Department for Business, Energy & Industrial Strategy

UNIVERSITY OF CAMBRIDGE

Final Project Report

This version: 14th September 2017

Do House Prices and Rents in the Private Rented Sector Reflect Energy Efficiency Levels?

A Report for the Department of Business, Energy and Industrial Strategy (BEIS)

BEIS Research Paper Number 2020/027

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Executive Summary

1. The Private Rented Sector (PRS) is a key concern for policies trying to improve dwelling-level energy efficiency levels. Similarly to the owner-occupied segment, investors and landlords require reassurance that any energy efficiency investments they are considering will enhance the value of the property.
2. Currently, stepping up energy efficiency levels in the domestic sector is hindered by a number of uncertainties. For owners and investors, uncertainy persists over key parameters such as the payback period and market-supported rent increases. Technological progress and falling prices for the current range of energy efficient technologies and materials introduce further uncertainty into the timing of the investment decision. For tenants, energy efficiency ratings and even energy bills from previous tenants may only have limited predictive value for their own energy consumption.
3. For PRS properties, this is complicated by the split incentive problem, i.e. landlords do not benefit directly from the savings arising from these investments. Instead, the benefits are enjoyed by the tenants of these upgraded properties via lower energy bills and/or enhanced thermal comfort. Hence, the only way to recoup the investments is typically for landlords to obtain higher rents.
4. This study confirms that energy efficiency features, as measured by the Energy Performance Certificate (EPC) rating, are associated with a small but significant influence on quoted rental prices. Conversely, there appears to be a price discount of some 6% for dwellings in the lowest energy performance category. Although it is not possible to establish with certainty that these premiums and discounts are indeed caused by EPCs and not by unobserved factors correlated with EPCs such as the state of repair of a property, the evidence is statistically significant.

5. A model of time-on-market yields inconclusive results but there is some, albeit weak, evidence of a negative relationship between time-on-market and energy efficiency ratings as more energy efficient dwellings tend to lease up more quickly.
6. Despite the known limitations of EPC ratings as a tool to accurately measure the expected energy performance or carbon footprint of a dwelling, it appears that the housing market, both in the sales and rental sectors, is responding to this information and the increased transparency regarding the expected energy performance of a dwelling, even if the information is subject to limitations and inaccuracies.
7. More research is required to determine the most cost effective ways of improving the accuracy of EPCs. In the review of EU-mandated legislation upon the UK's exit from the European Union, retaining EPCs or a similar mandatory energy efficiency rating may ensure that transparency and awareness levels with regard to energy performance of dwellings in the housing transaction market are maintained or even increased.
8. However, an effective strategy for lowering both energy demand and greenhouse gas emissions is unlikely to succeed if it solely relies on transparency and information measures. New standards and regulatory measures should be considered for increasing the role of energy efficiency in property market investments.
9. For example, starting in 2018, rental units with an EPC rating below E will be legally excluded from the rental market in the UK. This government intervention is likely to stimulate energy efficiency retrofits for poorly rated rental units across England.
10. An obvious concern are the implications of upgrading the lowest performing segment of the stock which is mainly occupied by lower income households. While it is currently not possible to predict the exact effects of this policy on vulnerable households, careful statistical monitoring of the PRS and future deliberations on suitable policies to mitigate any such effects are warranted.

1. Background

In 2013, the Department of Energy and Climate Change commissioned the Universities of Cambridge, Reading and University College London to investigate the price effect of EPC ratings on residential dwelling prices in England. That study which is reviewed in more detail below found that dwellings with a high energy efficiency rating sold at significant price premiums compared to their non-efficient peer properties. The present follow-up study focusses on a crucial sector of the housing market, the private rented sector (PRS) which has experienced high growth rates in recent years and now provides housing to some 5 million households in the UK (Paragon, 2015).

Why the PRS matters for achieving higher energy efficiency

Apart from its size and importance for the overall housing market, the PRS also presents an economic dilemma not typically observed in the owner-occupied segment which acts as an obstacle to achieving higher standards of energy efficiency. This dilemma is known as the split incentive problem and arises because capital investments in energy efficiency are made by one party, the landlord, but the benefits are reaped by another, the tenant, as they enjoy lower utility bills and enhanced thermal comfort. Hence, the only economic channel for recouping the initial capital outlay is for the landlord to be able to charge a higher rent. Whether higher rents are indeed achievable for properties with higher energy efficiency is therefore a crucial practical question which landlords and property investors need to consider before committing to an investment in energy efficiency (Adan and Fuerst, 2015).

