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Can tenants afford to care? Investigating the willingness-to-pay for improved energy efficiency of rental tenants and returns to investment for landlords

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Abstract: Throughout the developed world, residential buildings in the rental sector exhibit lower levels of energy efficiency than the owner-occupied building stock. A double-bounded dichotomous choice contingent valuation method is used to examine how much renters are willing to pay in their monthly rent for improved energy efficiency, measured via energy performance certificates. The results of this analysis are used to examine the returns to investment available to landlords for various measures. Using an administrative dataset of residential retrofits, we examine the upfront cost to landlords of engaging in energy efficiency retrofits of varying depths and calculate the relevant payback period. Conditional upon possessing a non-zero willingness-to-pay, we find that tenants in Ireland are willing to pay an average of over €40 for each one-grade improvement in their accommodation's Building Energy Rating. We find short payback periods for attic and cavity wall insulation and prohibitively long payback periods for external wall insulation and solar heating.

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1. Introduction

The European Union has mandated a 20% reduction in energy use by 2020 (European Parliament and the Council of the European Union, 2012) with further reductions mandated into the future, while the Paris Agreement has emphasised the need to reach peak greenhouse gas emissions as soon as possible (United Nations, 2015). One-sixth of emissions in the European Union are estimated to occur in residential buildings (European Commission, 2011a), while space and water heating account for 67% and 14% of residential energy consumption, respectively (European Commission, 2011b). Similarly, 22.5% of energy consumption in the U.S. occurs in residential buildings (Department of Energy, 2012). Two-thirds of buildings in the European Union were built before the introduction of energy performance standards, with an average of only 1% of these buildings being renovated each year (European Commission, 2016). As such, improving the energy efficiency of the residential building stock provides a significant opportunity to contribute to limiting global warming to below 2°C.

The rental market accounts for a large share of residential buildings throughout the world. In the European Union, 29.9% of residential buildings are occupied by tenants, rising to 33.1% in the Euro area and as high as 35.2% and 47.6% in the UK and Germany, respectively (Eurostat, 2015). In the United States, 34.6% of occupied housing units are occupied by rental tenants (U.S. Census Bureau, 2015). The rental sector, however, is generally less energy efficient than that of owner-occupied homes. In the U.S., 70% of rental properties are considered either 'well insulated' or 'adequately insulated', relative to 84% of owner-occupied properties, while 13% of rental properties possess water heaters of more than 20 years old, relative to just 8% of owner-occupied homes (EIA, 2013). Similar patterns exist in the EU. In England, for example, private rental accommodation had lower levels of cavity insulation and loft insulation than owner-occupied homes (DfCLG, 2013). In Ireland, where the energy performance certificate database is publicly available, the distribution of energy labels for rental and other properties can be examined in detail. These are known as Building Energy Ratings (BER) and Figure 1 shows the distribution of all known Building Energy Ratings for private rental dwellings alongside that of Building Energy Ratings assessed for purposes other than private rental. As can be seen, both distributions are heavily skewed toward less efficient grades.

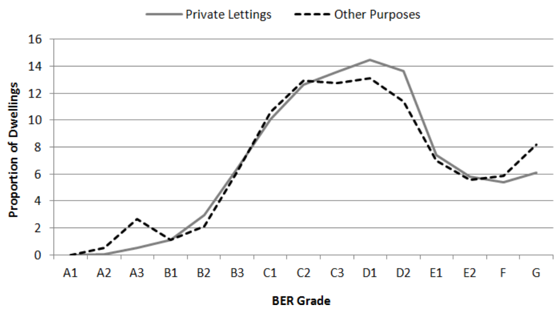

Figure 1: Proportional distribution of Irish Building Energy Ratings

While the total distribution possesses a slightly greater proportion of homes in the least efficient grades, 'F' and 'G', the distribution of rental properties is further skewed, possessing a greater proportion of homes in 'C', 'D' and 'E' grades.

There is clearly potential to improve the energy efficiency of the rental stock and, as such, it is of interest to understand whether landlords require incentives to do so. As will be discussed in Section 2, improved energy efficiency, in the form of improved energy performance certificates, has been shown to attract a price premium in many rental markets, which in turn provides an incentive to landlords to improve the energy efficiency of their property/properties. Rental market conditions, however, may act as a disincentive for landlords to engage in retrofitting works which would lead to greater energy efficiency. We refer to a stressed rental market as one in which demand for rental properties is growing at a faster rate than supply, forcing rent prices upward. In such conditions, rental income to landlords will increase regardless of the condition of the accommodation, thus reducing the need to maintain or improve living standards as a means of generating greater income. The upward pressure on rental prices will also place downward pressure on the willingness-to-pay of renters for improved energy efficiency, as higher rent costs will reduce the ability of renters to pay for improved energy efficiency within their budget constraint, while less choice and greater search times will reduce the standard of living accepted by individual renters in order to find accommodation.

The Irish rental market from 2013 to 2016 provides an example of such stressed market conditions. During the four year period from Q3 2013 to Q3 2016, rents rose by an average of 7.27% (RTB, 2016), compared to an average increase in average weekly earnings of 0.95% (CSO, 2016). This is due to a number of forces in the market. Economic recovery in Ireland has mainly been confined to its cities, particularly the capital, Dublin, increasing employment in these areas, which in turn increased the number of people living in these areas. Increasing costs in the housing market, combined with tighter mortgage regulation in Ireland have forced households from the purchase market to the rental market, while a deficit in social housing has led to a movement of households into the rental market who would otherwise receive social housing. This increase in demand for rental accommodation has coincided with a consistent decrease in supply, for example the year to October 2016 saw a 12% fall in the number of homes available for rent nationwide (Lyons, 2016).

This study aims to use survey data to estimate the willingness-to-pay of rental tenants for improved energy efficiency, measured using energy performance certificates, and how this varies across the characteristics of households. We use Ireland as a case study, where high rental demand, particularly in cities, combined with a decreasing supply has created significant upward pressure on rents. We then use a dataset of energy efficiency retrofits to gauge the costs incurred and energy efficiency improvements available through engaging in various retrofitting measures. These are used to calculate guideline payback periods for investments in energy efficiency by landlords.

The remainder of the paper is organised as follows. Section 2 outlines related literature. Section 3 outlines the data used and methods of analysis. Section 4 presents and discusses the results of the analysis. Section 5 then concludes

2. Relevant Literature

The literature on willingness-to-pay for household energy efficiency is dominated by stated preference techniques. Discrete choice experiments are used to model the preferences of home owners with regard to energy efficiency measures under choice models such as those developed by McFadden (1984). Modelled trade-offs in utility between costs and energy efficiency improvements are then used to estimate the willingness of home owners to pay for either overall measured energy efficiency improvements (Achtnicht, 2011) or for specific energy efficiency measures (Cameron, 1985; Jaccard and Dennis, 2006; Banfi et al., 2008; Kwak et al., 2010). Others have used discrete choice methods to examine revealed preferences, imposing ex-post discrete choice sets comprised of observed retrofits among home owners and other retrofit options foregone for these observed choices (Grösche and Vance, 2009; Collins and Curtis, 2016b).

A wide literature exists examining the observed price premiums for energy efficiency in the purchase sector. Carroll et al. (2016) provided a review of literature on this relationship. There is an expansive literature with regard to this premium for the sale of homes in various countries, including the U.S. (Bloom et al., 2011), across EU countries (DG Energy, 2013) and more specifically in Germany (Cajias and Piazolo, 2013), the Netherlands (Brounen and Kok, 2011), England (Fuerst et al., 2015), Wales (Fuerst et al., 2016) and Ireland (Hyland et al., 2013). In the rental sector, however, there exists a narrower but emerging literature on rental price premiums for energy efficiency. In a review of energy performance certificates (EPC) in selected European countries, DG Energy (2013) found rental price premiums for an increase of one EPC letter grade or equivalent of 4.4% in Austria, 1.5–3.2% in different areas of Belgium and 1.4% in Ireland. Hyland et al. (2013) also found an average increase in rental costs of €5 per month for each EPC grade in Ireland.

Looking specifically toward willingness to pay for rental accommodation, discrete choice modelling of stated preference data again dominates the literature. For example, Farsi (2010) undertook a discrete choice experiment and used random effects regressions of various functional forms to analyse risk premia and willingness-to-pay for energy efficiency in rental apartments in Switzerland, finding a willingness-to-pay for various retrofit measures of between 0 and 11.3% of monthly rent. Phillips (2012) also used a discrete choice experiment to elicit willingness to pay for energy efficiency ratings of home owners, renters and landlords. Using a nested logit, Phillips found a median willingness-to-pay of $3.23 per week for Home Energy STAR certification in the United States. Galassi and Madlener (2016) used a discrete choice experiment, asking survey respondents to imagine they lived in a cold apartment and presenting a s eries of discrete choices between retrofitting measures for that cold apartment. Using a mixed effects logit, Galassi and Madlener found that rental tenants expected a greater disutility from the costs of retrofitting than home owners. As such, renters were less likely to choose greater energy efficiency improvements as these would be more expensive. In Ireland, Carroll et al. (2016) conducted a survey of rental tenants, providing respondents with a discrete choice between differing apartments. Carroll et al. (2016) found, using a mixed logit, that tenants were willing to pay more for EPC improvements than they would be expected to save on energy costs, with willingness-to-pay falling when moving from less efficient to more efficient grades.

