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The value of domestic building energy efficiency – evidence from Ireland

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Abstract

Following the transposition of the EU Energy Performance of Buildings Directive into Irish law, all properties offered for sale or to let in Ireland are obliged to have an energy efficiency rating. This paper analyses the effect of energy efficiency ratings on the sale and rental prices of properties in the Republic of Ireland. Using the Heckman selection technique we model the decision to advertise the energy efficiency rating of a property and the effect of energy efficiency ratings on property values. Our results show that energy efficiency has a positive effect on both the sales and rental prices of properties, and that the effect is significantly stronger in the sales segment of the property market. We also analyse the effect of energy efficiency across different market conditions and we find that the effect of the energy rating is generally stronger where market conditions are worse.

Key words: domestic building energy ratings, hedonic valuation, Ireland

1. Introduction

Buildings, in particular homes, account for a significant proportion of emissions in developed economies. In the EU, residential emissions account for roughly one sixth of emissions (European Commission, 2011), while in the U.S., buildings accounted for 41% of all energy consumption in 2010, up from 33% in 1980, with residential buildings alone accounting for 22.5% (U.S. Department of Energy, 2012).

In order to limit the extent of global warming to 2°C, world leaders have endorsed proposals in the Copenhagen and the Cancun Agreements for developed economies to drastically reduce their emissions. For example, the European Union aims to reduce greenhouse gas emissions by 80-95% by 2050. The European Commission believes that the key to achieving this reduction will be increased energy efficiency, estimating that by 2050 built environment emissions could be 90% lower (ibid.).

However, upgrading a home to improve its energy efficiency could, depending on the property, involve a significant financial investment. Likewise, new properties being built to high standards of efficiency are likely to have higher input costs. Therefore, an important question to ask is: are potential renters or buyers willing to pay for this increased energy efficiency, and if so how much? Furthermore, as property purchasers are likely to reap the rewards of owning an energy efficient home for longer than renters, is there a difference in the premium purchasers and renters are willing to pay? And does this willingness to pay extra vary by market conditions?

In this paper we examine the effect of the Irish system of energy efficiency ratings on house prices and rental rates, using an extensive dataset of property listings from 2008 to 2012. A Building Energy Rating (BER) is an objective measurement of the energy efficiency of a building. Homes which have been assessed are given a rating from A1 to G (where A1 is the most efficient) on the basis of the efficiency of the space and water

heating, ventilation, insulation and lighting fixtures in the building. A higher efficiency rating for a home is expected to translate to lower energy bills. However, the SEAI (2010) note that the BER is only indicative of energy usage, and that actual energy usage will be dependent upon the behaviour of household members; thus, they state, it is similar to a miles per gallon rating for a car. As well as the energy efficiency of a building, a BER certificate also reports the carbon dioxide emissions associated with the building (expressed as kgCO₂/m²/year) (SEAI).

BER certificates were adopted in Ireland following the passing of the EU Directive on the Energy Performance of Buildings into Irish law in 2006. The Sustainable Energy Authority of Ireland (SEAI) was designated as the issuing authority for BER certificates in Ireland. As of January 1st 2007, if planning permission is sought for a new dwelling, a BER certificate is compulsory and, as of January 1st 2009, any existing home offered for sale or for rental must have a BER certificate. In 2013, new legislation (the Recast Energy Performance of Buildings Directive) will ensure that when properties are offered for sale or to let, provided the property has a BER certificate, the energy rating must be stated in the advertisement (European Parliament and Council, 2010). As per the Energy Performance of Buildings Directive, certain buildings are exempt from the BER legislation¹. A fine of up to €5,000 can be levied for non-compliance with the legislation (European Communities, 2006).

The BER assessment can be carried out by any assessor who has been certified by the SEAI, and the charge per assessment depends upon the assessor but, on average, ranges between €109 and €250 depending on the size of the building (from various assessor

¹ These are: protected structures, national monuments, places of worship, certain temporary buildings, industrial/agricultural buildings with low installed heat capacity and stand-alone buildings with a useful floor area of less than 50m².

websites). Once a BER assessment has been carried out, the BER certificate is valid for 10 years, provided that no significant change is made to the building within that time (SEAI, 2010). Any building which is being let or sold on the basis of plans must have a provisional BER certificate, which is valid for a maximum of two years.

There is a small existing literature on this subject, principally based on the commercial property sector, almost all of which find a positive effect of energy ratings on property prices and rental rates, although there is no consensus yet on the scale of the effect. The literature on residential energy ratings is much smaller, although studies from the Netherlands, Australia and China all find a positive effect.

The contribution of this paper is threefold. Firstly, it is the first paper to examine Ireland's BER system and the impact it has on property valuations. Secondly, it is the first paper that we know of which examines the extent to which there is a residential lettings premium, and thus it is also the first to compare across residential sales and lettings segments. In this sense, it is the residential market equivalent of Eichholtz, Kok & Quigley (2010). Lastly, it is the first paper to examine whether there are structural variations in the house price premium associated with greater energy efficiency, including between urban and rural markets, between large and small properties and in different periods with different market conditions.

The rest of the paper is structured as follows: Section 2 contains a review of the relevant literature, Section 3 outlines the methodology, Section 4 describes the data, Section 5 presents the results and, finally, Section 6 concludes.

2. Previous research

Early literature on the effects of energy efficiency in the real estate market dates back to Gilmer (1989) and Dinan and Miranowski (1989) who found positive impacts of energy

labels and energy-efficiency improvements. More recently Banfi et al. (2008) examined households' willingness-to-pay for more energy efficient buildings in Switzerland. The results show that respondents are willing to pay approximately 8% for improved ventilation, and 6-7% for façade insulation. However, householders were asked to choose between hypothetical options and their willingness-to-pay may be different when faced an actual economic decision.

Much of the more recent research on energy efficiency has used market data. A study of the impact of energy efficiency in the residential housing market was commissioned by the Australian Department of the Environment, Water, Heritage and the Arts (Australian Bureau of Statistics, 2008). The study finds that in 2005, for each additional 0.5 score on the energy rating scale, house prices increases by 1.23 percent, *ceteris paribus*; this figure increases to 1.91 percent in 2006. However, the size of the label effect falls when the energy label and energy efficiency characteristics of the house are accounted for separately.

Brounen and Kok (2011) examine the effect of energy ratings on house prices in the Netherlands. The authors use a two-stage selection model to look at the factors that influence whether or not a home has an energy rating, and the effect the rating has on the price of those properties that are rated. The authors find that larger buildings are less likely to have an energy label and that label adoption tends to be associated with difficult selling conditions. Furthermore, they find that a positive rating has a significant, positive effect on the transaction price of the property; homes with a "green" label (rated A, B or C) receive a price premium of 3.7% *ceteris paribus*. And homes with an "A" rating receive a transaction price 10.2% higher than similar homes with a "D" rating.

Zheng et al. (2012) examine the emerging market for eco-friendly real estate in China. The authors construct a measure of "greenness", based on marketing by property developers.

The authors find that “green-marketed” properties initially receive a price premium but subsequently resell or are leased at a price discount. They note that this may be due to the fact that buildings marketed as “green” may not be more energy efficient, and thus recommend the introduction of an official system of energy efficiency ratings.

Evidence of the effect of energy efficiency in the German residential market is provided by Cajias and Piazzolo (2012) who find that a one percent increase in energy efficiency increases rents by 0.08 percent and the market value of properties by 0.45 percent.

Research on residential property in California has found a larger effect; Kahn and Kok (2012) estimate that homes which are labelled as “energy efficient” transact at a premium of 9 percent.

All these studies agree on the positive relationship between residential property values and energy efficiency. However, studies by Yoshida and Sugiura (2011) and Amecke (2012) have found mixed results. Analysing the transaction prices of condominiums in Tokyo, Yoshida and Sugiura (2011) find that while green buildings generally trade at a price premium, once building age and quality are controlled for this price effect disappears and, in some cases, having an energy-efficient rating may lead to a fall in transaction prices. The authors believe that this may be due to a perception of higher maintenance costs, and uncertainty about the quality of materials amongst potential buyers. The authors also note a potential omitted variable: it may be that certain buildings are built in an energy-efficient way in order to compensate for factors such as poor location or a developer’s unfavourable reputation.

Amecke (2012) examines the effectiveness of energy performance certificates in helping home buyers to incorporate energy efficiency into their purchasing decisions. The author conducted a survey of property owners who had purchased their homes since 2009, and found that energy efficiency certificates had only a limited effect on purchasing decisions.