Closely related to the question of an energy efficiency rent premium is the question of transaction prices, i.e. whether buy-to-let investors recognise the added value of an energy-efficient dwelling and are prepared to pay a higher price to own one. Price signals are a key feature of markets. When information about important characteristics of a good is unavailable or expensive to obtain, price signals may be used to indicate quality and attractiveness. In the real estate market, sellers with high quality assets use these signals to extract price premiums. Real estate buyers need to determine and screen out low-quality assets from high-quality ones despite not being able to directly and fully observe the quality characteristics. With regard to the environmental and energy efficiency performance of a building, potential sellers are often unable to directly verify intrinsic green attributes of a property and must rely on incoming information from the marketplace in the form of eco-labels. To improve the information available to those in the Private Rented Sector (PRS) in EU countries, an energy performance certificate (EPC) must be provided by the landlord to the tenant before a property can be let out or sold. Overall, the current situation is marked by a number of uncertainties which impede further progress towards rapid greening of the UK housing stock. For owners and investors, uncertainty persists over key parameters such as the payback period and market-supported rent increases. Technological progress and falling prices for the current range of energy efficient technologies and materials introduce further uncertainty into the timing of the investment decision. For tenants, energy efficiency ratings and even energy bills from previous tenants may only have limited predictive value for their own energy consumption.

Design of the study

The present study first examines an empirical sample of PRS properties in England with a hedonic regression model ,dividing a property's price into different components related to its corresponding characteristics, to establish if home energy efficiency can lead to increased property sales prices. This has been shown previously in the owner-occupied market but it is also present in the PRS, with its particular characteristics, which may lead to a different capitalisation pattern. The results indicate that high EPC ratings in dwellings are associated with a significant sale price premium, relative to average EPC-rated dwellings. In the second

Key facts about the rental market and its relation to energy efficiency

- A large fraction of the future building stock in the United Kingdom and most of Western Europe already exists today, and new construction typically only adds 1-2% per year to the existing stock (Thomsen, 2011).
- Hence, energy efficiency retrofits, including, for example, additional wall and loft insulation as well as new energy-efficient windows and heating systems, play a key role in delivering UK national as well as international policy objectives of climate change mitigation.
- In the private rented sector, achieving these policy goals hinges not so much on the availability of suitable products and technologies but on a clear analysis of the upfront cost of green investment and the extent the market enables the investors to recoup it via future income streams.
- The PRS houses about 4.9 million households and is now the second largest housing tenure in the UK, making up about 20% of the dwelling stock (Paragon, 2015).).
- This sector offers a flexible form of tenure and contributes to increased labour mobility in the economy (Böheim, 1999).
- Yet, levels of energy efficiency in the private rented sector are significantly below the standards in the owner-occupied segment (Howden-Chapman, 2004).
- Typically, landlords are not incentivised to make upfront capital investments in energy efficiency when the benefits of lower utility bills are reaped by the tenants, a problem commonly referred to as the split-incentive problem.
- However, any monetary returns such as higher rents, reduced risks of rent arrears, and lower vacancy risks, that would accrue to the landlord are inherently uncertain, thus making payback periods uncertain and subject to rent fluctuations (Burfurd et al., 2012).
- Despite this, the prospective risk-adjusted returns embedded in these building efficiency investments are likely to serve as a core metric for investors to navigate through the complex decision-making process.
- EPCs and related disclosure and certification schemes can provide vital information which may then be factored into property prices and in turn incentivise lower greenhouse gas emissions (Yudelson, 2010).

part of this report, rental rates and time-on-market are analysed using the same analytical framework. Similar to transaction prices, a rental premium is found for energy efficient properties, even when controlling for a large number of rental determinants such as size,age and location. These findings suggest that capitalisation of green features into rental and sale prices are expected to create a new housing market segment, and as a result, accelerate adoption of more energy efficient buildings. This line of research lends support to innovative financing practices that internalise long-term energy savings by, for example, including the added costs of improved energy efficiency in the mortgage financing of properties.

2. Transaction prices and EPC ratings in the PRS

Very few studies have attempted to quantify the price effect of energy efficiency levels in the residential market, let alone the PRS. Below is a short review of the existing empirical evidence.

Some studies confirm a significant and positive relationship

- Berry et al., (2008) conducted one of the first studies on the effect of mandatory green certification on residential house prices controlling for all relevant building characteristics. This study was commissioned by the Australian Department of the Environment, Water, Heritage and the Arts. Housing transactions in the Australian Capital Territory (ACT), which made energy disclosure mandatory for all properties in 1999, were sampled between 2005 and 2006. The study reports a statistically significant relationship between the energy efficiency rating of a dwelling and its sale price, with premiums of 1.23% found in 2005 and 1.91% found in 2006, in response to a 0.5 score increase on the 0-10 energy rating scale.
- In the European Union, Brounen and Kok (2011) examined the impact of energy labels on residential house prices in the Netherlands. The study combined various data sources from Agentschap NL (an agency of the Dutch Ministry of Economic Affairs), the Dutch Association of Realtors (NVM) and the Dutch Central Bureau of Statistics (CBS) to create a sample of 32,000 properties transacted between 2008 and 2009. Applying a standard hedonic estimation strategy as well as a Heckman procedure, a two-step method that corrects for potential sample selection bias stemming from the voluntary nature of the energy certification. Residential properties with an above-average green label rated A, B and C were found to command premiums of 10%, 5.5% and 2.2% respectively, relative to medium energy-efficient properties rated D.