We intend to add to the literature on household willingness-to-pay for energy efficiency in the rental sector in three ways. Firstly, we understand that not all households in the sector are willing to pay for improved energy efficiency and attempt to determine whether significant predictors of whether a household is in fact willing to pay for such improvements exist. Secondly, in addition to complementing the literature on the magnitude of the willingness-to-pay by using a different methodology to analyse a similar issue to Carroll et al. (2016), we examine whether the introduction of information regarding energy performance certificates affects either of these issues. Thirdly, we examine the necessity of government subsidies as a means of improving the energy efficiency of the rental building stock.

3. Data and Methodology

3.1. Data Collection

To explore the willingness-to-pay for improved energy efficiency of rental tenants, responses were collected as part of a wider survey of energy related decision-makers in Ireland. An online survey was designed in three iterations. Firstly, the survey was developed and pre-tested by colleagues, most of which possessed post-graduate degrees in economics or other social sciences. This led to the exclusion or modification of several items. This was followed by a pilot survey to test to a small sample of respondents, recruited by a market research firm and finally, a full launch. A nationally representative sample of the Republic of Ireland was recruited in the final stage (n=2,430). This sample is demographically representative of age and region in Ireland. Of this sample, 866 responses were made by individuals living in rental accommodation, renting either from a private landlord, from a local authority or from a voluntary or co-operative housing body.

Of the recruited panel, screening questions were used to first ensure respondents were involved, either solely or jointly, in energy-related decision-making and secondly to ensure data quality through tests of respondents attentiveness to the survey. Any respondents who completed the survey in a time below the 1st percentile or above the 99th percentile of the distribution were excluded. Our final sample consists of 436 rental tenants.

3.2. Survey Design

The survey included several modules related to energy efficiency and background characteristics. After gathering information on the characteristics of respondents' dwellings and their rental tenure, a dichotomous choice contingent valuation methodology was used to determine willingness-to-pay. All respondents were first asked the following:

> "Consider a situation where you are approached with the following proposition regarding your accommodation.
>
> Your landlord offers you a similar property to your current accommodation, which is the same size, has the same number of rooms, same location in terms of proximity to shops, transport, neighbours, work, college, etc. The only difference is that the new accommodation is more energy efficient and therefore has a lower combined cost for heating, lighting and ventilation. Energy efficiency is measured on the BER scale with 15 grades from A1 to G, with A1 being the most efficient.
>
> Taking into account your own circumstances, would you be willing to pay more in your monthly rent if the new accommodation was one grade better on the BER scale (e.g. D1 instead of D2 or B3 instead of C1)?"

Answers in the affirmative were then provided with a double-bounded dichotomous choice willingness-to-pay bidding scenario. Those who expressed an unwillingness to pay for an improved Building Energy Rating were screened out of the two bid questions, which were then presented as follows:

> "Would you be willing to pay €XX in increased monthly rent if your landlord engaged in renovations that would improve the

> Building Energy Rating of the property by ONE GRADE (e.g. from E1 to D2, or from C3 to C2)?"

Respondents were randomly assigned starting bids of €20, €30 or €40. Positive responses led to an increased bid of €10 greater, while negative responses were followed by a second bid €10 less than the original bid. These figures were chosen based on the estimated savings associated with improvements in a dwelling's Building Energy Rating, as published by the Sustainable Energy Authority of Ireland (SEAI, 2014). Based on pilot survey responses, these bid values were broadly spread across the central distribution of willingness-to-pay.

This was followed by the treatment, i.e. the introduction of information. Regardless of their knowledge of Building Energy Ratings prior to the survey, all respondents were provided with the following information:

> "A Building Energy Rating (BER) is an indication of the energy performance of a home. BER is the calculated energy use for space and hot water heating, ventilation and lighting based on standard consumption, in kilowatt hours, for every square metre of a dwelling. A BER is similar to the energy label for a household electrical item like your fridge. The label has a scale of A-G. A-rated homes are the most energy efficient and tend to have the lowest energy bills.
>
> In a typical apartment, a one grade improvement from D1 to C3 could save the occupant approximately €200 in energy costs each year. For a large, detached house, the same improvement could save €800, based on standard occupancy. The reductions in costs associated with improvements in BER vary depending on the size of a home and how efficient it is prior to having energy efficient renovations undertaken.
>
> In light of this information, taking into account your own circumstances, would you be willing to pay more in your monthly rent if the new accommodation was one grade better on the BER scale"

Those who answered in the affirmative were then presented with a further double-bounded dichotomous choice willingness-to-pay bid scenario. Bid questions following the treatment replicated the bid questions prior to the introduction of information.

Those who expressed an unwillingness to pay for an improved Building Energy Rating following the treatment were screened to a question regarding reasons for this unwillingness. In addition to an open-ended response, respondents were asked to state their agreement with a number of potential explanations. The distribution of responses to this question is provided in fig. 2. As can be seen, the most common reason provided for this unwillingness was that respondents did not feel they could afford to pay any more in their monthly rent, with approximately 85% of those unwilling to pay agreeing either somewhat or strongly with the statement. This was followed by those who believed any energy cost savings would be offset by increased rent. The third-most 'agreed with' statement was that respondents' accommodation was already suitably energy efficient. Further reasons cited were that respondents did not want to provide more income to their landlord, while approx. 30% of those unwilling to pay for improved energy efficiency expressed a lack of trust in Building Energy Ratings as a reliable indicator of energy efficiency. We therefore categorise responses to this question as either those of respondents possessing a willingness-to-pay (WTP) of zero or as protest responses. Those who agreed with the former three statements were deemed to possess a WTP of zero. Responses which did not express agreement with these three statements but did agree with one or both of the latter two statements were deemed *protest responses*. This is because those lacking trust in Building Energy Ratings may be otherwise willing to pay for greater energy efficiency, while those not willing to provide their landlord with greater income may be willing to do so with a more preferable landlord. Responses agreeing with one or both of the latter two statements who also agreed with one of the former three statements were categorised as possessing a WTP of zero. This is because these three statements dominate the latter two. We provide an example of a respondent who does not want to provide their landlord with more income but who also cannot afford more rent. In the case that the respondent was in a similar rental situation but with a landlord who they did not have an issue with providing more income to, they would remain unable to afford higher rent costs. Further respondents were also classed as protest responses based on open-ended responses, such as those

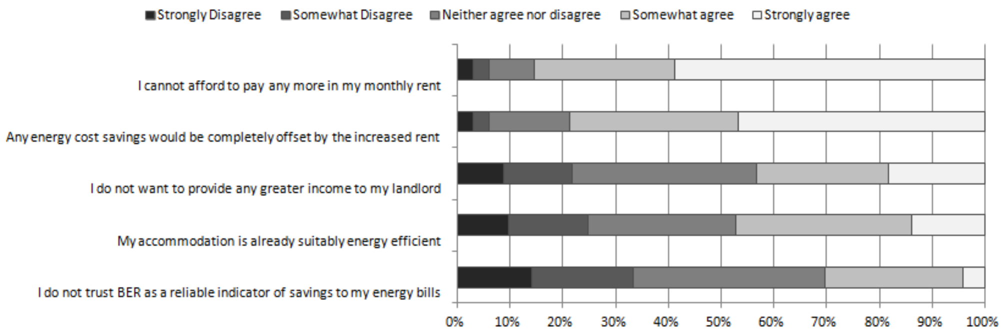

Figure 2: Reasons given for expressing an unwilling to pay for improved energy efficiency

misunderstanding the question and citing an unwillingness to go through the process of moving home, a misunderstanding of how BER is calculated, complaints about landlords being unwilling to refurbish their accommodation, etc. Of 436 respondents, removing protest responses left a remaining sample of 415 respondents.

Table 1 provides summary statistics of the responses to the double-bounded dichotomous choice questions. After the introduction of information, a greater number of respondents expressed a willingness to pay for improved energy efficiency, although the proportion of those responding negatively to the first bid also increased. Without information, 156, or 38% of respondents expressed a willingness to pay more in their monthly rent for an improved Building Energy Rating. This proportion increased to 55.2%, or 229 respondents, following the provision of information. Figure 3 then provides the proportional distribution of respondents present in each bounded willingness-to-pay bracket based on answers provided to the dichotomous choice questions. The introduction of information led to changes in the proportion of households in the €0-30 and €40-50 categories but otherwise has not altered the shape of the distribution.

