavins, 2017. "Assessing the Energy-Efficiency Gap", *Journal of Economic Literature*, Vol. 55, No. 4, pp. 1486-1525. https://doi.org/10.1257/jel.20161360.

Gilbertson, J., M. Stevens, B. Stiell and N. Thorogood, 2006. "Home is Where the Hearth is: Grant Recipients' Views of England's Home Energy Efficiency Scheme (Warm Front)", *Social Science & Medicine*, Vol. 63, No. 4, pp. 946-956. https://doi.org/10.1016/j.socscimed.2006.02.021.

Gillingham, K., R. G. Newell and K. Palmer, 2009. "Energy Efficiency Economics and Policy", *Annual Review of Resource Economics*, Vol. 1, No. 1, pp. 597-620. https://doi.org/10.1146.

Granade, H. C., J. Creyts, A. Derkach, P. Farese, S. Nyquist and K. Ostrowski, 2009. "Unlocking Energy Efficiency in the US Economy", McKinsey & Company.

Havas, L., J. Ballweg, C. Penna and D. Race, 2015. "Energising Households: A Financial Analysis of Incentivised Energy Efficiency Measures in Remote Australia", *Energy Efficiency*, Vol. 8, No. 5, pp. 951-962. https://doi.org/10.1007/s12053-015-9326-6.

Healy, J. D. and J. P. Clinch, 2004. "Quantifying the Severity of Fuel Poverty, Its Relationship With Poor Housing and Reasons for Non-Investment in Energy-Saving Measures in Ireland", *Energy Policy*, Vol. 32, No. 2, pp. 207-220. https://doi.org/10.1016/S0301-4215(02)00265-3.

Hilke, A. and L. Ryan, 2012. "Mobilising Investment in Energy Efficiency: Economic Instruments for Low-Energy Buildings", International Energy Agency, Paris.https://www.iea.org/publications/insights/insightpublications/Mobilising investment EE.pdf.

Hirst, E. and M. Brown, 1990. "Closing the Efficiency Gap: Barriers to the Efficient Use of Energy", *Resources, Conservation and Recycling*, Vol. 3, No. 4, pp. 267-281. https://doi.org/10.1016/0921-3449(90)90023-W.

Hoicka, C. E., P. Parker and J. Andrey, 2014. "Residential Energy Efficiency Retrofits: How Program Design Affects Participation and Outcomes", *Energy Policy*, Vol. 65, pp. 594-607. https://doi.org/10.1016/j.enpol.2013.10.053.

Huntington, H. G., 2011. "The Policy Implications of Energy-Efficiency Cost Curves", *The Energy Journal,* pages 7-21. http://www.jstor.org/stable/41323306.

Hyland, M., R. C. Lyons and S. Lyons, 2013. "The Value of Domestic Building Energy Efficiency: Evidence from Ireland", *Energy Economics*, Vol. 40, pp. 943-952. http://doi.org/10.1016/j.eneco.2013.07.020.

Jaffe, A. B. and R. N. Stavins, 1994a. "The Energy-Efficiency Gap What Does It Mean?", *Energy Policy*, Vol. 22, No. 10, pp. 804-810. https://doi.org/10.1016/0301-4215(94)90138-4.

Jaffe, A. B. and R. N. Stavins, 1994b. "Energy-Efficiency Investments and Public Policy", *The Energy Journal,* pages 43-65. http://www.jstor.org/stable/41322875.

Jaffe, A. B., R. G. Newell and R. N. Stavins, 2004. "Economics of Energy Efficiency" in Cleveland, C., (ed.), *Encyclopaedia of Energy*, Volume 2, pp. 79-90. Elsevier: Amsterdam, the Netherlands.

Kerr, N., A. Gouldson and J. Barrett, 2017. "The Rationale for Energy Efficiency Policy: Assessing The Recognition of the Multiple Benefits of Energy Efficiency Retrofit Policy", *Energy Policy*, Vol. 106, pp. 212-221. https://doi.org/10.1016/j.enpol.2017.03.053.

Maidment, C. D., C. R. Jones, T. L. Webb, E. A. Hathway and J. M. Gilbertson, 2014. "The Impact of Household Energy Efficiency Measures on Health: A Meta-Analysis", *Energy Policy*, Vol. 65, pp. 583-593. http://dx.doi.org/10.1016/j.enpol.2013.10.054.

Markandya, A., X. Labandeira and A. Ramos, 2015. "Policy Instruments to Foster Energy Efficiency", in *Green Energy and Efficiency*, pp. 93-110. Springer. https://doi.org/10.1007/978-3-319-03632-8 4.

McFadden, D., 1973. "Conditional Logit Analysis of Qualitative Choice Behavior" in Zarenmbka, P., (ed.)*, Frontiers in Econometrics*, pp.105-142. Academic Press, New York.

Michelsen, C. C. and R. Madlener, 2012. "Homeowners' Preferences for Adopting Innovative Residential Heating Systems: A Discrete Choice Analysis for Germany", *Energy Economics*, Vol. 34, No. 5, pp. 1271-1283. https://doi.org/10.1016/j.eneco.2012.06.009.

Neuhoff, K., K. Stelmakh, H. Amecke, A. Novikova, J. Deason and A. Hobbs, 2012. "Financial Incentives for Energy Efficiency Retrofits in Buildings", *ACEEE Summer Study on Energy Efficiency in Buildings*. http://aceee.org/ffles/proceedings/2012/data/papers/0193-000422.pdf.

Neveu, A. R. and M. F. Sherlock, 2016. "An Evaluation of Tax Credits for Residential Energy Efficiency", *Eastern Economic Journal*, Vol. 42, No. 1, pp. 63-79. https://doi.org/10.1057/eej.2014.35.

Ryan, L. and N. Campbell, 2012. "Spreading the Net: The Multiple Benefits of Energy Efficiency Improvements", International Energy Agency. http://dx.doi.org/10.1787/5k9crzjbpkkc-en.

Sovacool, B. K., 2015. "Fuel Poverty, Affordability and Energy Justice in England: Policy Insights from the Warm Front Program", *Energy*, Vol. 93, pp. 361-371. https://doi.org/10.1016/j.energy.2015.09.016.

Suter, J. F. and M. R. Shammin, 2013. "Returns to Residential Energy Efficiency and Conservation Measures: A Field Experiment", *Energy Policy*, Vol. 59, pp. 551-561. https://doi.org/10.1016/j.enpol.2013.04.003.

United Nations, 2015. "Paris Agreement", United Nations. http://unfccc.int/ffles/essential background/convention/application/pdf.

Whitehead, J. C. and T. J. Hoban, 1999. "Testing for Temporal Reliability in Contingent Valuation With Time for Changes in Factors Affecting Demand", *Land Economics*, pp. 453-465. http://www.jstor.org/stable/3147190.