- In a parallel study in Ireland, Hyland et al., (2013) applied a standard hedonic method to show, for a sample of 15,060 dwellings transacted between 2008 and 2012, there was a 9.3% price premium for A-rated dwellings compared to D-rated dwellings; a 5.5% premium for B ratings, and a significant -10.6% discount for F and G ratings. The sample used was obtained from daft.ie, the largest property website in Ireland, and The Sustainable Energy Authority of Ireland. A small but positive relationship between energy performance and sale prices is also found for the housing market in Northern Ireland (Davis et al., 2015.
- Studies conducted in the UK draw a similar conclusion. In a study commissioned by the Department of Energy and Climate Change, Fuerst et al., (2015), using 325,950 dwellings sold at least twice in the period from 1995 to 2011, the largest sample of housing transactions to date, report significant positive premiums for dwellings rated A/B (5%) or C (1.8%), compared to an average D-rated dwelling. For dwellings rated E (−0.7%) and F (−0.9%), statistically significant discounts are found. The relative price effects are also found to be highest for terraced dwellings.
- Recent studies in other EU Countries; Denmark (Jensen et al., 2016) and Finland (Fuerst et al 2016) confirm a significant role of energy efficiency ratings for sale prices for these Nordic countries, albeit in the latter case only for the premium segment of the market.

…while others find no or even a negative relationship

The consensus of a green premium in the housing market is not unanimous among all studies. An important theoretical economic argument underpinning the lack of a premium would be that landlords are already charging the maximum obtainable rent based on local wages and local amenities. This argument has its antecedents in Ricaridian rent theory and has been reformulated by Samuelson (1959). When housing markets are inelastic this will entail that housing supply is fixed in a particular market because it is already built up and/or for a number of other reasons. In this situation, landlords will charge the maximum rent they can obtain from tenants based on the latter's wages which, in turn, reflect the marginal product of their labour. Put simply, any improvements in energy efficiency may remain unrewarded if tenants already pay the maximum share of their incomes. For example, the two empirical studies below find a negligible impact on prices.

- Using Swedish housing transactions between 2009 and 2010, Cerin and Semenova (2014) show that energy performance is not rewarded across all property-price classes and ages of residential properties and conclude that there is little evidence of price penalties for the least energy efficient properties, although, within the most energy efficient houses, a statistically significant association between energy performance certification and house prices is reported.
- Similarly, Yoshida and Sugiura (2010) used data on the transaction prices of condominiums in Tokyo to show that there was a significant price discount of 5.5% and a lower depreciation rate for newly constructed green condominiums. Interestingly, this suggests that properties with high energy efficiency ratings are likely to command lower market prices. Also, factors such as the use of renewable energy, use of eco-friendly materials and greening are reported to attract price discounts. This may be due to buyers' perceptions of higher future repair costs or uncertainty about the quality of materials. An overview of empirical studies examining the possible impact of energy efficiency ratings on house prices is presented in the appendix in which there is slight trend towards smaller green premiums in more recent studies.

2.1 How to determine the value of energy efficiency in a property transaction

Standard econometric models are often sub-optimal for analysing markets in which assets are thought of as being traded in a single market but are actually quite different. Assets such as housing are not characterised by a single market price but by a range of sale prices that depend upon the quality of the house or the attributes it contains (Ekeland et al., 2002).

The present study uses a hedonic pricing model as proposed by Rosen (1974) to estimate the impact of each relevant property characteristic on sale price. The rationale of using a hedonic pricing model is to divide a property's price into different components related to its corresponding characteristics, including the size, number of bedrooms, date of construction, local amenities, energy efficiency features etc such that the values of these attributes manifest themselves and are summed to make up the observed market price.

The number of attributes could, theoretically, be large in number but usually a small number of characteristics tend to be the key price determinants. A further assumption is that location, quality and EPC rating are also determined by a multitude of factors. For instance, locational desirability is often linked to proximity to the town centre as well as urban features and amenities such as level of infrastructure, green space, school quality, crime rate and availability of public services.

What determines a property buyer's willingness to pay?

However, the EPC rating is determined by a combination of other factors, such as energy-efficient design features and the intrinsic energy performance of measures such as lighting, insulation, water heating and glazing. How much an investor is willing to pay for an energy efficient dwelling may depend on the investor's income and wealth profile as well as on their assumptions of future energy price inflation and appropriate discount rates of future prices and savings (Fuerst et al., 2016). Other characteristics including education and environmental consciousness may also influence an investors willingness to pay. In the present study of the PRS, it is important to bear in mind that investors are likely to consider energy efficiency only to the extent that they can charge higher rents, achieve a shorter marketing period or increase the attractiveness of their investment. The market rent of a property is thus likely to be directly linked to the rental rate and occupancy rate.