As a proxy for market stress, we asked respondents their location, dividing responses into four regions. These are based on responses to a question asking to what extent "rental market pressures" influenced their choice of rental accommodation. The first of these are Dublin City and the remaining Greater Dublin Area (GDA), which comprises Dublin County and the counties of Meath, Kildare and Wicklow. Thirdly, the other cities of Ireland, i.e. Cork, Limerick, Galway and Waterford, and lastly, the rest of Ireland. These areas were chosen based on responses to how much influence market pressure placed on respondents' choice of rental accommodation. As described in fig. 4, market pressure exerted greatest influence in Dublin and the GDA, with approximately 55% of respondents in both areas indicating that market pressure exerted a major influence on, or took precedence in influencing their decision. This falls to approximately 40% in other cities, with the rest of Ireland citing market pressure the least.

Other information collected included a range of socio-demographic characteristics of respondents, including their working status, location, age, the number of and age of occupants in the household and whether they are in receipt of specific housing supports[1]. With regard to the characteristics of their rental tenure, respondents are asked the length and type of their tenure, in addition to the cost of rent. Respondents are also asked whether they know the Building Energy Rating of their accommodation and if so, into which letter-grade category does their accommodation fall. Unknown Building Energy Ratings are estimated according to Curtis et al. (2015). Also collected are questions on energy-related knowledge and on pro-environmental and energy-related behaviours. The answers to these questions are collated to create knowledge and behaviour indices, both of which are standardised about zero. Details of questions asked and the calculation of these behaviour and knowledge indices are provided in appendices A and B, respectively. Descriptive statistics are provided in Table 2.

[1] Subsidies chosen are those which provide eligibility for the Sustainable Energy Authority of Ireland's Better Energy Warmer Homes scheme, which provides grant aid for households subject to fuel poverty.

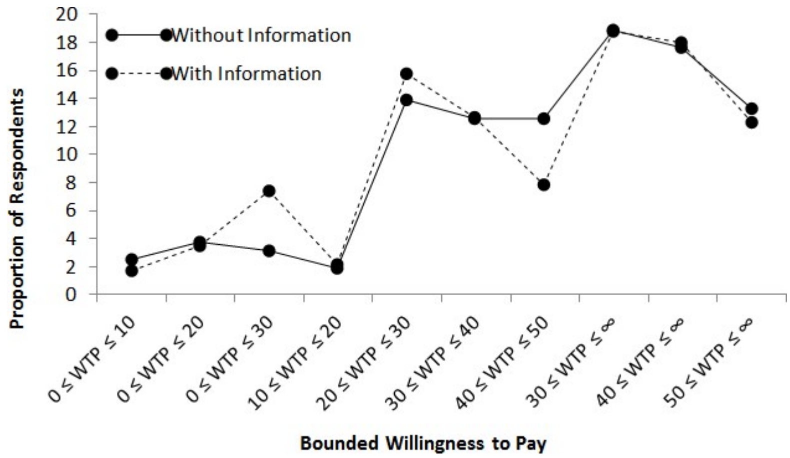

Figure 3: Bounded Willingness-to-Pay of respondents to dichotomous choice contingent valuation survey

Table 1: Responses to double-bounded dichotomous choice questions

Without Information					
Non-Zero Willingness-to-Pay	**No**	**Yes**			
Respondents	**259**	**156**			
(Proportion)	**(62.4)**	**(37.6)**			
First Bid		**No**		**Yes**	
Respondents		**25**		**131**	
(Proportion)		**(6)**		**(31.6)**	
Second Bid		**No**	**Yes**	**No**	**Yes**
Respondents		**14**	**11**	**53**	**78**
(Proportion)		**(3.4)**	**(2.7)**	**(12.8)**	**(18.8)**
With Information					
Non-Zero Willingness-to-Pay	**No**	**Yes**			
Respondents	**186**	**229**			
(Proportion)	**(44.8)**	**(55.2)**			
First Bid		**No**		**Yes**	
Respondents		**53**		**176**	
(Proportion)		**(12.8)**		**(42.4)**	
Second Bid		**No**	**Yes**	**No**	**Yes**
Respondents		**29**	**24**	**64**	**112**
(Proportion)		**(7)**	**(5.8)**	**(15.4)**	**(27)**

3.3. Methodology

3.3.1. Possessing a non-zero willingness-to-pay

Assuming non-negative willingness-to-pay for improved energy efficiency and given that only a proportion of respondents expressed a non-zero willingness-to-pay, we are interested in examining whether there are any significant predictors of possessing a willingness-to-pay. We therefore specify a selection model of the likelihood of possessing a non-zero willingness-to-pay for improved energy efficiency as follows:

$$Pr(WTP > 0) = Pr(y_{1i} = 1) = \alpha z_i + u_{i1} \quad (1)$$

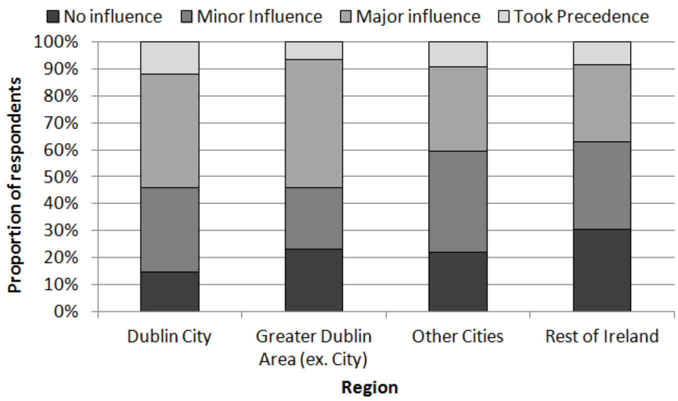

Figure 4: Reported influence of "rental market pressures" on respondents' choice of rental accommodation, by region

where y_{1i} takes a value of one if respondent i possesses a non-zero willingness-to-pay, α is a vector of parameters, z_i is a vector of explanatory variables and u_1 is the error term. We estimate this model using a standard probit regression. To test for sample selection bias in the outcome model, i.e. the willingness-to-pay equation, we must include an explanatory variable which affects the likelihood of possessing a non-zero willingness-to-pay but which does not affect the outcome. We include respondents' region, which, as previously discussed, acts as a proxy for market pressure but it is arguable that income, which is likely to be correlated with region, affects respondents' willingness-to-pay.

3.3.2. Contingent Valuation

We employ a double-bounded dichotomous choice contingent valuation, estimating an interval-censored model which is seen as best practice in the literature (Cameron and Quiggin, 1994; Haab, 1998). Conditional upon possessing a non-zero willingness-to-pay, the true willingness-to-pay for improved energy efficiency, y^*, of respondent i can be expressed as follows:

$$y^*_{2i} = \beta x_i + u_{i2} \qquad (2)$$

where β represents a vector of parameters, x_i represents a vector of determinants of willingness-to-pay and the error, u_2, is assumed to possess a normal distribution with mean 0 and standard deviation σ. This equation forms the basis for estimating the valuation function of each respondent. In order to estimate a valuation function depicting the monetary value of improved energy efficiency, we categorise each respondent possessing a non-zero willingness-to-pay into four binary outcomes. These are based on responses to bid offers presented in the contingent valuation questions and described as follows, with B_{1i} and B_{2i} representing the first and second bid presented to respondent i, respectively:

$$\begin{aligned} I_i^{YY} &= 1(B_{1i} = \text{"yes"}, B_{2i} = \text{"yes"}) \\ I_i^{YN} &= 1(B_{1i} = \text{"yes"}, B_{2i} = \text{"no"}) \\ I_i^{NY} &= 1(B_{1i} = \text{"no"}, B_{2i} = \text{"yes"}) \\ I_i^{NN} &= 1(B_{1i} = \text{"no"}, B_{2i} = \text{"no"}) \end{aligned} \qquad (3)$$

where $1(.)$ is an indicator function taking a value of one when the argument is true and zero if false. Taking this into account, the log-likelihood function of the double-bounded dichotomous choice contingent valuation model can be described as follows:

$$\begin{aligned} lnL = \textstyle\sum_{i=1}^{N} \{ & I_i^{YY} \, ln[1 - \varphi(\frac{B_{2i} - \beta x_i}{\sigma})] + \\ & I_i^{YN} \, ln[\varphi(\frac{B_{2i} - \beta x_i}{\sigma}) - \varphi(\frac{B_{1i} - \beta x_i}{\sigma})] + \\ & I_i^{NY} \, ln[\varphi(\frac{B_{1i} - \beta x_i}{\sigma}) - \varphi(\frac{B_{2i} - \beta x_i}{\sigma})] + \\ & I_i^{NN} \, ln[\varphi(\frac{B_{1i} - \beta x_i}{\sigma})] \} \end{aligned} \qquad (4)$$

where $\varphi(.)$ is again the standard normal cumulative distribution function and ln stands for natural logarithm.