However, the authors do note that new mandatory legislation which will come into effect in 2013 is likely to boost the effectiveness of energy ratings.

A slightly more established literature has examined the effect of energy ratings in the commercial property market. Evidence of a positive association between “green” certification and the financial performance of commercial property in the United States has been found by Wiley et al. (2008), Das et al. (2011), Fuerst and McAllister (2011b) and Reichardt et al. (2012). Evidence of this positive relationship has also been found in the UK, by Chegut et al. (2011), and in the Netherlands, by Kok and Jennen (2011).

Eichholtz, Kok & Quigley have published two of the most well-known studies in the area. Eichholtz et al. (2010) find a significant positive effect for buildings which were certified as “green”: on average green offices command approximately 3% higher rents *ceteris paribus*. Furthermore, they find that green labels increase effective rent (rent adjusted for occupancy) by 7% and sales prices by 16%. The authors note that the premium for green buildings is higher in areas where market conditions are worse, i.e.: areas that generally command lower rents. In a second paper with an expanded dataset and more refined econometric techniques, Eichholtz et al. (2013) confirm their original finding that energy efficiency is capitalised in property values and find no evidence that the relative demand for energy-efficient office space weakened during the recent economic downturn.

As with the residential market, not all studies find a positive effect. Fuerst and McAllister (2011a) measure the effect of energy ratings on the rental and capital values of commercial office space in the UK. While they find that energy rating certificates have no significant impact, they also note the relative small sample size (n=708) and the fact that the study was based on assessor valuations rather than transaction prices.

The main findings from the literature are summarised in the table below.

Table 1: Summary of research results

Citation	Country	Property type	Transaction type	Major finding
Gilmer, 1989	USA (Minnesota)	Residential	Sales	Energy-efficient labels shorten search times
Dinan & Miranowski, 1989	USA (Des Moines, Iowa)	Residential	Sales	Efficiency improvements increase expected sales price
ABS, 2008	Australia	Residential	Sales	House prices increase by 1.2% in 2005 and 1.91 in 2006 for each increase along the efficiency scale
Brounen & Kok, 2011	Netherlands	Residential	Sales	Buildings certified as “green” receive approx. 3.7% sales premium
Zheng et al., 2012	China	Residential	Sales	“Green-marketed” residential projects receive an initial sales price premium, but resell or are let at a price discount
Cajias & Piazzolo, 2012	Germany	Residential	Sales and Rentals	A 1% increase in energy efficiency increases rents by 0.08% and market value by 0.45%
Kahn & Kok, 2012	USA (California)	Residential	Sales	Homes labelled as “energy efficient” transact at a premium of 9%
Yoshida & Sugiura, 2011	Japan	Residential	Sales	Green buildings trade at a price <i>discount</i> of approx. 5.5%
Amecke, 2012	Germany	Residential	Sales	Energy performance certificates have a limited effect on purchasing decisions
Kok & Jennen, 2011	Netherlands	Commercial	Rentals	Buildings labelled as energy <i>inefficient</i> trade at a 6.5% discount
Eichholtz, Kok, Quigley, 2010	USA	Commercial	Sales and Rentals	Buildings certified as “green” receive approximately a 3% rental premium and a 16% price premium
Reichardt et al., 2012	USA	Commercial	Rental	Energy-efficient buildings enjoy a premium of, on average, 2.5-2.9%. Positive association with occupancy rates
Das et al., 2011	USA	Commercial	Rental	Positive returns to certification, stronger in difficult market conditions: a green certificate adds 2.4% to rental price in a down-market, and 0.1% in an up-market
Wiley et al., 2008	USA	Commercial	Sales and Rentals	Rental premium for green buildings is between 7% and 17%, and sales price premium is from approx. \$30 to \$130/ft ² , depending on the type of certification
Fuerst & McAllister,	USA	Commercial	Sales and Rentals	Rental price premium of 4-5% and sales price premium of approx.

Citation	Country	Property type	Transaction type	Major finding
2011b				30% for certified “green” buildings
Eichholtz, Kok, Quigley, 2013	USA	Commercial	Sales and Rentals	A certified “green” building translates to a 3% premium for rental rates, 8% for effective rents ² and 13% for sales
Fuerst & McAllister, 2011a	UK	Commercial	Rental and Capital values	Found green certificates had no significant effect on the financial performance of properties
Chegut et al., 2011	UK	Commercial	Sales and Rentals	Green buildings receive 21% rental premium and 26% price premium. Increasing the number of green buildings decreases the premium

3. Methodology

Hedonic regression techniques are commonly used to estimate the value of individual attributes of a property whose prices are not directly observed. As outlined by Rosen (1974), hedonic prices are revealed by the observed price of the house and the attributes associated with it. The implicit prices of the characteristics are estimated by regressing the observed price of a house on its attributes (such as size, number of bedrooms/bathrooms, location, etc.).

As Rosen (1974) explains, in the hedonic regression the size of the coefficient on each variable represents the value each characteristic contributes to overall value. A hedonic regression takes the following form:

$$p = f(x, n, c) + \varepsilon$$

In this case, p refers to the price of the property, x is a vector of house/apartment characteristics, n is a vector of location characteristics, c is the energy rating (i.e.: the BER certificate) and ε is the error term.

² Rental rates adjusted for occupancy

Running this regression should yield an estimate of the implicit value of a more energy efficient home. However, in Ireland not all homes have a BER certificate and, for those that do have one, not all owners advertise the BER when listing the property for sale or rent. Thus, it is possible that the sample used in this study is subject to selection bias, meaning it would be unsafe to apply the inferences from a simple hedonic regression to unobserved groups, i.e., the results may apply only to an atypical set of houses. According to Heckman (1979) when individuals self-select into a sample "...fitted regression functions confound the behavioral parameters of interest with parameters of the function determining probability of entrance into the sample". In order to control for sample selection bias (which may be thought of as a form of omitted variable bias), we employ the Heckman selection model.

A detailed explanation of the Heckman procedure can be found in Greene (2002), who outlines that the problem of "incidentally truncated" or non-randomly selected samples can be formulated in a two equation model. The first equation determines selection into the sample and takes the following form:

$$z_i^* = w' \gamma_i + u_i$$

The second equation is the outcome equation, which is the equation of interest:

$$y_i = x_i' \beta_i + \varepsilon_i$$

Where y_i is observed if z_i^* is greater than zero, i.e.:

$$y_i = \begin{cases} x_i' \beta + \varepsilon_i & \text{if } z_i^* > 0 \\ - & \text{if } z_i^* \leq 0 \end{cases}$$

Greene notes that u_i and ε_i are bivariate normal with correlation coefficient ρ :

$$u_i \sim N(0,1)$$

$$\varepsilon_i \sim N(0, \sigma^2)$$

$$\text{corr}(u_i, \varepsilon_i) = \rho$$

If u_i and ε_i are uncorrelated (i.e. if $\rho = 0$), estimating the selection and outcome equations with OLS will yield consistent estimates of β . However, in the case of property prices and BER certificates we have reason to believe that the error terms from the two equations are correlated; it may be that sellers of better quality homes are more likely to advertise their BER and also more likely to command a higher price, i.e.: there is an unobserved “quality” effect that affects both the decision to advertise a BER and the value of a property. As such we estimate our equation using the Heckman procedure. In this case, the first stage of the Heckman procedure models the decision to include a BER in the house listing on the daft.ie site (see Section 4), and the second stage models the effect of having a higher or lower BER on house prices or rental rates. Figure A1 in the appendix compares the distribution of BER ratings in our sales and lettings samples relative to the entire population of BER-certified properties. This graph shows that the BER of those properties who choose to advertise a BER is skewed towards the higher end of the distribution, indicating that sample selection is likely.

In practice, to implement the Heckman model it is necessary to have an exclusion restriction – akin to an instrument, i.e., a variable which is an important determinant of the decision to advertise the BER (the selection equation) but which is uncorrelated with property price (the outcome equation). In our analysis we use mandatory BER legislation as our exclusion restriction. As of January 1st 2009 all homes offered for sale or rental were obliged to possess a BER certificate. Although this regulation did not require sellers and lessors to advertise the BER to potential purchasers or lessees, it seems reasonable to expect that possessing a BER makes advertising it more likely. We therefore include a dummy variable in the selection equation set equal to zero before this date and 1 after it. It

is important in the second stage of the model that the variable satisfying the exclusion restriction be independent of property value; therefore, to control for any correlation between property prices or rents and this variable we include time dummies in our regressions.