A quick primer on hedonic modelling

The hedonic pricing model is the standard methodology for examining value determinants in houing. In the present study, this method is used to primarily isolate the effect of EPC rating on price and takes the following form:

$$P_{it} = \propto_i + \sum_{j=1}^{J} B_j \, X_{jit} \, e_i \qquad (1)$$

where P_{it} is the transaction price of a property (measured as the natural logarithm of the price in £ per square metre), and X_{jit} is a vector of several explanatory locational and physical characteristics, including categorical variables for the energy labelling and characteristics such as the number of bedrooms, age and size of the properties in the sample. βj is a vector of parameters to be estimated, and e_i is a random error term with a mean of zero, capturing additional factors affecting house prices other than those captured in Xj. The hedonic weights assigned to each variable are equivalent to their overall contribution to the price. The semi-log specification mitigates the effect of extreme values and it also facilitates interpretation of the coefficients as average percentage premiums.

In the above specification, the estimated price index is prone to bias if, for example, an independent variable capturing house quality is missing from the sample. For this reason, an additional hedonic analysis with repeat sales transactions is often conducted. This method, considered as a variant of the hedonic method, examines the change in price between two periods for the same property rather than the actual price level in a particular year. In so doing, this methodology removes the need to control for property specific characteristics that remain unchanged over time (Coulson and McMillen, 2007). However, the analysis may still be prone to bias if some properties in the sample underwent improvements between the two sales periods or if for example some properties located in premium locations have experienced abnormal price appreciation irrespective of their individual characteristics. Since properties transacted at least twice may not be representative of the overall housing market, there may also be a selection bias. Likewise, the repeat sample is likely to include properties which were purchased for owner-occupation in the first period but later purchased by new owners to let out.

For the subset of properties in the sample that are sold at least twice, a repeat sales analysis provides unbiased estimates of the price change without requiring data on housing characteristics. However, as the mix of properties that are sold in each period changes, there is a need to control for both regional trends and housing characteristics such as size, age, and type. Similar to Fuerst et al., (2015), a regional index is constructed to capture 'expected' appreciation following the general regional trend and the property-specific price components:

$$\frac{{P_t}^2}{P_t^1} = \frac{RI_t^2}{RI_t^1} + \sum_{j=1}^{J} X_{jt} + u_j \qquad (2)$$

where the first and second sale periods are denoted by the superscripts 1 and 2, respectively. The regional index ratio is represented by the first term and Xj is a vector of property-specific characteristics. The error term u captures unobserved characteristics likely to have an impact on house price change. The relative prices are thus likely to be driven by trends in the local housing market and a set of observed (Xj) and unobserved (uj) property characteristics that cause individual transaction prices to deviate from the regional trend (Fuerst et al., 2015).

2.2 Data and Descriptive Statistics

The hedonic analysis outlined above requires a large sample of property transaction prices and characteristics.

How was the dataset for this study compiled?

For the purpose of the present study, data from several sources were merged. In the first step, data on market prices were obtained from the UK`s Land Registry, comprising residential transaction prices submitted in the period 1995-2013. In the second step, through full address matching, this data was cross-referenced with the HomeCo rental data to obtain the following information: property size (floor areas and number of bedrooms), dwelling type (detached, semi, terraced etc.), age (suitably constructed age bands), and energy performance of the dwellings in the sample. In essence, properties logged on the Land Registry's database and advertised for rent via the HomeCo Internet Property listing service shortly after the sales transaction are considered to be part of the PRS, either temporarily or permanently. The sample was further enhanced by adding socio-economic data from the Office for National Statistics Postcode Directory and a series of indicators published by the UK Census. Particularly, the Index of Multiple Deprivation (IMD) which contains an aggregation of seven domains of neighbourhood profiles: income, employment, health deprivation and disability, education skills and training, barriers to housing and services and crime and living environment. All reported to be important locational control variables in previous studies. To ensure a representative sample, observations across hundreds of different neighbourhoods in England were obtained via a stratified random draw. Applying this criterion, the sample used in this study covers approximately 4,200 rental observations out of which 2,202 also contain information on sales prices as they were sold between 2008 and 2013. The repeat-sales analysis sample contains information on approximately 2,000 properties sold at least twice where at least one of the transactions was recorded after August 2008, when EPCs became mandatory for residential properties in the UK. Figure 1 illustrates how the sample of dwellings used in this study compares to the general distribution of all EPCs reported by DCLG (2011) and the most recent English Housing Survey. Despite some minor differences in the distribution, the proportions can be considered sufficiently comparable to alleviate concerns of distortion or bias induced by sample selection bias. Additionally, the hedonic regression model should control for smaller variations between the sample and the underlying population from which it is drawn.