Table 2: Descriptive Statistics

	Observations	Proportion
Tenure		
Rent from a private landlord	317	0.76
Rent from a local authority	85	0.20
Rent from a voluntary/co-operative housing body	13	0.03
	415	
Type of accommodation		
Student/Shared	13	0.03
Other	402	0.97
	415	
Receipt of Subsidies		
Yes	152	0.37
No	263	0.63
	415	
Building Energy Rating		
ABC	161	0.39
DEFG	254	0.61
	415	
Respondent knew BER		
Yes	137	0.33
No	278	0.67
	415	

	Observations	Proportion
Tenure Length		
Less than one year	76	0.18
1 - 3 years	136	0.33
3 - 5 years	83	0.20
5 - 10 years	61	0.15
10 + years	59	0.14
	415	
Working Status		
Working full-time	167	0.40
Working part-time	74	0.18
Working the home/carer	46	0.11
Unemployed	40	0.10
Retired	29	0.07
Student	37	0.09
Unable to work due to sickness/disability	22	0.05
	415	
Region		
Dublin City	109	0.26
Other Cities	64	0.15
Greater Dublin Area (ex. D)	61	0.15
Rest of Ireland	181	0.44
	415	

	Observations	Mean	Std. Dev.	Min	Max
Occupants under 18	415	0.75	1.06	0	5
Occupants aged 19 - 64	415	1.93	0.96	0	7
Occupants aged 65 +	415	0.10	0.37	0	2
Age	415	37.37	12.74	18	78
Energy-related behaviour (scale 0-1)	415	0.62	0.14	0.15	0.91
Energy-related knowledge (scale 0 - 14)	415	5.59	1.75	1	11
Rent per person (€)	408[1]	320.50	253.84	6	2500

[1] Reduced sample size due to non-completion or incorrect completion of question and removal of outiers.

Estimating such a model yields an estimate of the willingness-to-pay of rental tenants for improved Building Energy Ratings. However, our dataset is comprised of a sample of respondents who expressed an explicit unwillingness to pay for improved energy efficiency and a sample of respondents who are willing to pay varying amounts for a one-grade BER improvement. This specification assumes the two yes/no willingness-to-pay responses produced in the survey to be jointly distributed discrete random variables. If this assumption is incorrect, the specification outlined risks underestimating mean WTP for the population and a bivariate specification may be more appropriate Cameron and Quiggin (1998). As we can only analyse our model based on those who expressed a willingness to pay of greater than zero, it is possible that our estimates are subject to selection bias, i.e. estimated levels of willingness-to-pay would likely be greater than those of the population as those possessing a willingness-to-pay of zero are not included in the analysis. In order to test for selection bias, we follow Heckman (1979) in including the inverse Mills ratio, calculated using the estimation of results of the probit model discussed in Section 3.3.1, as an explanatory variable.

4. Results and Discussion

4.1. Willingness to pay for energy efficiency

4.1.1. Likelihood of possessing a non-zero willingness-to-pay

We are first interested in identifying characteristics of rental tenants who may be more likely to possess a willingness-to-pay (WTP) of greater than zero. These are tenants which provide an incentive for landlords to improve the energy efficiency of rental properties. In the case that rental tenants possess a non-zero WTP, landlords could invest in energy efficiency and extract greater surplus, potentially in many instances without reducing consumer welfare. We estimate the selection equation discussed in Section 3.3.1, results of which are presented in Table 3.

Without information, findings can be categorised into four principal areas. These are that tenure length, socio-demographics, market pressure and individual characteristics matter. The results show that the length of time a household has lived in their accommodation has an effect on the likelihood that decision-makers are willing to pay for improved energy efficiency. Those living in their accommodation for between one to three years, three to five years and 5 to ten years are all more likely to possess a non-zero willingness-to-pay than short term tenancies of less than one year and long-term tenancies of greater than ten years. The differences in likelihood across these three categories, however, are not statistically different to one another. Other rental characteristics were not found to be significant predictors prior to the treatment.

With regard to market stress, respondents in the Greater Dublin Area and other cities were found to be no more or less likely than those in Dublin City to possess a non-zero WTP. Those in the rest of Ireland, however, are found to be less likely to possess a non-zero WTP. While it is unclear the exact cause of this, it is possible that tenants in more stressed areas, i.e. the cities and commuter belt, are forced to or feel obliged to choose accommodation which does not meet their initial preferences, while those in low pressure areas are more likely to be able to find accommodation with which they are satisfied.

Age and working status are found to be significant predictors. As people age, they are less likely to possess a non-zero WTP, while those working part-time, students and those working the home and carers were all found to be more likely than those working full-time to be willing to pay more in their monthly rent for improved energy efficiency. Those with higher scores in self-reported pro-environmental behaviour were also found to be more likely to possess a non-zero WTP, although those with greater levels of energy-related knowledge were not. The structure of the household, with regard to the number of occupants of varying age categories, was not found to be statistically significant. The Building Energy Rating of properties did not play a significant role in prediction, nor did the the indicator variable of whether a respondent knew their dwelling's BER.

The introduction of information led to an increase in the likelihood of being willing to pay for improved energy efficiency for those working full-time and those not in receipt of subsidies. These are categories more likely to be able to afford to pay for higher rents. Upon the introduction of information, those paying higher rents also became less likely to possess a non-zero WTP.

As discussed in Section 3.2, a number of options were presented to home owners who expressed an unwillingness-to-pay for improved energy efficiency. As discussed, the valid reasons most cited were that respondents' could not afford to pay higher rents, that energy cost savings would be offset by increases in rent and that their accommodation was already suitably energy efficient. That 85% of those expressing an unwillingness to pay for energy efficiency cited an inability to pay higher rent could be seen as worrying from a standard of living perspective, although rent costs per occupant was not found to be a significant predictor of possessing a non-zero WTP in the no information condition.

4.1.2. Conditional willingness-to-pay

We next estimated the willingness-to-pay for improved energy efficiency, conditional on possessing a non-zero WTP. Results of the WTP estimation are presented in Table 4. Estimates from our model indicate a mean WTP in our sample of €41.72 with a standard deviation of 8.71. As discussed in Section 3.3.2, we include the inverse Mills ratio of the selection model as an explanatory variable in the outcome equation, i.e. the willingness-to-pay model. As shown, this term is not statistically significant either before or after the treatment. As such, we can conclude that sample selection is not an issue in the outcome equation and therefore that the selection and outcome equations are independent. Alternatively, the insignificance of the inverse Mills ratio could be due to an unsatisfactorily specified selection model. The implication of such situation is that there may be bias introduced into the magnitude of estimated WTP, though the overall policy conclusion is unlikely to be effected.

We identify significant predictors of household WTP for improved energy efficiency. We find the type of rental tenure to be significant, with those renting from a local authority found to possess a WTP of €15.54 less than those renting from private landlords, increasing to €46.16 for those renting from voluntary or co-operative housing bodies. This is likely due to income and therefore budget constraints. These effects diminish with the introduction of information, with the difference in WTP between those renting from private landlords and those renting from local authorities falling to €9.14, while the difference between those renting privately and those renting from housing bodies losing significance. The introduction of information led to an increase in WTP of those with members of the household under the age of 18, with WTP rising by €3.72 for every additional minor.

Upon receiving information, the WTP of those who knew their BER fell by €6.64, relative to those who did not. Those living in energy inefficient homes are found to possess a WTP €11.36 less than those living in homes with a BER of 'A', 'B' or 'C', a difference

Table 3: Likelihood of possessing a non-zero willingness-to-pay

	Without Information (1)		With Information (2)	
Tenure (ref = Rent from a private landlord)				
Rent from a local authority	0.295	(0.202)	0.0600	(0.199)
Rent from a voluntary/co-operative housing body	-0.452	(0.459)	-0.202	(0.388)
Student/Shared Accommodation	0.0540	(0.377)	0.0575	(0.399)
In receipt of subsidy	-0.105	(0.179)	-0.330*	(0.180)
Tenure length (ref = Less than one year)				
1 - 3 years	0.517**	(0.203)	0.473**	(0.195)
3 - 5 years	0.794***	(0.226)	0.702***	(0.222)
5 - 10 years	0.620**	(0.242)	0.911***	(0.240)
10 + years	0.166	(0.274)	0.601**	(0.269)
Rent per person (€)	-0.000464	(0.000330)	-0.000584*	(0.000307)
Region (ref = Dublin city)				
Greater Dublin Area (ex. Dublin city)	-0.258	(0.216)	-0.266	(0.210)
Other Cities	-0.177	(0.221)	-0.0989	(0.220)
Rest of Ireland	-0.313*	(0.178)	-0.192	(0.174)
Working status (ref = Working full-time)				
Working part-time	0.363*	(0.197)	0.103	(0.193)
Working in the home/ Carer	0.443*	(0.249)	0.297	(0.251)
Unemployed	0.437	(0.270)	0.198	(0.280)
Retired	0.622	(0.464)	0.559	(0.496)
Student	0.641**	(0.253)	0.559**	(0.250)
Unable to work due to illness/disability	0.478	(0.332)	0.469	(0.339)
Age	-0.0159*	(0.00832)	-0.0255***	(0.00817)
Occupants 18 or under	-0.0726	(0.0735)	-0.0844	(0.0711)
Occupants aged 19 - 64	-0.0122	(0.0858)	-0.0769	(0.0840)
Occupants aged 65 +	0.0780	(0.266)	0.175	(0.286)
Building Energy Rating = DEFG	-0.0162	(0.169)	0.243	(0.163)
Knew BER	-0.160	(0.177)	0.0893	(0.172)
Behaviour (z)	0.143**	(0.0721)	0.123*	(0.0690)
Knowledge (z)	0.00104	(0.0704)	0.0500	(0.0672)
Constant	-0.00562	(0.480)	0.858*	(0.458)
Observations	408		408	
Pseudo R-Squared	0.0776		0.0696	