4. Data employed

According to the Sustainable Energy Authority of Ireland, the body responsible for energy certificates in Ireland, in early 2012 there were 269,843 properties in Ireland with a BER certificate. With preliminary results from the 2011 census indicating 2,004,175 houses in Ireland, this means that approximately 13% of the total housing stock has a BER certificate. It is a subset of these properties, i.e. those offered for sale or rental on daft.ie, which we are using in our analysis of the effectiveness of BER certificates. Furthermore, bearing in mind the potential for selection bias, it is worth noting that the properties in the BER data set are different from the population of Ireland's properties in a number of significant ways; see Appendix, Section 1 for a more detailed discussion of these differences.

4.1 Daft.ie data

Data on house prices and rental rates are from daft.ie, the largest property website in Ireland, with approximately 90% of all properties for sale or to rent in Ireland advertised on daft.ie.³ The data used in our analysis cover the period from January 2008 to March 2012.

³ Internet-based listings of properties for sale by the small number of agents not connected with daft.ie have been included in the dataset where possible. This means that omissions primarily relate to properties not listed for sale on the Internet at all. This is unlikely to be an issue of sample selection for sales properties. For lettings properties, this includes lettings filled by word of mouth and so may form a greater proportion of the total but ultimately their omission is unlikely to systematically bias results.

The daft.ie data contain information on the list price (sales) or rental rate (lettings) of a property, the location of the property, the number of bedrooms and bathrooms in the property, for sales properties details on the property type (detached, semi-detached, apartment, etc.), and the period in which the property was advertised for sale or rental. The dataset contains 397,258 properties listed for sale and 888,211 properties listed to rent. Of these listings, the BER certificate is known for 5.0% of properties for sale and 2.3% of properties to let. Table A1 in the Appendix summarises the variables drawn from the daft.ie data.

Summary statistics for the variables used in the paper are shown in Table 3. Additional summary statistics are presented in Table A3 in the (Online) appendix.

Table 3: Summary statistics

<i>Variable description</i>	<i>Variable name</i>	<i>N</i>	<i>Mean</i>	<i>Std Dev</i>	<i>Min.</i>	<i>Max.</i>
Advertised rent (all properties)	rent	888,211	€1,005	540	€100	€20,000
Advertised rent (BER properties)	rent (BER)	20,825	€1,000	528	€105	€12,000
Advertised sales price (all properties)	price	397,258	€302,672	234,682	€30,000	€6,000,000
Advertised sales price (BER properties)	price (BER)	19,743	€294,421	195885	€31,000	€5,200,000
<i>Proportion of properties in each category:</i>	<i>Sales - All</i>	<i>Sales - With BER</i>	<i>Rental⁴ - All</i>	<i>Rental - With BER</i>		
BER:						
A		2.70%			10.52%	
B		16.77%			23.72%	
C		38.92%			37.83%	
D		21.93%			17.57%	
E		9.40%			6.91%	

⁴ Additional control variables used only in the rentals model are described in Table A2 in the (Online) appendix.

F/G		10.28%		3.45%
No. of bedrooms:				
1	2.53%	2.42%	9.41%	7.09%
2	14.96%	14.96%	39.85%	38.39%
3	40.17%	40.84%	31.08%	32.48%
4	33.47%	32.93%	16.26%	18.28%
5	8.87%	8.84%	3.40%	3.76%
No. of bathrooms:				
1	39.76%	38.86%	44.90%	37.61%
2	33.48%	32.67%	37.26%	39.24%
3	21.61%	22.85%	15.39%	19.56%
4	4.02%	4.25%	1.94%	2.71%
5	0.89%	1.07%	0.42%	0.70%
6	0.21%	0.23%	0.09%	0.17%
7	0.03%	0.05%	0.01%	0.01%
8	0.00%	0.02%	0.00%	0.00%
House type:				
Terrace	17.38%	19.09%		
Semi-detached	26.75%	29.00%		
Detached	30.43%	29.37%		
Apartment	9.88%	10.66%	43.36%	42.48%
Bungalow	15.55%	11.88%		
House			54.31%	56.48%
Flat			2.34%	1.04%

Nature of price data: It should be noted that the prices (and rents) used as dependent variable are listed prices, rather than final transaction outcomes. This is due to the lack of available micro-datasets of property values in Ireland during this period. While transaction prices would be preferred, the bulk of evidence, primarily from the U.S., shows that appraised values are a good substitute in the absence of such data, particularly when hedonics are applied (Malpezzi 2003, Shimizu et al, 2012). More specifically, research relating to Ireland for this period shows that despite the poor market conditions, the variation both over time and within a cross-section in asking prices was very highly correlated with the variation in transaction prices (Lyons 2013a).

5. Results

5.1 Modelling the decision to advertise a BER

The first stage of the Heckman model is the selection equation which models the decision to advertise a BER when listing a property for sale or rental. There are four principal

results, which are broadly consistent across sales and lettings segments: time matters (later being more likely to have a BER), size matters (larger is more likely) and location matters (in general, more urban areas are more likely to have a BER) – but a property’s type, perhaps surprisingly, does not matter.

The results show that house type is generally an insignificant predictor of the decision to advertise a BER; only in the lettings equation is one dwelling type (“flat”) significant. On the other hand the number of bedrooms in a home does have an effect on the decision to include a BER. Relative to 3-bedroom homes, 1-bedroom homes are significantly less likely to advertise a BER, while 4- and 5-bedroom homes are more likely. These results hold for both the sales and lettings models; although the coefficient on 5-bedroom properties is only significant in the sales model.

For property sales we found that location affects the decision to include a BER: relative to being located in West Dublin, properties located in Dublin city centre, south Dublin city, south county Dublin, north county Dublin, Cork city, and counties Meath, Clare, Sligo and Wexford are significantly more likely to list a BER. Coefficients on all other counties were negative and significant, except for Co. Kildare which was found to be insignificant.

Likewise for rental homes, location matters: relative to properties in west Dublin, properties in Dublin city centre, south Dublin city, north Dublin city, south county Dublin, north county Dublin, Cork, Galway and Limerick cities, counties Meath, Kildare, Wicklow, Carlow, Longford, Kerry, Clare, Galway, Sligo and Leitrim are more likely to advertise BERs. Properties to let in Waterford city, and counties Offaly, Westmeath, Kilkenny, Mayo, Roscommon and Monaghan are significantly less likely to list one.

BER advertising is increasing over time: in both the lettings and sales models the coefficient on a continuous time variable was positive and significant. In the sales model

the probability that a property listed a BER certificate increased by 2.3% per quarter; for the lettings model the effect of time was even stronger at 3.5%. Finally, the coefficient on the mandatory BER legislation variable, the variable satisfying the exclusion restriction, is positive and highly significant in both models. For sales properties, the probability that a property listed a BER certificate jumped by 52.9% on January 1st 2009; again the effect is even stronger for rental properties at 62.8%. This is an important result as it helps confirm the validity of our exclusion restriction.

A subset of the results from the selection equation is presented below; the coefficients on the county dummies are available in the (Online) appendix, Table A4.