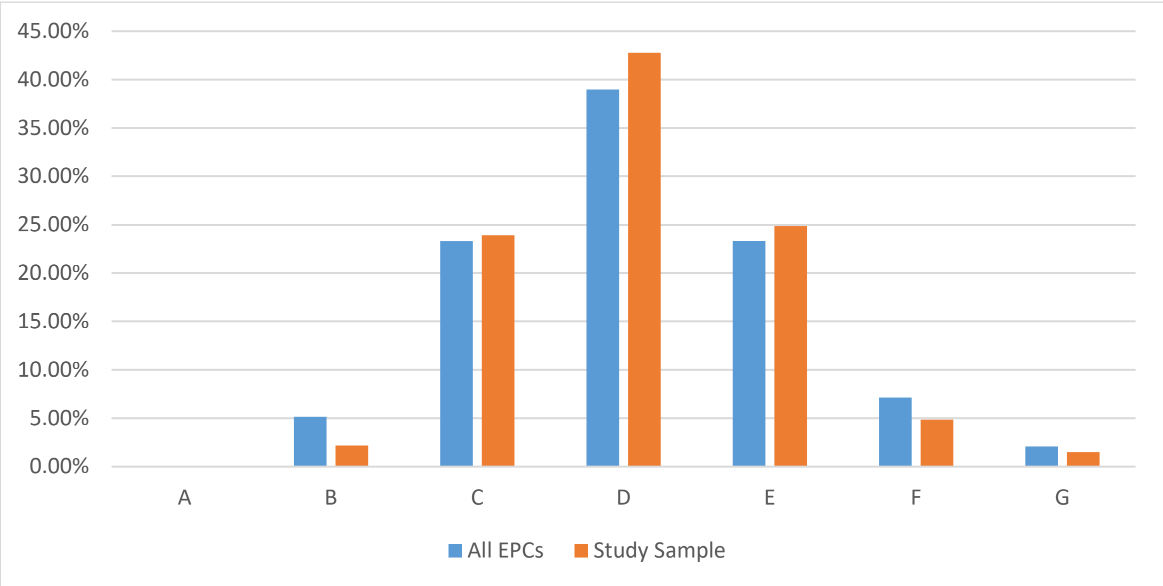

Figure 1 Distribution of EPC bands for study sample (orange) & external reference, DCLG (blue)

What if a good EPC rating just means that a property is generally more modern?

A further concern is that important price determinants may be highly correlated with EPCs which may lead to under or overestimation of the price premium. If, for example, dwelling age and EPC rating were highly correlated, the estimated effects of age may bias the EPC effect upwards or downwards. A visual inspection of Figure 2 confirms that the distribution of EPC bands varies considerably depending on the year of construction with more recent buildings obtaining higher EPC ratings and vice versa. Hence, it will be necessary to include age of construction (vintage bands) in our hedonic regression model to disentangle these two effects. However, there may be other confounding effects that remain uncontrolled for even when building age is included in the model. For example, it is to be suspected that F and G rated properties could generally be in worse condition and have lower overall aesthetic appeal which would then inflate the discount attributed to buildings with low EPC ratings. Since there is no information on the condition and visual appeal of a property in the present analysis, it cannot be ruled out that these price drivers enter the calculated EPC price effects. Similarly, it is possible that F and G rated properties are perceived to entail higher general maintenance costs for their owners in the longer run, not only due to their substandard energy efficiency levels and higher energy bills but also in terms of general maintenance work as many parts of the dwelling are likely to require above-average capital investments. The equilibrium sales price would then adjust downwards to reflect the present value of these deferred maintenance costs.