Robust standard errors in parentheses (*** p<0.01, ** p<0.05, * p<0.1).
Reduced sample size due to non-complete responses to cost of rent and removal of outliers.

that falls to €9.21 with the introduction of information. This might appear to indicate a longer payback period for investment in improved energy efficiency. Less efficient homes, however, possess more potential for improvement. For example, an equally costly energy efficiency investment may lead to a greater BER improvement in an E-rated home, relative to a C-rated home, resulting in an overall greater level of WTP from tenants.

Figure 6 shows the comparison of the distributions of conditional willingness-to-pay before and after the treatment. The pane on the left of the figure shows the overall distribution of conditional WTP for all respondents possessing a non-zero WTP either before or after the treatment, while the pane on the right compares these distributions including only those who expressed a non-zero WTP both before and after the treatment. Both panes present similar patterns, with the introduction of information leading to a convergence in WTP toward a greater peak in the distribution, with a reduction in the size of the tails. It is likely that the information provided gave respondents a reference case for cost reductions available from improving energy efficiency and thus a benchmark level of increased rent respondents would be willing to pay for improved energy efficiency.

As shown in table 5, the point estimate of conditional WTP for the sample fell by almost €9, although this change is not statistically significant. However, the introduction of information led to an increase in the number of respondents expressing a willingness to pay for improved energy efficiency. As shown in Table 1, the number of such respondents possessing a non-zero WTP rose from 156 to 226, an increase of almost 45%. Including those expressing an unwillingness to pay for improved energy efficiency, the mean unconditional WTP of the sample as a whole rose from €17.45 to €20.77 with the introduction of information[2].

Our estimated levels of conditional WTP differ to those found by Carroll et al. (2016), who found a progressively increasing WTP when moving from more to less efficient grades. At the lowest grades, where a change in alphanumeric grade corresponds to a change in letter grade, i.e. from 'G' to 'F' and from 'F' to 'E', Carroll et al find a WTP of €82 and €61, respectively. While we estimate WTP for improvements of one alphanumeric grade, e.g. 'D1' to 'C3', Carroll et al. (2016) estimate same for changes in letter grade. WTP at other grades are therefore not directly comparable. For example, an estimated WTP of €39 to improve from an E to a D may exceed that of certain sub-groups in our population in the case that this improvement were from a 'E1' to a 'D2', whereas this would not be the case for an improvement from 'E2' to 'D1' or from 'E1' to 'D1'. Our estimates are also higher, in turn, than the rental premium associated with energy efficiency in the market estimated by Hyland et al. (2013), who found an average premium of 0.5% of rental costs for each alphanumeric grade. With an average rental price of dwellings of €1,005, this equates to a premium of €5 per grade, much lower than the conditional WTP estimated in this study. Given that only a sub-sample of tenants possess a non-zero WTP, similarly landlords might not all see a value in improved Building Energy Ratings with regard to setting asking prices for rental properties.

4.2. Payback period of investment

In order to examine the returns available to landlords from engaging in energy efficiency investments, we calculate a guideline payback period of certain retrofit measures. This is done by analysing data on costs of retrofits and measured energy efficiency improvements from the Better Energy Homes grant aid scheme. This is an administrative dataset comprising all applications to the scheme, which is operated by the Sustainable Energy Authority of Ireland and provides grants to home owners, including landlords, for a range of retrofit measures. These are attic insulation, three types of wall insulation (cavity wall insulation, internal dry-lining or external wall insulation), three types of heating system upgrade (high efficiency gas or oil boiler with heating controls or heating controls upgrade only) and/or solar heating. This dataset provides information on the retrofit measures for which grant aid was applied, the total cost of each measure and the overall energy efficiency improvement as a result of each retrofit[3].

[2]Excluding protest responses, mean WTP is calculated as a weighted average of the point estimate for the sample of respondents possessing a willingness-to-pay and 0 for those unwilling to pay for improved energy efficiency

[3]This is calculated as the difference between the estimated BER of the property prior to retrofitting and a registered BER assessment following retrofit works. For a more detailed discussion of this process, please see Collins and Curtis (2016a)

Table 4: Conditional willingness-to-pay for improved energy efficiency

	Without Information (3)		With Information (4)	
Tenure (ref = Rent from a private landlord)				
Rent from a local authority	-15.54***	(5.773)	-9.138**	(4.016)
Rent from a voluntary/co-operative housing body	-46.16***	(15.92)	-1.584	(6.890)
Student/Shared Accommodation	-6.521	(9.910)	-6.063	(6.672)
In receipt of subsidy	-0.474	(4.399)	7.784	(5.685)
Tenure length (ref = Less than one year)				
1 - 3 years	-2.152	(8.320)	-6.648	(8.765)
3 - 5 years	-7.422	(11.88)	-12.60	(12.15)
5 - 10 years	-0.399	(10.24)	-13.32	(13.97)
10 + years	-0.0119	(8.411)	-12.68	(11.53)
Rent per person (€)	-0.00936	(0.0101)	0.0154	(0.0102)
Working status (ref = Working full-time)				
Working part-time	-2.439	(6.282)	-1.315	(4.499)
Working in the home/ Carer	-6.329	(7.621)	-2.526	(6.628)
Unemployed	-3.068	(7.872)	0.356	(5.483)
Retired	-4.504	(11.78)	-1.152	(13.09)
Student	-0.781	(9.701)	-11.06	(9.020)
Unable to work due to illness/disability	-12.56	(7.881)	-11.08	(9.200)
Age	0.171	(0.268)	0.276	(0.395)
Occupants 18 or under	1.697	(1.867)	3.726**	(1.847)
Occupants aged 19 - 64	-2.822	(2.285)	0.642	(2.079)
Occupants aged 65 +	-3.812	(5.004)	-5.490	(6.684)
Building Energy Rating = DEFG	-11.36***	(3.610)	-9.209*	(4.703)
Knew BER	1.258	(4.288)	-6.644*	(3.610)
Behaviour (z)	-0.951	(2.350)	0.110	(2.234)
Knowledge (z)	0.690	(1.567)	-0.473	(1.523)
Inverse Mills Ratio	-11.59	(17.45)	-23.54	(23.79)
Constant	70.93***	(20.82)	56.86***	(15.11)
sigma (σ)	14.97***	(1.537)	16.74***	(1.433)
Observations	152		225	

Robust standard errors in parentheses (* p<0.01, ** p<0.05, * p<0.1).**
Reduced sample size due to non-complete responses to cost of rent.
Willingness-to-pay calculated from above as follows: $WTP = \beta_0 + \sum \beta_i X_i$.

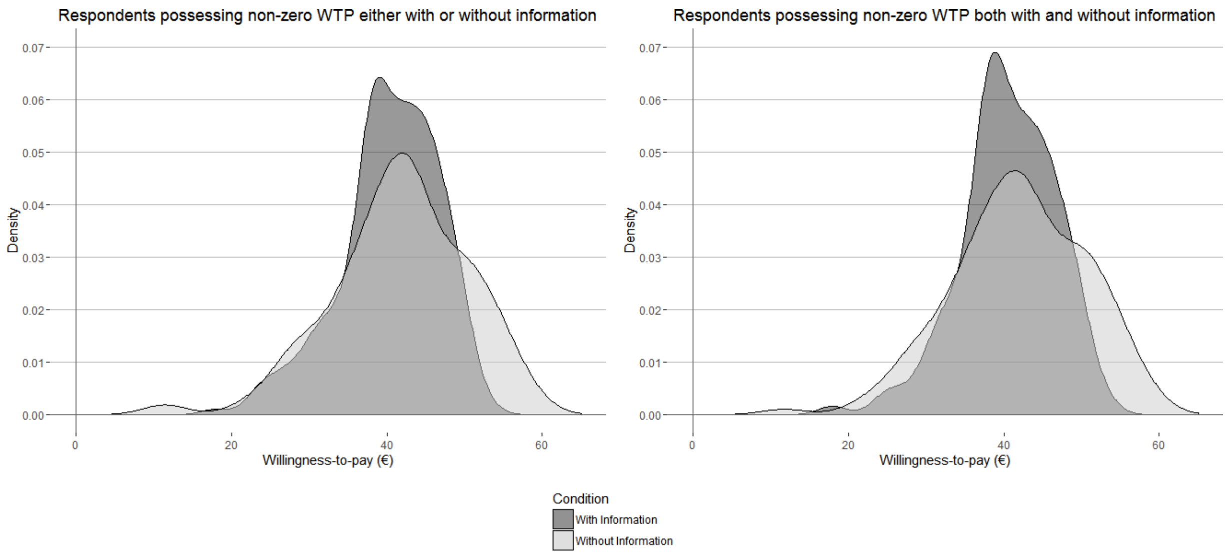

Figure 6: Distribution of predicted willingness-to-pay before and after treatment