Table 4: Selection equation

Dependent variable: BER advertised	Sales Model		Dependent variable: BER advertised	Lettings Model	
	Coefficient	Std error		Coefficient	Std error
BER law	0.529***	0.015	BER law	0.628***	0.016
Dwelling type:			Dwelling type:		
Terrace	0.006	0.012	House	-0.008	0.009
Semi-detached	<i>(Reference)</i>		Apartment	<i>(Reference)</i>	
Detached	0.011	0.012	Flat ⁵	-0.272***	0.028
Apartment	-0.014	0.019			
Bungalow	0.004	0.013			
Size:			Size:		
1 bedroom	-0.074**	0.032	1 bedroom	-0.084***	0.017
2 bedroom	-0.024	0.017	2 bedroom	0.025	0.017
4 bedroom	0.127***	0.015	4 bedroom	0.089***	0.021
5 bedroom	0.149**	0.026	5 bedroom	0.056	0.043
Bed/ bathroom:			Bed/ bathroom:		

⁵ In the data there are no clear rules on how “flat” differs from “apartment” but typically “flat” is part of a house, while “apartment” is purpose-built as an apartment

bb1m	0.004	0.149	bb1m	0.138**	0.070
bb2m	0.121***	0.023	bb2m	0.100***	0.010
bb32	0.172***	0.014	bb32	0.082***	0.013
bb3m	0.364***	0.016	bb3m	0.201***	0.014
bb41	-0.119***	0.021	bb41	-0.106***	0.024
bb4m	0.195***	0.014	bb4m	0.149***	0.016
bb51	-0.301***	0.059	bb51	0.033	0.071
bb5m	0.155***	0.029	bb5m	0.081**	0.037
New development	0.180***	0.022	Rent allowance	0.148***	0.008
Time	0.023***	0.001	Time	0.035***	0.001
Constant	-2.500***	0.023	Constant	-3.371***	0.026
_n	397,258		_n	888,211	

Notes: This table reports the estimation results for some of the variables used in the selection equation. Due to the high volume of dummy variables used in the regression Table 4 above is a truncated version of the regression results. The coefficients on the county dummies are presented in the Appendix, Table A3. ***, **, *: Significant at the 1%, 5% and 10% levels respectively

5.2 Effect of the BER on house prices and rents

Tables 5 and 6 present the results of the outcome equation for the sales and lettings segments respectively, and relate the property price/rental rate to the characteristics of the property, including the energy-efficiency rating (BER), for approximately 15,000 properties offered for sale and 21,000 to let. The BER is represented in two ways; as a categorical variable (Model 1) and along a continuous scale (Model 2). Numerous controls are included in the regressions, with some of the more important covariates reported in Tables 5 and 6 below. We find that bungalows and detached homes are sold/leased at a price premium, and that, relative to 3-bedroomed properties, 4- and 5-bedroom properties transact at a premium, while 1- and 2-bedroom properties transact at a price discount. The results illustrate that, *ceteris paribus*, being in a new development does not significantly affect the value of a property.

5.2.1 A positive energy rating has a positive effect on sale prices:

Our results show that energy efficiency is capitalised in house prices: relative to obtaining a D energy rating, an A-rated property receives a price premium of 9.3%, and a B rating increases the price by 5.2%. At the other end of the scale, receiving an F or G rating reduces the price by 10.6% relative to D-rated properties, *ceteris paribus*. If the BER is measured as a 15-point scale from A1 to G, we find that each rating decline along the BER scale is associated with a reduction in price of 1.3%.

5.2.2 A positive energy rating has a positive effect on rental prices:

We find that while the magnitude of the effect is weaker in the rental market, a positive relationship still holds between energy ratings and rental prices. Relative to D-rated properties, A-rated properties experience rental rates that are 1.8% higher, and counter-intuitively, the premium is even higher for B-rated properties at 3.9%.⁶ Relative to D-rated properties, E-rated properties receive a rental price that is 1.9% lower and F- or G-rated properties experience a price discount of 3.2% relative to comparable D-rated properties. Modelling the BER as a continuous variable we find that each decline in energy efficiency along the BER scale is associated with a decline in rental price of 0.5%.

These results show that, while both buyers and renters value the energy efficiency of a home, buyers place a higher value on it than renters⁷. This is consistent with the results of Eichholtz et al. (2010) who find that, for commercial properties, the premium in rental rates for being “green” certified is between 7.9% and 10% (depending on the model specification) but the premium in sales prices ranges from 15.8% to 16.8%.

⁶ This result may be driven by sample sizes, or a discrepancy between reported and actual BER certificates.

⁷ While we are comparing the capitalisation rate of energy efficiency between buyers and renters, an important limitation, which we should highlight, is that the control variables used in each of the models are not identical; there are some additional property characteristics available for the lettings model which we do not have for the sales model. However, these relate to characteristics which are typically not relevant to owner-occupiers.

Differences in discount rates between buyers and renters may mean that the mitigation offered by energy efficiency against depreciation is given a greater value by buyers. However, it is also present in other attributes, such as four or five bedrooms, relative to three (Tables 5 and 6), where buyers place greater value on desirable attributes than renters. Thus, buyer-renter differences in the valuation of energy efficiency or other property-specific attributes and location-specific amenities may reflect structural differences in demand, tenant search costs or buyer lock-in concerns; for more, see Lyons (2012a).

Table 5: Outcome equation – Sales Model

Dependent variable: Price	Sales Model			
	Model 1: Coefficient	Std error	Model 2: Coefficient	Std error
Decline in BER label (continuous)			-0.013***	0.001
BER label score:				
A	0.093***	0.015		
B	0.052***	0.008		
C	0.017***	0.006		
E	-0.004	0.009		
F/G	-0.106***	0.009		
Dwelling type:				
Terrace	-0.108**	0.009	-0.111***	0.009
Detached	0.284***	0.008	0.281***	0.008
Apartment	-0.1***	0.014	-0.100***	0.014
Bungalow	0.226***	0.01	0.226***	0.01
Size:				
1 bedroom	-0.539***	0.024	-0.536***	0.024
2 bedroom	-0.213***	0.013	-0.219***	0.013
4 bedroom	0.299***	0.011	0.300***	0.011
5 bedroom	0.493***	0.02	0.497***	0.02

New development	-0.01	0.017	-0.002	0.017
Constant	11.59***	0.028	11.729***	0.003
Lambda (λ)	-0.016	0.069		
Rho (ρ)	-0.053	0.224		
_n	15,060		15,060	

Notes: This table reports the estimation results for some of the variables used in the model. Due to the high volume of dummy variables used in the regression, Tables 5 and 6 are truncated versions of the regression results; the coefficients on the additional control variables are presented in the Appendix, Table A5. The coefficients on the disaggregated BER scores are presented in Table A6. Models (1) and (2) only differ in the outcome equation (the second stage) and are identical in the selection equation⁸. P-values are reported in parentheses.

***, **, *: Significant at the 1%, 5% and 10% levels respectively

Table 6: Outcome equation – Lettings Model

Dependent variable: Price	Lettings Model			
	Model 1: Coefficient	Std. Error	Model 2: Coefficient	Std. error
Decline in BER label (continuous)			-0.005***	0.001
BER label score:				
A	0.018***	0.006		
B	0.039***	0.005		
C	-0.006	0.004		
E	-0.019**	0.007		
F/G	-0.032***	0.009		
Dwelling type:				
House	-0.009**	0.005	-0.01**	0.005
Flat	-0.206***	0.016	-0.208***	0.016
Size:				
1 bedroom	-0.331***	0.009	-0.332***	0.009
2 bedroom	-0.164***	0.008	-0.165***	0.008
4 bedroom	0.125***	0.01	0.122***	0.01
5 bedroom	0.248***	0.02	0.25***	0.02
Constant	7.095***	0.067	7.14***	0.068
Lambda (λ)	-0.009	0.023		

⁸ The only difference between these two models is how the BER certificate is represented; whether by score or as a continuous variable

Rho (ρ)	-0.041	0.105	
_n	20,825		20,825

Notes: See Table 5.***, **, *: Significant at the 1%, 5% and 10% levels respectively

Finally, we find that our models do a good job of explaining the variation in the data. We run OLS regressions as a robustness check and to identify how much of the variation in house prices and rental rates are captured in our data. We find that the coefficients, estimated by OLS, change little and the R^2 statistics of the sales and lettings models are 0.65 and 0.70 respectively.

5.2.3. The effect of the energy rating is stronger where selling conditions are worse:

The same models were run on three different sub-samples, to analyse whether the valuation of energy efficiency varied within the market, and in particular whether market conditions matter to the value home buyers place on energy-efficiency ratings.

We first compare the relative impact of energy efficiency across time, focusing on 2009Q1-2010Q2 compared to 2010Q3-2012Q1. During the earlier period, there was an average of 10,100 mortgages issued per quarter, according to Irish Banking Federation (IBF) statistics, compared to an average of 4,250 during the latter period. Prices were on average 27% below peak levels of 2007 in the earlier period and 45% below in the latter period (IBF 2012, Daft.ie 2012). Comparing the effect of energy-efficiency ratings across these time periods, we find that the impact on property price for dropping each level on the BER scale is larger when selling conditions are worse: for the period 2009-2010Q2 each decline along the BER scale results in a price which is 1.5% lower, whereas for 2010Q3-2012Q1 the impact is a decline of 2.0%. The higher value placed on energy efficiency in more illiquid markets could be reflective of tighter credit constraints. In the later period, due to the lack of availability of finance to conduct renovations on properties, it may be that buyers are looking for more energy-efficient properties, i.e.: properties which will not require further investment for renovation purposes.