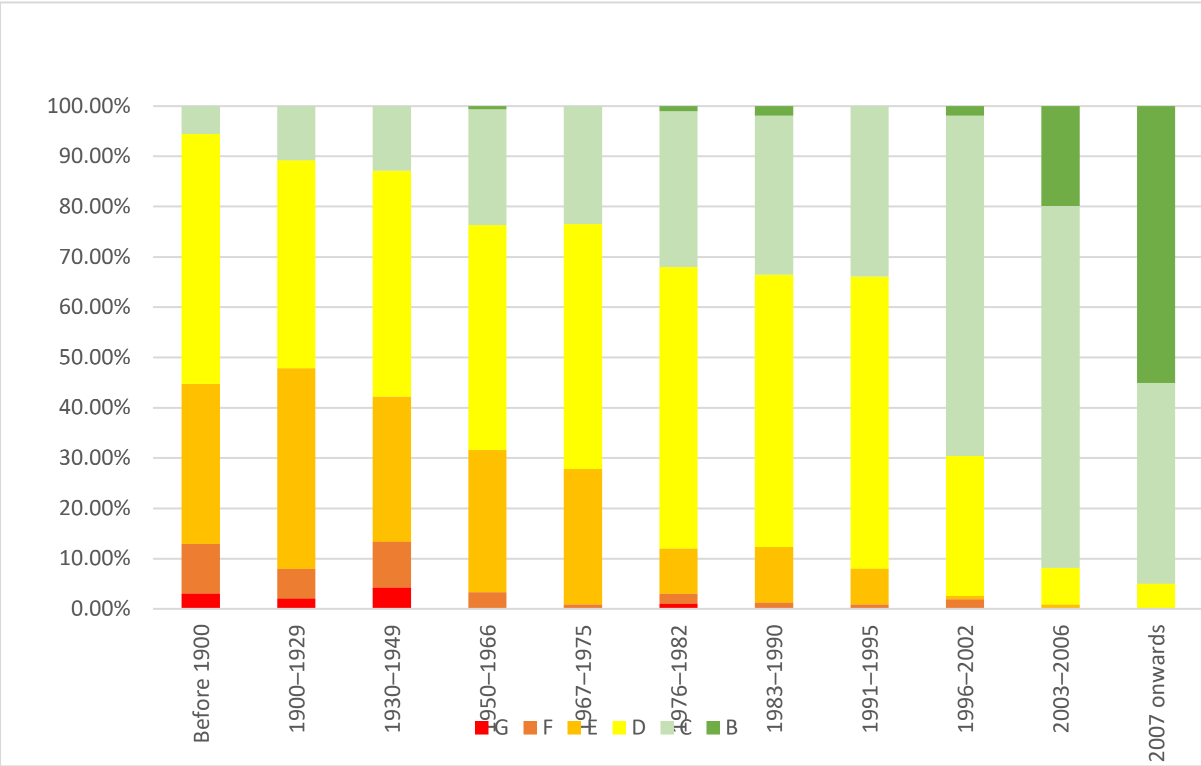

Figure 2 Sample distribution by EPC band and vintage period.

Importantly, a series of diagnostic and robustness checks were undertaken in estimating the hedonic regressions. For example, as some flats and terrace houses in the sample are held on a leasehold basis, tenure is added as an additional control variable in the regression analyses. Moreover, only properties which changed hands more than once were included in the sample to minimise measurement error and missing information in some of the key variables. The Variance Inflation Factor, which quantifies the severity of high level of correlation among the control variables, was also used to test for multicollinearity causing imprecise estimates of coefficient values in the model. Overall, the estimation of the EPC price effects appears to be robust to these variations and tests but it is important to bear in mind that the magnitude of these effects may still be distorted by correlated factors that were not included in the model.

Key features of the dataset

The descriptive statistics provided in Appendix 2 show a number of interesting points related to some of the continuous and the categorical variables in the sample. The distribution of the different variables indicates that the sample is representative of the broader PRS market in England based on English Housing Survey data.

- Average prices seem to be somewhat lower than in the overall housing market which is perhaps to be expected as the high-priced prime segment of the housing market, with the possible exception of the London market, consists almost exclusively of owner-occupied properties. This is also consistent with new evidence published by the Bank of England in which Bracke et al., (2015) find that buy-to-let investors, on average, pay less than other homebuyers for equivalent properties.
- Also, in line with national PRS statistics from English Housing Survey, the descriptive statistics of the final sample suggest that transacted buy-to-let

properties are relatively smaller in size. The average floor area for properties in the sample is 80 square metres and 42% of the properties in the sample contain only two bedrooms.

- Turning to the descriptive statistics on categorical variables, there is no information on vintage class for nearly 12% of the observations, but where this has been observed, the dwelling stock in the sample is relatively old; almost half of the properties were constructed before 1950 with less than 6% built in the last decade.
- Terraced properties account for approximately 54% of the sample. Semi-detached properties represent around a quarter of the sample, and detached properties and flats each account for approximately 10% of the sample. The relatively low share of flats in the sample is due to the technical difficulty of matching EPC information to specific units within a building. Hence, the final sample excludes a large number of flats with building-level EPC information.
- Most properties in the sample are also held on a freehold tenure.
- Overall, the properties in the sample appear to be spread evenly across the different deprivation levels based on the aggregated seven domains of the Index of Multiple Deprivation. Dwellings located in the 10 per cent most deprived neighbourhoods are in the bottom decile (IMD-1) and those in the 10 per cent least deprived neighbourhoods are in the top decile (IMD-10).
- Regarding the distribution across urban and rural areas, over 80% of the properties in the sample are located in the most urbanised areas, i.e. urban settlements with populations of 10,000 or more. This is, perhaps, not surprising as buy-to-let investors are likely to buy properties in urbanised locations.
- Turning to EPC ratings, approximately two-thirds of the dwellings in the sample

are recorded to have EPCs rating below C, with none being rated A and only 2% being rated B. Similarly, only 1.5% of the dwellings are in the G category. As low numbers in these categories may produce spurious or unreliable results, a combined B/C category and a combined F/G category are formed. In line with previous studies, EPC ratings exhibit a strong correlation with building age. A large share of newer dwellings are in B and C categories while older Victorian and Edwardian dwellings are predominantly found in bands E, F and G.