Table 5: Point estimates of willingness-to-pay for sub-groups of the sample

	1st WTP Question		2nd WTP Question Post information	
	WTP Point Estimate (€)	Standard Error	WTP Point Estimate (€)	Standard Error
Full sample	46.84	(7.67)	37.66	(2.49)
BER = ABC	53.94	(7.47)	43.51	(2.75)
BER = DEFG	42.58	(8.09)	34.30	(3.67)
Private landlord	51.44	(8.47)	39.64	(2.58)
Non-private landlord	34.41	(6.75)	31.22	(3.90)
Occupants under 18	48.39	(8.53)	41.29	(2.49)
No occupants under 18	45.59	(7.19)	34.96	(3.22)
BER = DEFG, Private landlord, No occupants under 18	45.93	(8.34)	33.59	(4.41)
BER = DEFG, Non-private landlord, Occupants under 18[3]	31.69	(7.89)	31.49	(4.47)

[1] Point estimates calculated using estimated parameters of models (3) and (4), holding all characteristics other than those of interest at their mean sample value.
[2] Calculated using the delta-method (Oehlert, 1992).
[3] Mean number of occupants under the age of 18 of households comprising one or more occupant under the age of 18.

We estimate the payback period of investment using the average total cost of a variety of measures and discounted future income based on increasing rental costs at the average conditional willingness-to-pay of two sub-groups, these being those living in A-, B- and C-rated homes and those living in D-, E-, F- and G-rated homes. This is done for responses after treatment using the total cost of retrofitting. In addition, we examine how the receipt of grant aid via the Better Energy Homes scheme impacts these payback periods, reducing costs by the applicable level of grant aid currently available under the Better Energy Homes scheme. We choose an annual discount rate of 10%, which is representative of the interest rate offered on personal loans by leading Irish banks for amounts similar to the costs of retrofitting. We also estimated payback periods using a discount rate of 15% but payback periods for measures which were deemed to be affordable to landlords were not sensitive to this change.

Table 6 presents these estimated payback periods of some of the more popular combinations observed in the Better Energy Homes scheme, conditional on tenants possessing a non-zero willingness-to-pay for improved energy efficiency. The payback period is measured as the number of months required for a landlord to recover their investment. Strikingly, payback periods for external wall insulation and solar heating are virtually infinite. For the purposes of this analysis, we capped payback periods at 300 months, equivalent to 25 years, as investments with greater payback periods are unlikely to be seen as worthwhile. Without grant aid, only apartments or mid-terrace houses possessing a BER between 'D' and 'G' possess a payback period for external wall insulation of fewer than ten years, although the provision of grant aid does reduce the payback period below ten years for all homes rated 'D' or worse and A-, B- or C-rated apartments and mid-terrace houses. This is quite striking, given that the majority of rental properties for permanent residence are located in cities, where solid walls are much more common than cavity walls. With high rental prices, landlords are unlikely to be willing to engage in investments possessing a long-term return structure, as that may require foregoing rental income while renovations are undertaken. It may also be seen as undesirable to engage in such an investment when rental costs are rising as renovations need not be prioritised as a means of increasing income. In devising policy aimed at improving the energy efficiency of the rental market, the results of this analysis indicate that grant aid may be required for these measures with very long payback periods. This is because without grant aid, these investments would not be profitable for landlords. Low interest financing for landlords would be unlikely to lead to an increase in installations of external wall insulation or solar heating as these payback periods are not very sensitive to changes in the discount rate.

Each of the other retrofit combinations examined possess quite short payback periods. Even without grant aid, each of attic and cavity wall insulation, heating system upgrades and combinations thereof possess payback periods of approximately four years or less in homes considered energy inefficient. Even for homes in the most efficient three letter grades, payback periods do not exceed seven years, even in the absence of grant aid. On this evidence, grant aid may not seem necessary to induce retrofit activity in rental properties, provided tenants are in fact willing to pay for improved energy efficiency. Were policy-makers to consider subsidy schemes specific to the rental sector to promote retrofitting activities there is no reason why the level of subsidy should differ from existing subsidy levels for residential properties. A rental sector specific scheme may act as a nudging mechanism to raise the awareness of the availability of funding for these works. For retrofit measures where payback periods are very long or virtually infinite, a more comprehensive subsidy system may be required to improve energy efficiency, though whether subsidising such measures is prudent is arguable.

4.3. Robustness checks

As discussed in Section 3.2, not all respondents knew the the Building Energy Rating of their accommodation and, as such, unknown ratings were estimated according to Curtis et al. (2015). It is possible that these are not entirely accurate. As a robustness check, we estimate mean WTP before and after the treatment for both the sample as a whole and including only those respondents with knowledge of the Building Energy Rating of their accommodation. This is done by re-estimating models (3) and (4) for both the full and reduced sample. The estimated parameter presented here is point estimate of the mean willingness-to-pay and its confidence intervals. This mean WTP calculated in each instance is presented in Table 7 alongside the log-likelihood of the model. As can be seen, while those who know their BER have a much larger estimated WTP in the no information

Table 6: Payback periods of specific energy efficiency retrofit investments for landlords, in months

	No Grant Aid		Better Energy Homes Grant Aid	
BER of property:	**ABC**	**DEFG**	**ABC**	**DEFG**
Attic and cavity wall insulation	42	24	25	15
External wall insulation - Apartment/mid-terrace house	>300	103	120	55
External wall insulation - End-of-terrace/semi-detached house	>300	297	>300	108
External wall insulation - Detached house	>300	>300	181	84
High efficiency boiler with heating controls	49	40	38	31
Heating controls only	40	24	22	14
Solar thermal	>300	>300	253	>300
Attic and cavity wall insulation, high efficiency boiler with heating controls	81	45	50	30
Attic and cavity wall insulation, heating controls	39	32	18	15

Mean Costs and BER grades improved:

	Costs (€)		BER Grades Improved	
	Total	**With Current Grant**	**ABC**	**DEFG**
Attic and Cavity Insulation	1,537	937	1	2
External wall insulation - Apartment/Mid-terrace	5,285	3,035	1	2
External wall insulation - End-of-terrace/Semi-D	8,337	4,937	1	2
External wall insulation - Detached House	8,656	4,156	1	2
Boiler with Heating Controls	3,494	2,794	2	3
Heating Controls only	1,470	870	1	2
Solar Thermal	5,923	4,723	1	1
Attic, Cavity, Boiler	5,157	3,557	2	4
Attic, Cavity, HC	2,880	1,380	2	3

	ABC	DEFG
Average WTP (€)	43.51	34.3

[1] Payback period calculated with annual discount rate of 10%.

[2] Mean WTP for each sub-group are those presented in table 5 and may vary by the average grade number of grades associated with BER improvements for each retrofit measure.

[3] The amount of grant aid awarded for external wall insulation varies by dwelling archetype. As such, costs and improvements associated with these archetypes, while WTP is not found to vary across archetype. Information on the level of grant aid available for retrofit works is available at http://www.seai.ie/Grants/Better_energy_homes/About_the_Scheme/.

condition, the confidence intervals in which this estimate is bounded are quite large, perhaps owing to the small sample size. Regardless, differences in estimates are not statistically significant.

5. Conclusion and Policy Implications

Residential retrofits have been identified by policy-makers in Ireland as an opportunity for policy-makers to help meet policy targets for energy efficiency, and carbon emissions. The majority of retrofitting work completed through the market-based Better Energy Homes scheme have occurred in owner-occupied homes. Due to upward pressure on rents in Ireland over a number of years, there is less incentive for landlords to improve the energy efficiency of rental properties. We examine, using stated preference data, the willingness-to-pay of tenants for improved energy efficiency to identify whether certain tenants are more likely to be willing to pay for energy efficiency. In turn, we then examine how much tenants are willing to pay for energy efficiency, measured using the Irish Building Energy Rating. Using an administrative dataset of grant-aided retrofits, we examine whether grant aid is necessary to encourage landlords to invest in energy efficiency retrofit works.