The second subsamples we test are urban versus rural properties. There are a number of reasons to believe that conditions during this period were worse in rural property markets. According to the Department of the Environment, National Housing Survey 2011, there were almost 3,000 unfinished estates in Ireland by mid-2011. Just 354 were in Dublin, home to 1.3 million people (28% of Ireland's population). The three Ulster counties of Donegal, Cavan and Monaghan, home to fewer than 300,000 people, had 325 unfinished estates at the same period (Department of the Environment 2011). In addition, demand for properties is likely to be stronger in urban markets due to agglomeration forces and the concentration of new jobs growth in cities. The results of this test provide further evidence to support the hypothesis that energy efficiency matters more where selling conditions are more difficult. In urban areas the price discount associated with each decline along the energy efficiency scale is 1.2% whereas in rural areas the discount is almost double this at 2.3%.

Finally, we examine whether the effect of energy efficiency differs by property size (1/2 bed vs. 3 bed vs. 4-5 bed); in related research, Lyons (2013c) finds clear evidence of a shift in price away from smaller properties (1-2 beds) towards larger properties (3-4 beds), with the price premium of 4-bedroom properties over 2-bedroom properties, *ceteris paribus*, increasing from 45% to 57%. This suggests that conditions were likely to be tougher for those selling smaller properties. We find that energy efficiency ratings are more important the smaller the property. The discount for dropping down one grade on the energy-efficiency scale is 2.3% in the market for 1-2 bedroom homes, while for 3 bedroom and 4-5 bedroom homes the discount is lower at 1.7% and 1.6% respectively.

All three subsamples indicate that the effect of the BER on prices is generally stronger where selling conditions are more difficult. As a final check on this, the same subsamples were constructed for the lettings segment. Whereas market conditions in urban and rural

lettings markets and in markets across large and small rental properties more than likely mirrored those of sales, there is a significant difference in the time subsamples. The former period (2009Q1-2010Q2) saw rents fall on average by 3.3% per quarter. During the latter period, rents were largely stable, falling by 0.3% on average (and rising marginally on average in Dublin).

Crucially, the BER effect in the lettings market is stronger in the earlier period, as would be expected if it is related to market conditions. In the earlier period, the effect is 0.8%, compared to 0.6% in the later period. Lettings results by size subsamples are similar to those for sales, however: the effect is largest for 1-2 bedroom properties (0.9%) and smallest for 4-5 bedroom properties (0.4%).⁹ In urban lettings markets, the BER effect is 0.8%, compared to 0.6% in rural markets.¹⁰

Table 7: Outcome equation – sub models

<i>Dependent variable: Price</i>	<i>Effect of a decline in BER label (continuous)</i>	
	Sales	Rentals
<i>Sub model 1:</i>		
2009-2010Q2	-0.015***	-0.008***
vs.		
2010Q3-2012Q1	-0.020***	-0.006***
<i>Sub model 2:</i>		
Urban	-0.012***	-0.008***
vs.		
Rural	-0.023***	-0.006***
<i>Sub model 3:</i>		
1-2 bed	-0.023***	-0.009***
vs.		
3 bed	-0.017***	-0.007***
vs.		

⁹ One potential explanation of the greater magnitude of the effect in prices and more generally of buyer/renter differences in the valuation of attributes is that the nature of demand is different. In this case, one might expect that home-buying families pay more attention to factors such as energy efficiency than home-renting younger couples. The fact that in both sales and lettings segments the BER effect is stronger, not weaker, the smaller the property would imply that this is not the case and factors such as market conditions, tenant search costs or buyer lock-in concerns are more important (Lyons, 2012a).

¹⁰ The regional, size and time effects remain when all three variables are included in a joint model.

4-5 bed	-0.016***	-0.004***
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Notes: This table reports the estimation results for only the outcome variables of interest. In Sub model 2, urban refers to Dublin plus Cork, Galway and Limerick cities, whereas rural is the rest of the country. ***, **, *: Significant at the 1%, 5% and 10% levels respectively

5.3 Sample selection

As discussed previously, we chose to model the relationship between property values and energy efficiency using the Heckman selection model because of our priors that there may be some unobserved “quality” characteristics affecting both the decision to advertise a BER and the property’s transaction price. Interestingly, we found that self selection was not significant in our model. In the Heckman model, sample selection can be detected by looking at either the inverse Mill’s ratio (λ), or the correlation between the error terms from the selection and outcome equations (ρ). Tables 5 and 6 present these coefficients for the sales and lettings models respectively and show that these terms are not statistically significant in our models. Furthermore, for both the sales and lettings model, a likelihood ratio test of the independence of selection and outcome equations fails to reject the null hypothesis that the equations are independent¹¹.

The lack of correlation between the error terms implies that sample selection may not be present in our data. This suggests that the unobserved factors that influence the decision to advertise a BER are uncorrelated with the unobserved factors influencing property values. Re-estimating both models based on an OLS regression of the second stage yields results that are highly similar to those obtained from the Heckman model.

6. Conclusions

According to the SEAI, energy efficiency certificates will “allow buyers and tenants to take energy performance into consideration in their decision to purchase or rent a home” (SEAI, from FAQs on BER certificates); in this paper we have confirmed that buyers and

¹¹ The χ^2 statistic for the sales model was 0.03, and for the lettings model was 0.09.

tenants do place a positive and significant value on increased energy efficiency. We have provided the first set of estimates for Ireland of the value of increased energy efficiency in the residential sector. Based on previous research in this area, and on other hedonic studies, we expected that property buyers would be willing to pay more for energy efficiency than tenants; this result was confirmed in our estimates: relative to D-rated properties A-rated properties receive a sales price premium of 9% and a rental price premium of just under 2%. However, we have not been able to identify whether this is due to structural differences in demand, tenant search costs or buyer lock-in concerns. These differences in the capitalisation rates of energy efficient properties between owners and tenants are similar in magnitude to those estimated by Eichholtz et al. (2013) for the commercial property market in the US.

There is scope for future research in this area. In particular, it would be useful to compare the value of energy savings at higher BER levels as revealed in market transactions with the hypothetical value from engineering studies. Market transactions may over- or underestimate the actual value of savings due to imperfect information or other market imperfections, but engineering studies may also give a distorted view of the actual savings because of omitted behavioural or environmental parameters. Comparing estimates could yield improvements in both sources of information.

The ideal source for comparison would be a detailed engineering-based study of the cost savings that could be realised by living in a more energy efficient property, calculated separately for different property sizes, ages and types. This does not seem to be available for Ireland at present. However, we can make a simple comparison using energy cost averages published in SEAI, 2010. According to their estimates, for a typical 3-bedroom semi-detached home the average running costs for principal energy use can range from €300 per annum for an A2-rated home to €3,100 for a G-rated home (see SEAI BER

information leaflet (Version 4, 09 / 2010)). By plugging the estimates from our model back into the sales and rental prices, we can compare the estimated cost savings with the rate at which energy efficiency is capitalised into property values¹². For a 3-bedroom property in west Dublin, the engineering-based model says that moving from an F to a B1 rating would yield an average cost savings of €2,040 but, for such a property, the sales price premium for moving from an F to a B1 rating is only €1,617 (79% of the estimated cost savings) and the rental premium is only €1,119 (55%). For a 4-bedroom property in Munster, moving from an F to a B1 rating implies energy cost savings of €4,100, but the sales price premium is only €2,640 (64%), and the rental premium is significantly lower at €563 (14%). These results imply that actual energy savings are not yet fully incorporated into sales or rental price premiums, that engineering-based estimates overstate the actual savings, or both. These results are for illustration purposes only, and it should be noted that the cost saving estimates are based on averages for the relevant house types.

Other future work could utilise other datasets, for example, moves in Ireland to compile a database of geo-coded property prices and BER certificates could facilitate a more precise calculation of the parameters estimated in this paper. It would also allow researchers to analyse how the parameters evolve as macroeconomic conditions change.