2.3 Regression Results and Discussion

Key results of sales price analysis:

- **The hedonic models explain a relatively large proportion of house price variation as indicated by the adjusted R-squared.**
- **An additional bedroom is predicted to increase the sale price by approximately 12-13% per square metre.**
- **Semi-detached and terraced properties achieve significantly lower prices per square metre, with the latter selling for approximately 32% less per square metre relative to detached properties.**
- **Flats achieve only 18-20% lower sale prices than detached homes.**
- **Freehold properties command price premiums of 12-13% per square metre relative to leaseholds.**
- **Properties located in rural areas with population levels under 10,000 achieve 4-6% lower sale price percentages per square metre, relative to those located in dense urban areas**
- **The model confirms that higher socio-economic status and lower deprivation scores increase the average house price of an area.**
- **Regarding EPC effects, a statistically significant relationship between the energy performance rating and sale price is found.**
- **B/C-rated dwellings are associated with a green sales price premium of approximately 5% relative to D-rated properties. These properties also experience a 5.6% price appreciation per square metre.**
- **For properties in the F/G category, depending on the specification, there is a statistically significant discount of 9-11% compared to D-rated properties.**
- **A percentage increase in the 0-100 energy efficiency score produces an approximately 0.1% increase in predicted dwelling price per square metre.**
- **However, these numbers need to be interpreted with caution as it cannot be ruled out that unobserved factors may influence the estimation of premium and discounts.**

The estimation results for the hedonic regression are outlined in Table 1. The logarithm of the transaction price per square metre is explained by the explanatory variables representing property and area characteristics. Using the measurement per square metre reduces the predictive power of the model but gives us a more robust measure of prices as it eliminates the size effect contained in the total transaction price. With the exception of a few variables in Table 1, most coefficients are significantly different from zero and confirm with expectations from previous research. The model fit as indicated by the adjusted R-squared is also good, capturing between 57% and 63% of the variation in sale price. Before considering the impact of EPC labelling on the sale price, the control variables included in the model are interpreted.

Dwelling size and price

Interestingly, when the number of bedrooms variable is included in the hedonic model but the independent variable capturing the actual floor area in square metre is excluded, the 'number of bedrooms' coefficient takes a negative value. This is the case as, holding the floor area fixed; an increase in the number of bedrooms entails a reduction in the amount of space per room (Boymal et al., 2013). For the purpose of the analysis here, the size effect is largely eliminated by expressing the dependent variable as price per square metre and including floor area as an additional independent variable. The number of bedrooms coefficient is still positive and significant. An additional bedroom is predicted to increase the sale price by approximately 12-13%.

Dwelling type and price

With detached dwellings as the reference category, semi-detached and terraced properties achieve significantly lower prices per square metre, with the latter selling for approximately 32% less per square metre than detached homes. So far this is intuitive. Yet, when considering flats, they achieve only 18-20% lower sale prices than detached homes. This may be attributable to the fact that flats are often located in micro-locations with good transport links and good amenities, so they are more likely to attract buy-to-let investors. While location is controlled in our model, small variations in micro-locations may be captured by our dwelling type variables.

Tenure, age and area characteristics and price

In line with expectations, freehold properties command price premiums of 12-13% per square metre relative to leaseholds. Properties located in rural areas with population levels under 10,000 are also found to achieve 4-6% lower sale price percentages per square metre, relative to those located in populated urban areas. As most tenants prefer to rent centrally, buy-to-let investors may outbid owner-occupiers in this segment of the market and may therefore pay a price relatively higher than otherwise expected. A similar intuition can be used to interpret the effect of property age and vintage. Depending on the specification, properties built between 1900 and 1975 achieve significantly lower sale prices relative to the reference category of those constructed after 2002. This may reflect preferences of buy-to-let investors in the marketplace. For instance, these investors may be more willing to offer higher bids for relatively newer dwellings, requiring less renovation and maintenance work, which they can easily let out and maintain.

Considering the socio-economic characteristics of the local areas in which the properties in the sample are located. The IMD is used to score each property in the sample according to its Lower-layer Super Output Area (LSOA), a geographic hierarchy created by the Office for National Statistics to improve the reporting of small area statistics with an average of approximately 1,500 residents or 650 households. There are 32,844 LSOAs in England. The different domains of IMD are separately controlled for. The coefficients have the expected signs, albeit the effects being negligible. A percentage increase in income score, quality of education, employment score and health score is each associated with an approximately 0.019% - 0.031% increase in sale price. Some of these findings have considerable support in the empirical literature, notably the positive relationship between quality of education services and house prices is well-documented (see Leech and Campos, 2003; Gibbons and Machin, 2003; and Rosenthal, 2003). Barriers to housing and services, which include geographical barriers and issues relating to access to housing such as affordability, are also found to be positively linked to sale price, perhaps reflecting investors' willingness to bid higher for properties located in places with limited owner-occupation options and in-demand privately rented properties. Next, consistent with Gibbons' (2004) findings, a one-level increase in crime level decile (out of 10) is predicted to reduce the sale price by 5% per square metre. The living environment, on the other hand, is found to be insignificant in explaining the variation in sale price. In model 1 of Table 1, the coefficient for the overall deprivation index is positive and statistically significant, and its inclusion increases the model fit (the adjusted R-squared) by 6% relative to the full sample. A 1% improvement in the deprivation score (IMD) produces a 0.3% increase in the predicted dwelling price per square metre.