Conditional upon possessing a non-zero willingness-to-pay, we find that tenants in Ireland are willing to pay an average of €46.84 for each one-grade improvement in their accommodation's Building Energy Rating. This falls to €37.66 on the introduction of improved information regarding Building Energy Ratings, but this difference is not statistically significant. This paper also investigates the expected payback period of certain retrofit measures for landlords, using mean observed BER improvements and investment costs as observed in the Better Energy Homes scheme. We find short payback periods for attic and cavity wall insulation and virtually infinite payback periods for external wall insulation and solar thermal panelling. This has significant welfare implications, as investing in those measures with short payback periods can lead to welfare improvements.

We complement the literature on the willingness-to-pay for improved energy efficiency among rental tenants. This study differs from other studies by examining rental willingness-to-pay in current, stressed market conditions and by using a contingent valuation method. We also add an application to investment decision-making by landlords, considering potential policy measures which could help to improve the energy efficiency of rental properties, which at the moment lags behind the energy efficiency of the owner-occupied sector.

Various policy implications can be taken from the findings of this research. Information has been shown to increase the likelihood that tenants are willing to pay increased rent for energy efficiency, with those possessing a non-zero willingness-to-pay also more likely to value non-monetary benefits of engaging in retrofit works, such as improved comfort and health. While informing tenants of these benefits may induce a willingness to pay for improved energy efficiency, certain retrofit measures will not provide an 'adequate' return on investment for landlords even with current levels of subsidy grants.

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Table 7: Mean willingness-to-pay for improved energy efficiency for sub-groups of the sample

	Respondents	Mean WTP (€)	95% Confidence Intervals		Log Likelihood
Before Treatment	All Respondents	46.84	31.8068	61.8732	-170.42976
	All respondents who knew BER	73	31.79	114.22	-33.180335
After Treatment	All Respondents	37.66	21.8036	53.5164	-263.27974
	All respondents who knew BER	39.99	35.45	44.53	-80.50003

[1] Point estimates calculated using estimated parameters of models (3) and (4), holding all characteristics other than those of interest at their mean sample value.

[2] Confidence intervals calculated using delta-method standard errors (Oehlert, 1992).

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Appendix A. Pro-environmental and energy-related behaviour index

The following details questions regarding pro-environmental behaviours and the score attributable to each answer. The mean score across all applicable questions provides a raw score between 0 and 1, with 1 being the most preferred. Observed scores were standardised around 0 for use in analysis, using the following formula:

$$\frac{Score_i - \bar{Score}}{\sigma_{Score}}$$

1. How often would you say you engage in each of the following:

   - Average of:

	Rarely	Sometimes	Often
Turn off lights when leaving a room	0	0.5	1
Decide not to buy products due to excess packaging	0	0.5	1
Leave tap running while brushing your teeth	1	0.5	0
Bring your own bag when shopping	0	0.5	1
Walk of cycle for short journeys (up to 3km)	0	0.5	1
Car share with others who make a similar journey	0	0.5	1
Avoid disposable products in favour of reusable	0	0.5	1

2. Which of the following do you separate from your general waste? (Please select more than one if applicable)

   - Sum of:

0.33: Dry Recycling (paper, cardboard, plastic, tetra-pak)
0.33: Organic Waste (cooked or raw food, teabags, napkins, etc.)
0.33: Glass (bottles and jars)
0.33: I do not separate any of above

3. How do you dispose of small batteries?

   - One of:

1: Bring to shop or recycling centre
1: Bring in to work for recycling
1: Children bring to school for recycling
1: Other collection point
1: Other
0: General waste (do not recycle batteries)

4. Thinking of the last time your household purchased an electric appliance, such as a toaster, washing machine, etc., how much did each of the following influence your decision?

   - If applicable, sum of:

	Had no influence	Had only a minor influence	Had a major influence	Took precedence in influencing the decision
Price	0	0	0	0
Brand Reputation	0	0	0	0
Size	0	0	0	0
Colour	0	0	0	0
Energy efficiency Rating	0	0.33	0.66	1
Other aspect(s)	0	0	0	0

5. **What is your household's main method of disposing of small electrical and electronic equipment such as toasters, hair-dryers, mobile phones, etc.?**

    - **If applicable, one of:**

0: Put them in household general waste
1: Return them to retailer
1: Bring to a recycling centre
1: Re-use, e.g. give to a family member or friend
1: Stored at home

6. **How often do you change electricity and/or gas provider?**

    - **One of:**

1: Every year
0.75: Every 2–3 years
0.5: Every 4–5 years
0.25: Every 6–10 years
0: Never

7. **If you own a car, how much did each of the following influence your decision when making the purchase?**

    - **If applicable, sum of:**

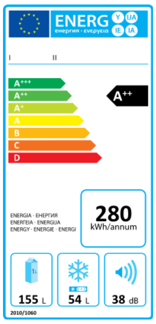
	Had no influence	Had a minor influence	Had a major influence	Took precedence in influencing the decision
Price	0	0	0	0
Annual level of motor tax	0	0	0	0
Fuel consumption	0	0	0	0
Other costs (insurance, servicing, etc.)	0	0	0	0
Environmental concerns (e.g. car emissions)	0	0.33	0.66	1
Resale Value	0	0	0	0
Family Requirements	0	0	0	0
Other aspects	0	0	0	0

Appendix B. Energy-related Knowledge Index

The following details questions regarding energy-related knowledge and the score attributable to each answer. The sum of all scores provides a raw score, which is then standardised about zero using the following formula:

$$\frac{Score_i - \bar{Score}}{\sigma_{Score}}$$

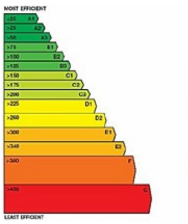
1. To which of the following does this label refer?



- **One of:**

0: Building Energy Rating
0: Vehicle fuel efficiency label
1: Home appliance energy efficiency label
0: Water efficiency label
0: Don't know

2. To which of the following does this label refer?



- **One of:**

1: Building Energy Rating
0: Vehicle fuel efficiency label
0: Home appliance energy efficiency label
0: Water efficiency label
0: Don't know

3. What is your yearly electricity consumption, in kilowatt hours?

- **One of:**

1: 0 – 5,000
1: 5,000 – 10,000
1: 10,000 – 15,000
1: 15,000 – 20,000
1: 20,000 – 25,000
1: 25,000 – 30000
1: 30,000+
0: Don't know

4. How much do you think each of the following fuels cost per delivered unit og energy (kilowatt hour)?

- **Sum of:**

	1–10 cent	10–20 cent	20–30 cent	Don't know
Peat	1	0	0	0
Coal	1	0	0	0
Oil	1	0	0	0
Natural Gas	1	0	0	0
Electricity (day rate)	0	1	1	0

5. In each of the following cases, please choose the option which you think produces less emissions per unit energy produced

- **Sum of:**

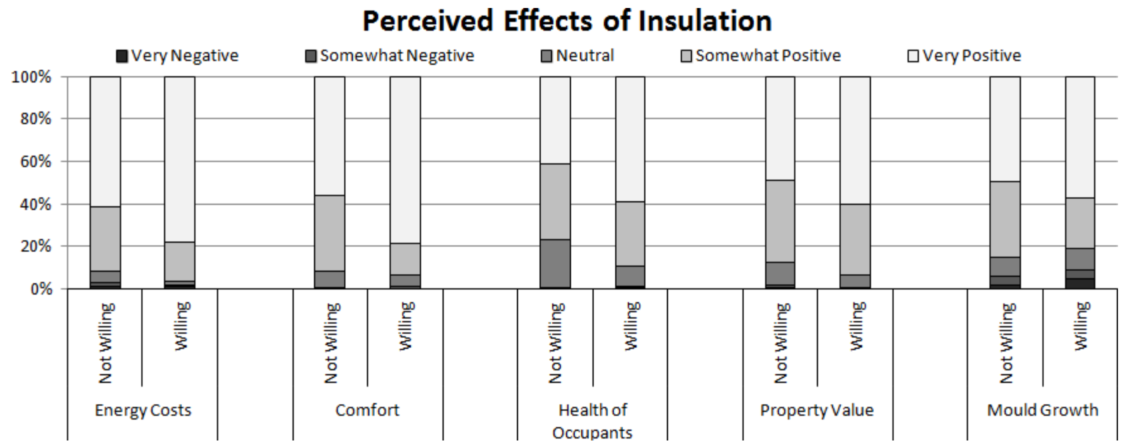
	A	B
A: Peat or B: Oil	0	1
A: Gas or B: Electricity	1	0
A: Gas or B Coal	1	0
A: Coal or B: Oil	0	1
A: Electricity or B: Peat	0	1