This paper can help inform policy in several ways. The first has to do with compliance with BER legislation. The relatively small number of properties listing an energy rating (20,825 for rentals and 19,743 for sales) relative to the total number of properties listed on daft.ie for this period (888,211 rental and 397,258 sales advertisements) may indicate a low level of compliance, particularly in the rental segment, with the legislation on the mandatory labelling of properties offered for sale or rent. However, the recast Energy

¹² For simplicity these calculations assume that the energy savings are valued as a perpetuity, using a discount rate of 5%

Performance of Buildings Directive which will be brought into effect in 2013, and which will make it compulsory for BER-assessed properties to list the energy rating at the point of advertisement, should alleviate this problem.

A second policy issue relates to retrofitting. The Irish government is committed to the implementation of *Better Energy: the National Upgrade Programme* (DCENR), which aims to support the retrofitting of one million homes, businesses and public buildings. This paper discusses the private benefits that can be gained from retrofits, and provides a method of estimating the value of retrofits. There have been a numerous papers to date analysing what is known as the energy efficiency gap (see for example Jaffe and Stavins, 1994 and Koopmans and te Velde, 2001). In a study of the energy efficiency gap in the US, Allcott and Greenstone (2012) find that while the size of the gap is small, it can vary substantially across the population. The authors note that if the public is imperfectly informed vis-à-vis energy efficiency, public awareness campaigns can be welfare improving. In an Irish context, there may be benefits to informing the public of how improvements in energy efficiency can lead to an increase in the value of housing assets. However, to date little research has been published into the effectiveness of such informational interventions in Ireland. An increasingly productive area for research internationally that could usefully be applied in Ireland involves conducting randomised controlled trials of proposed informational or retrofit programmes.

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Appendix

1. BER properties compared to the Irish housing stock

The properties in SEAI's dataset of all BER-certified properties are different from the population of properties in Ireland in a number of significant ways, and also the properties listed on Daft.ie with a BER are not representative of the population of BER-certified properties. Firstly, Figure A.1 shows the distribution of the entire population of BER properties compared to those that are in the Daft.ie database, and illustrates that BERs advertised are skewed towards the positive end of the scale. Figures A2 and A3 show that BER-certified properties are not representative of the Irish housing stock; in general, a

higher percentage of newer homes have a BER certificate relative to the distribution by age of the total housing stock. This may be a self-selection issue, i.e.: people owning newer homes know their homes are likely to be efficient and thus they chose to obtain a BER certificate. It could also be a result of the BER legislation on mandatory ratings: all new homes for which planning permission was sought after January 2007, and all properties offered for sale or letting after January 2009 were legally obliged to have a BER certificate. Figure A3 below shows that the sample of BER properties is not representative of the population of properties in terms of property type, in particular a larger share of the BER-certified properties are apartments.

Figure A1: Distribution of BERs

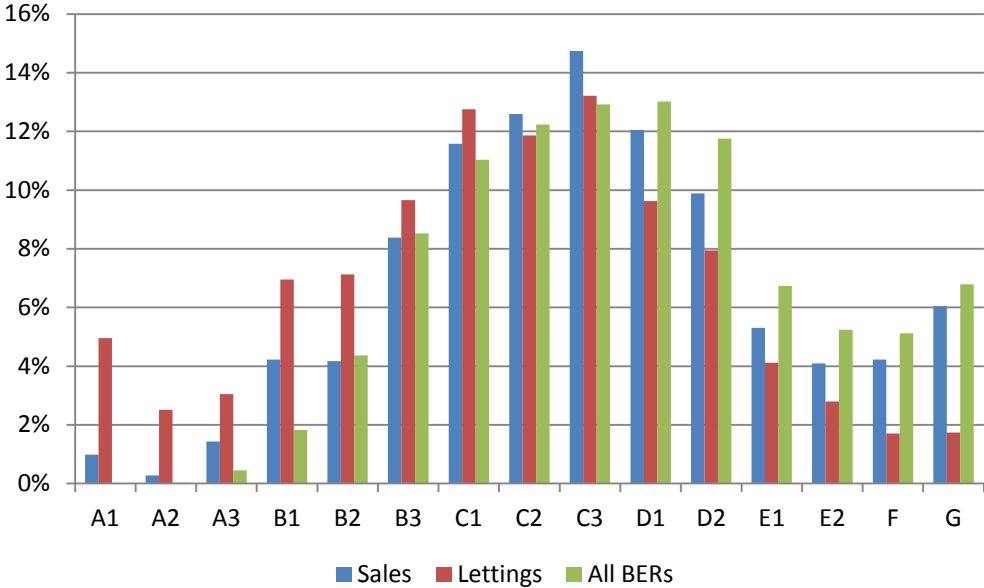


Figure A2: Distribution of BERs by property age¹³

¹³ Note that the population data come from the 2006 census as the results from the most recent census have not yet been released, thus in the population data we have no information on properties built after 2006

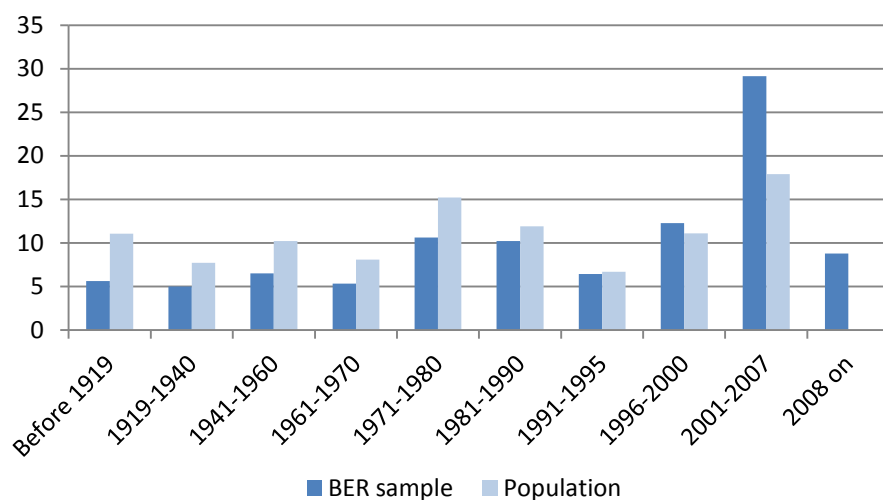


Figure A3: Distribution of BERs by property type¹⁴

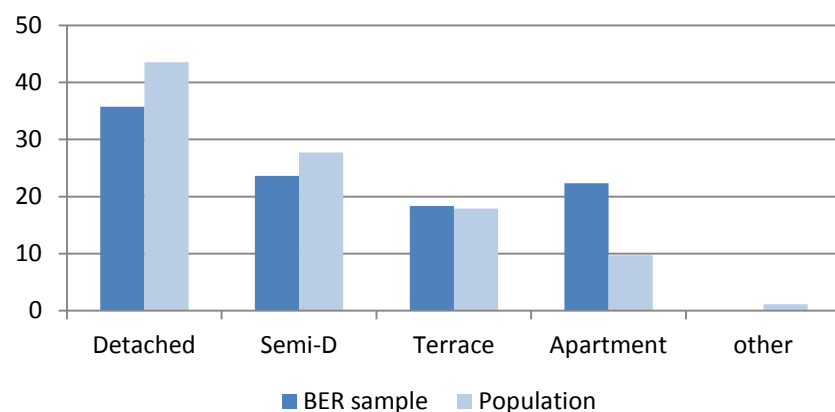


Table A1: Variable descriptions

Variable	Description
ber_id: 1-15	A categorical variable for each BER from A1 (most efficient) to G least efficient)
ber_A – ber_F/G	Sub-ratings grouped by letter; F and G grouped together
ber_law	A dummy variable indicating the date at which the legislation came into effect on the mandatory labelling of properties offered for sale/rental
ht1 – ht6	ht = house_type; 1 = terraced, 2 = semi-detached (control), 3 = detached, 4 = apartment, 6 = bungalow [sales only; for lettings, types or house, apartment and flat]
new_dev	A dummy variable that indicates whether or not a property is in a new development
beds1 – beds5	The number of bedrooms in the property

¹⁴ “Other” includes bed-sits and caravans/mobiles – none of these feature in the BER data

<i>Variable</i>	<i>Description</i>
bbxy	bb refers to bedroom-bathroom, x is the number of bedrooms, y is the number of bathrooms. E.g.: bb3m, is a property with 3 bedrooms and more than 1 bathroom. This variable ranges from bb1 to bb5m, where m refers to more than 1.
bx_ys	Size variable: x is number of bedrooms, y refers to the number that are single rooms, e.g.: b3_2s = property with 3 bedrooms, 2 of which are single rooms (the remainder of the rooms being twin/double rooms) [lettings only]
regm1 – regm35	35 regional dummies used (see Appendix, Table A2)
rural	Property is located in a rural area (reg3, reg4 and reg5)
q12008 – q42011	Dummy variables for quarter
yr2008 – yr2011	Dummy variables for year
time	Continuous time variable (by quarter, q=1 for 2008q1)

Online Appendix:

Table A2: Additional control variables used in the rentals model

garden	Property has a garden
parking	Property has a space for parking
alarm	Property has an alarm
cable	Property has cable television
washing_m	Property has a washing machine
dryer	Property has a dryer
dishwasher	Property has a dishwasher
microwave	Property has a microwave
pets	Pets are allowed
access	Property is wheelchair accessible
internet	Property has internet
is_furnished	Property is furnished
short_lease	Property is available to let short term
long_lease	Property is available to let long term
is_agent	Property is being let by an agent
is_price_ch	Observation is a property which is being re-listed at a different price

Table A3: Summary statistics – proportion of properties in the sample by county

Location:	Sales – All Properties	Sales - With BER	Rental – All Properties	Rental - With BER
Dublin city centre	0.86%	1.35%	5.95%	5.69%
North Dublin city	5.15%	7.90%	9.40%	9.68%
South Dublin city	6.20%	15.18%	14.37%	12.92%
North county Dublin	3.23%	5.25%	3.96%	4.42%
South county Dublin	2.45%	6.84%	5.01%	7.53%

West Dublin	4.29%	6.66%	6.08%	4.43%
Cork city	3.68%	3.93%	7.09%	6.77%
Galway city	2.47%	1.43%	3.75%	7.36%
Limerick city	2.07%	1.05%	2.38%	2.30%
Waterford city	2.37%	0.59%	2.01%	0.88%
Co. Meath	3.98%	5.35%	3.26%	3.60%
Co. Kildare	4.19%	4.14%	5.54%	5.16%
Co. Wicklow	2.50%	2.31%	2.85%	3.54%
Co. Louth	3.55%	1.88%	2.79%	2.09%
Co. Longford	0.99%	0.83%	0.46%	0.45%
Co. Offaly	1.83%	0.95%	0.95%	0.35%
Co. Westmeath	2.28%	1.23%	2.01%	1.32%
Co. Laois	2.05%	0.91%	1.47%	1.11%
Co. Carlow	1.24%	0.70%	1.04%	3.21%
Co. Kilkenny	1.66%	1.05%	1.41%	0.72%
Co. Wexford	4.79%	5.55%	2.25%	1.85%
Co. Waterford	2.21%	0.93%	0.77%	0.54%
Co. Kerry	3.88%	2.22%	1.32%	1.18%
Co. Cork	7.00%	5.29%	4.43%	3.64%
Co. Clare	3.00%	4.07%	1.65%	2.04%
Co. Limerick	1.87%	0.72%	0.61%	0.54%
Co. Tipperary	3.12%	1.26%	1.23%	0.92%
Co. Galway	3.09%	1.81%	1.07%	1.26%
Co. Mayo	2.65%	0.84%	1.23%	0.84%
Co. Roscommon	2.28%	1.24%	0.54%	0.16%
Co. Sligo	1.44%	3.42%	0.87%	1.60%
Co. Leitrim	1.04%	0.46%	0.28%	0.26%
Co. Donegal	3.11%	1.07%	0.87%	0.86%
Co. Cavan	2.69%	1.15%	0.71%	0.54%
Co. Monaghan	0.78%	0.45%	0.40%	0.24%

Figure A4: Number of BER certifications carried out each quarter

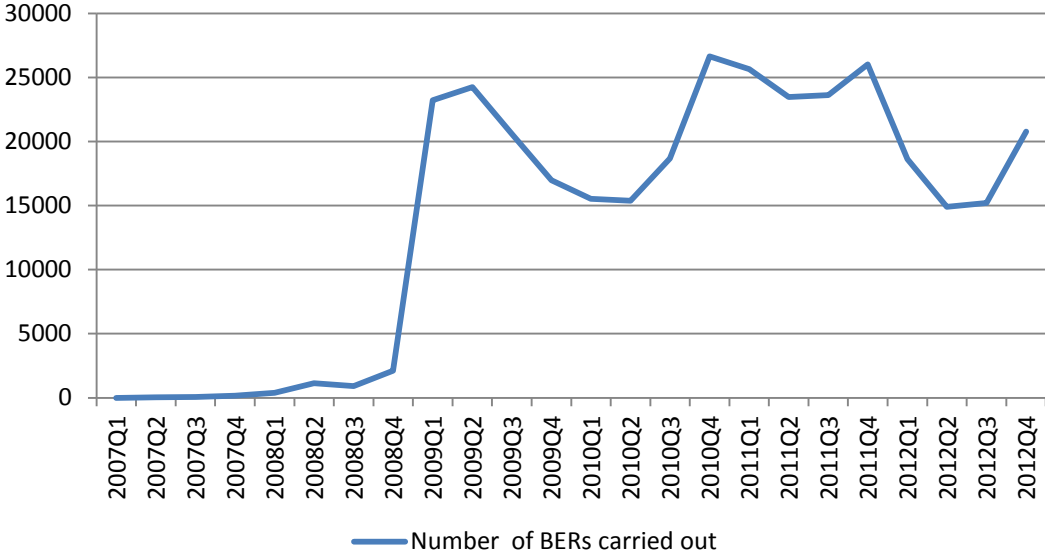


Table A4. Selection equation – county dummies

<u>Sales Model</u>				<u>Lettings Model</u>			
<i>Independent variables:</i>	<i>Coefficient</i> <i>[std error]</i>	<i>Independent variables:</i>	<i>Coefficient</i> <i>[std error]</i>	<i>Independent variables:</i>	<i>Coefficient</i> <i>[std error]</i>	<i>Independent variables:</i>	<i>Coefficient</i> <i>[std error]</i>
Dub. city centre	0.083* [0.045]	Co. Laois	-0.288*** [0.037]	Dub. city centre	0.268*** [0.019]	Co. Laois	-0.029 [0.031]
N. Dublin city	-0.152*** [0.026]	Co. Carlow	-0.201*** [0.042]	N. Dublin city	0.202*** [0.017]	Co. Carlow	0.630 *** [0.025]
S. Dublin city	0.298*** [0.022]	Co. Kilkenny	-0.176*** [0.036]	S. Dublin city	0.172*** [0.016]	Co. Kilkenny	-0.180*** [0.035]
N. Co. Dublin	0.193*** [0.025]	Co. Wexford	0.137*** [0.024]	N. Co. Dublin	0.181*** [0.020]	Co. Wexford	-0.006 [0.026]
S. Co Dublin	0.238*** [0.027]	Co. Waterford	-0.508*** [0.041]	S. Co Dublin	0.386*** [0.018]	Co. Waterford	-0.062 [0.041]
West Dublin	Reference	Co. Kerry	-0.263*** [0.029]	West Dublin	Reference	Co. Kerry	0.073** [0.031]
Cork city	0.088*** [0.025]	Co. Cork	-0.109*** [0.023]	Cork city	0.148*** [0.018]	Co. Cork	0.014 [0.021]
Galway city	-0.207*** [0.032]	Co. Clare	0.207*** [0.026]	Galway city	0.435*** [0.019]	Co. Clare	0.226*** [0.026]
Limerick city	-0.280*** [0.035]	Co. Limerick	-0.501*** [0.043]	Limerick city	0.123*** [0.024]	Co. Limerick	0.040 [0.043]
Waterford city	-0.561*** [0.043]	Co. Tipperary	-0.353*** [0.033]	Waterford city	-0.198*** [0.032]	Co. Tipperary	-0.030 [0.033]
Co. Meath	0.149*** [0.024]	Co. Galway	-0.291*** [0.031]	Co. Meath	0.146*** [0.021]	Co. Galway	0.171*** [0.031]
Co. Kildare	0.004 [0.025]	Co. Mayo	-0.479*** [0.037]	Co. Kildare	0.086*** [0.019]	Co. Mayo	-0.089 [0.034]
Co. Wicklow	-0.095*** [0.031]	Co. Roscommon	-0.212*** [0.034]	Co. Wicklow	0.221*** [0.022]	Co. Roscommon	-0.363 *** [0.065]
Co. Louth	-0.293*** [0.030]	Co. Sligo	0.517*** [0.029]	Co. Louth	-0.006 [0.024]	Co. Sligo	0.402 *** [0.030]
Co. Longford	-0.167*** [0.044]	Co. Leitrim	-0.357*** [0.049]	Co. Longford	0.207 *** [0.047]	Co. Leitrim	0.147** [0.006]
Co. Offaly	-0.259*** [0.039]	Co. Donegal	-0.513*** [0.036]	Co. Offaly	-0.251 *** [0.047]	Co. Donegal	0.047 [0.035]
Co. Westmeath	-0.212*** [0.034]	Co. Cavan	-0.468*** [0.037]	Co. Westmeath	-0.071** [0.028]	Co. Cavan	0.028 [0.042]
		Co. Monaghan	-0.191*** [0.052]			Co. Monaghan	-0.103* [0.060]