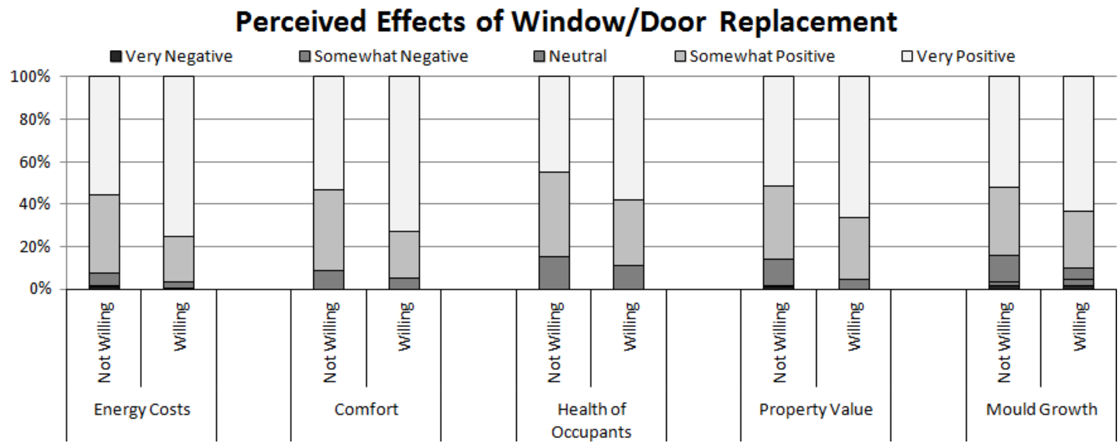
6. Do you know how much your last gas bill cost?

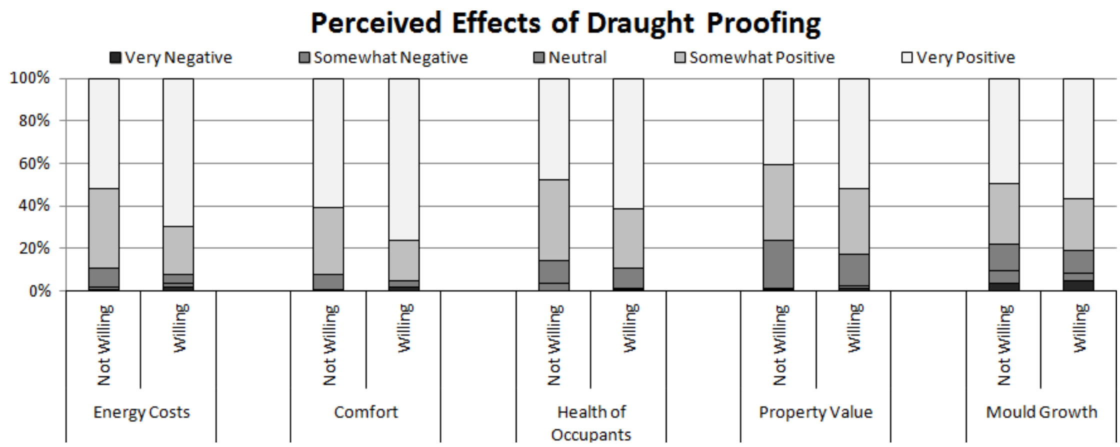
- **One of:**

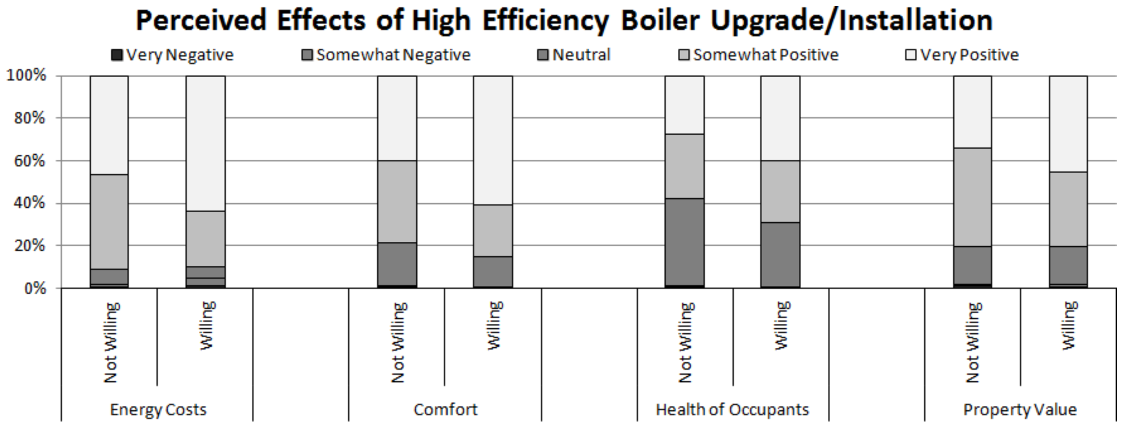
1: €0–€25
1: €26–€50
1: €51–€75
1: €76–€100
1: €101–€124
1: €125–€150
1: €150+
0: Don't know

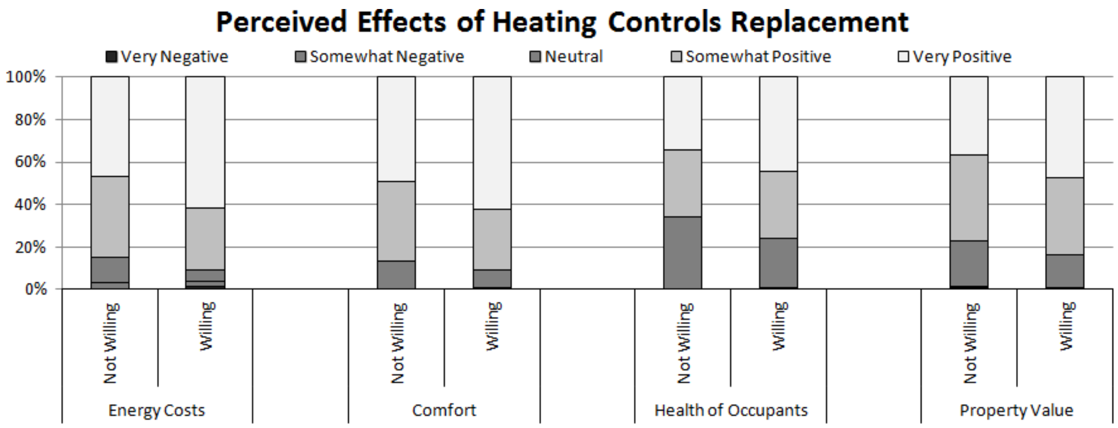
Appendix C. Perceived effects of engaging in certain retrofit measures

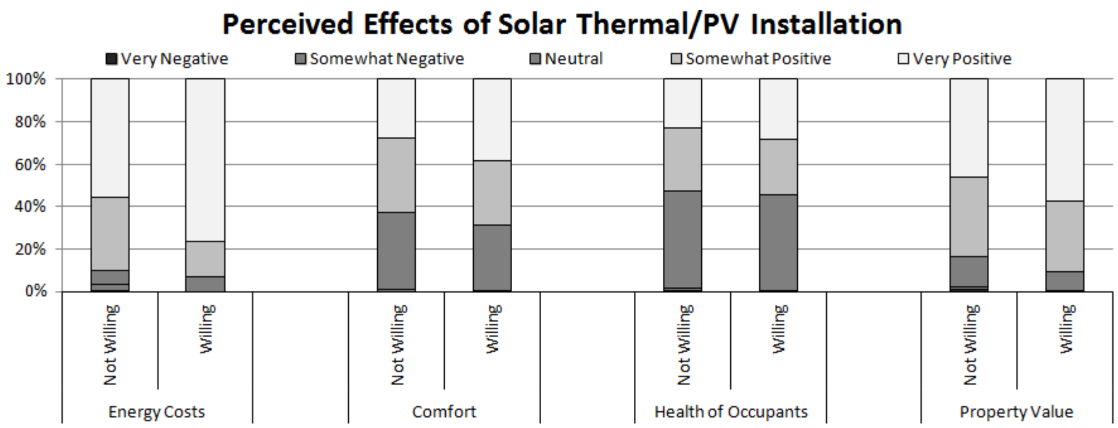







Perceived Effects of High Efficiency Boiler Upgrade/Installation
Very Negative
Somewhat Negative
Neutral
Somewhat Positive
Very Positive
100%
80%
60%
40%
20%
0%
Not Willing
Willing
Energy Costs
Comfort
Health of Occupants
Property Value


Perceived Effects of Heating Controls Replacement
Very Negative
Somewhat Negative
Neutral
Somewhat Positive
Very Positive
100%
80%
60%
40%
20%
0%
Not Willing
Willing
Energy Costs
Comfort
Health of Occupants
Property Value


Perceived Effects of Solar Thermal/PV Installation
Very Negative
Somewhat Negative
Neutral
Somewhat Positive
Very Positive
100%
80%
60%
40%
20%
0%
Not Willing
Willing
Energy Costs
Comfort
Health of Occupants
Property Value

Year	Number	Title/Author(s) ESRI Authors/Affiliates *Italicised*
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