Table A5. Outcome equation – additional control variables

<u>Sales Model</u>				<u>Lettings Model</u>			
<i>Independent variables:</i>	<i>Coefficient [std error]</i>	<i>Independent variables:</i>	<i>Coefficient [std error]</i>	<i>Independent variables:</i>	<i>Coefficient [std error]</i>	<i>Independent variables:</i>	<i>Coefficient [std error]</i>
Q12008	-0.089*** [0.024]	Dub. city centre	0.329*** [0.039]	Q12008	-0.029 [0.034]	Pets allowed	0.017*** [0.004]
Q22008	-0.123*** [0.020]	N. Dublin city	0.419*** [0.028]	Q22008	-0.023 [0.028]	Dublin city centre	0.187*** [0.014]
Q32008	-0.143*** [0.018]	S. Dublin city	0.744*** [0.033]	Q32008	-0.024 [0.024]	N. Dublin city	0.115*** [0.012]
Q42008	-0.176** [0.018]	N. Co. Dublin	0.031 [0.021]	Q42008	0.041** [0.019]	S. Dublin city	0.322*** [0.013]
Q22009	-0.052*** [0.013]	S. Co. Dublin	0.666*** [0.025]	Q22009	-0.053*** [0.008]	North Co. Dublin	-0.037*** [0.013]
Q32009	-0.087*** [0.013]	Cork city	-0.076*** [0.021]	Q32009	-0.060*** [0.008]	South Co. Dublin	0.262*** [0.014]
Q42009	-0.144*** [0.013]	Galway city	-0.339*** [0.026]	Q42009	-0.110*** [0.009]	Cork city	-0.150*** [0.012]
Q12010	-0.148*** [0.013]	Limerick city	-0.429*** [0.028]	Q12010	-0.131*** [0.009]	Galway city	-0.223*** [0.015]
Q22010	-0.173*** [0.012]	Waterford city	-0.653*** [0.036]	Q22010	-0.135*** [0.009]	Limerick city	-0.388*** [0.014]
Q32010	-0.193*** [0.013]	Co. Meath	-0.229*** [0.020]	Q32010	-0.137*** [0.009]	Waterford city	-0.407*** [0.019]
Q42010	-0.214*** [0.014]	Co. Kildare	-0.157*** [0.021]	Q42010	-0.159*** [0.010]	Co. Meath	-0.369*** [0.013]
Q12011	-0.245*** [0.013]	Co. Wicklow	-0.100*** [0.025]	Q12011	-0.153*** [0.010]	Co. Kildare	-0.209*** [0.012]
Q22011	-0.261*** [0.013]	Co. Louth	-0.499*** [0.025]	Q22011	-0.154*** [0.010]	Co. Wicklow	-0.093*** [0.014]
Q32011	-0.323*** [0.014]	Co. Longford	-0.750*** [0.034]	Q32011	-0.145*** [0.010]	Co. Louth	-0.398*** [0.014]
Q42011	-0.371*** [0.015]	Co. Offaly	-0.566*** [0.031]	Q42011	-0.167*** [0.011]	Co. Longford	-0.716*** [0.025]
Q12012	-0.386*** [0.014]	Co. Westmeath	-0.649*** [0.027]	Q12012	-0.163*** [0.012]	Co. Offaly	-0.578*** [0.027]
<i>Bed/bath:</i>		Co. Laois	-0.637*** [0.030]	<i>Bed/bath:</i>		Co. Westmeath	-0.541*** [0.016]
bb1m	0.207* [0.114]	Co. Carlow	-0.498*** [0.033]	bb1m	0.087*** [0.034]	Co. Laois	-0.598*** [0.017]
bb2m	0.169*** [0.017]	Co. Kilkenny	-0.511*** [0.029]	bb2m	0.052*** [0.006]	Co. Carlow	-0.405*** [0.018]
bb32	0.150*** [0.011]	Co. Wexford	-0.404*** [0.020]	bb32	0.037*** [0.007]	Co. Kilkenny	-0.444*** [0.020]
bb3m	0.268*** [0.012]	Co. Waterford	-0.614*** [0.035]	bb3m	0.054*** [0.008]	Co. Wexford	-0.500*** [0.015]
bb41	-0.136*** [0.016]	Co. Kerry	-0.451*** [0.024]	bb41	-0.032*** [0.012]	Co. Waterford	-0.498*** [0.022]
bb4m	0.140*** [0.011]	Co. Cork	-0.346*** [0.020]	bb4m	0.048*** [0.008]	Co. Kerry	-0.543*** [0.017]
bb51	-0.319*** [0.045]	Co. Clare	-0.375*** [0.021]	bb51	-0.049 [0.034]	Co. Cork	-0.433*** [0.013]
bb5m	0.128*** [0.021]	Co. Limerick	-0.633*** [0.036]	bb5m	0.119*** [0.018]	Co. Clare	-0.559*** [0.015]
		Co. Tipperary	-0.631*** [0.027]	Rent allow.	-0.045*** [0.005]	Co. Limerick	-0.433*** [0.022]

Co. Galway	-0.713*** [0.026]	Garden ¹⁵	0.026*** [0.000]	Co. Tipperary	-0.463*** [0.018]
Co. Mayo	-0.816*** [0.031]	Parking	0.042*** [0.000]	Co. Galway	-0.595*** [0.017]
Co. Roscommon	-0.973*** [0.028]	Alarm	0.030*** [0.000]	Co. Mayo	-0.540*** [0.019]
Co. Sligo	-0.285*** [0.023]	Cable TV	0.042*** [0.000]	Co. Roscommon	-0.616*** [0.038]
Co. Leitrim	-0.908*** [0.038]	Dish-washer	0.036*** [0.000]	Co. Sligo	-0.508*** [0.018]
Co. Donegal	-0.911*** [0.031]	Microwave	0.033*** [0.000]	Co. Leitrim	-0.762*** [0.030]
Co. Cavan	-0.975*** [0.031]	Furnished	-0.113*** [0.000]	Co. Donegal	-0.582*** [0.019]
Co. Monaghan	-0.709*** [0.040]	Long term lease	0.089*** [0.000]	Co. Cavan	-0.744*** [0.023]
		Let by agent	0.039*** [0.000]	Co. Monaghan	-0.490*** [0.000]
		Is price change	-0.044*** [0.000]		

¹⁵ Only those property amenities which were found to be significant are reported

Note: These models also included a full set of postcode dummies for Dublin city (the only area in Ireland for which postcodes exist). These postcode dummies are not included in the table above but are available upon request from the authors.

Table A6. Outcome equation: disaggregated BER scores

Dependent variable: Price

	<i>Sales Model</i>	<i>Lettings Model</i>
BER score		
A1	0.177*** [0.000]	0.031*** [0.000]
A2	-0.04 [0.402]	0.007 [0.533]
A3	0.104*** [0.000]	0.021** [0.029]
B1	0.046*** [0.001]	0.047*** [0.000]
B2	0.083*** [0.000]	0.038*** [0.000]
B3	0.061*** [0.000]	0.052*** [0.000]
C1	0.02** [0.044]	0.007 [0.263]
C2	0.015 [0.112]	-0.004 [0.455]
C3	Reference	Reference
D1	-0.003 [0.747]	0.01 [0.106]
D2	0.012 [0.257]	-0.005 [0.47]
E1	-0.003 [0.79]	-0.005 [0.553]
E2	0.052*** [0.000]	-0.024** [0.018]
F	-0.008 [0.585]	-0.012 [0.344]
G	-0.084*** [0.000]	-0.037*** [0.002]

P-values reported in parentheses