EPCs and price

Turning to the variable of interest, the model reveals a statistically significant relationship between the energy performance rating and sale price. Relative to band D, which is the most frequently reported EPC band and is thus used as the reference or baseline category, the pattern of price effects reveals a significant and positive effect of approximately 5% for B/C rated dwellings over D rated properties. For properties in the F/G category, depending on the specification, there is a statistically significant discount of 9-11% compared to D-rated properties. Albeit negative, no significant relationship is found for E-rated properties. When the price per square metre is regressed against the energy efficiency score and a vector of control variables, a percentage increase in the 0-100 energy efficiency score produces an approximately 0.1% increase in predicted dwelling price per square metre. The positive price premiums reported for dwellings with favourable energy efficiency ratings are broadly consistent with the hedonic buy-to-let analysis of Fuerst et al., (2016) in Wales and particularly the significant premiums found for the overall housing market in England (Fuerst et al., 2015). A diverging result from the Wales study, however, is our finding of a significant price discount for F and G rated buy-to-let properties. The new results for England do not appear to support the conclusion of the previous Wales study that PRS buyers do not price-discriminate against low-rated properties to the same extent as owner occupiers due to the split incentive problem. While it would be necessary to directly compare a matched sample of owner-occupied versus buy-to-let dwellings in England for a full assessment of this question, the diverging findings for the bottom-rated EPC group may be due to inherent structural differences of the stock and/or the time period considered in these studies. A further caveat is that hedonic regression models are necessarily imperfect and estimated price differences may be at least partly due to unobserved factors that are correlated with EPC ratings.

Table 1 Energy rating and price: hedonic estimations

Dependent variable: log price per square metre	Model 1	Model 2	Model 3
EPC band B/C	**0.047***	**0.049****	
EPC band D	**Reference**	**Reference**	
EPC band E	**-0.007**	**-0.019**	
EPC band F/G	**-0.11****	**-0.09****	
EPC rating score (log)			**0.09*****
Floor area in m2 (log)	-0.609***	-0.637***	-0.640***
Tenure (Freehold)	0.121***	.129***	0.131***
Rural area pop < 10k – sparse	-0.061**	-0.041*	-0.040*
Purchased new	0.022	0.012	0.009
IMD -2012/2013 score (log)	Components	0.299***	0.299***
Vintage era fixed effects	Yes	Yes	Yes
Property type fixed effects	Yes	Yes	Yes
Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
Adjusted R-squared (model fit)	*0.568*	*0.625*	*0.627*
Sample size	*2,202*	*2,202*	*2,202*

The asterisks show significance levels. *p = 0.05, **p = 0.01 and ***p = 0.001. Complete results are shown in Appendix 3.

Repeat sales analysis

In the repeat sales analysis, Table 2 presents the regression results. In terms of the vintage class of the dwellings in the sample, prices of dwellings built between 1983 and 1990 are found to have appreciated in comparison to dwellings constructed pre-1900. In contrast, dwellings built from 1930 to 1949 are found to have depreciated relative to those constructed pre-1900. Flats and terraced houses are shown to have appreciated at a significantly higher rate than detached or semi-detached properties. Interestingly, buy-to-let properties that were purchased brand new appear to have experienced a significantly lower rate of price appreciation per square metre. Similarly, prices of properties in rural areas are shown to have appreciated. Since neighbourhood profiles change over time, the coefficients of the English multiple deprivation index for both 2015 (based on 2012/2013 data) and 2007 (based on 2005/2006 data) are also controlled for but found to be insignificant. Considering the energy efficiency rating, only the coefficient of B/C-rated dwellings is significant. Compared to the reference point of D-rated dwellings, B/C-rated dwellings experience a statistically significant 5.6% price appreciation per square metre. Despite this, no significant price change is found for E or F/G-rated dwellings nor is the energy efficiency score coefficient significant in influencing changes in price per square metre of the properties in the sample. One possible explanation for the insignificant coefficients of the lowest EPC categories is that perhaps they are capturing a quality characteristic that is less evident in the repeat sales sample. For instance, if the worst energy performing dwellings are also the ones more likely to be in bad condition, a price discount for these dwellings is more likely to be observed in the previous cross-sectional sample than in the repeat sales sample. Although neither the cross-sectional nor the repeat sales hedonic estimations are able to measure the EPC price effects with absolute precision, the results from both approaches are consistent and are indicative of a relationship between energy efficiency levels and house prices.

Table 2 Energy rating and price growth: repeat sales estimations

Dependent variable: log change in price per square metre	Model 1	Model 2	Model 3
EPC band B/C	**0.056****	**0.056****	
EPC band D	**Reference**	**Reference**	
EPC band E	**-0.022**	**-0.022**	
EPC band F/G	**0.035**	**0.035**	
EPC rating score (log)			**0.007**
Regional price index	1.05***	1.05***	1.05***
Tenure (Freehold)	0.03	0.03	0.03
Rural area pop < 10k – sparse	0.058**	0.058**	0.057**
Purchased new	-0.114**	-0.114**	-0.107**
IMD score 2015 (log)	-0.021	-0.021	-0.022
IMD score 2016 (log)		0.0006	0.0005
Vintage era fixed effects	Yes	Yes	Yes
Property type fixed effects	Yes	Yes	Yes
Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
Adjusted R-squared (model fit)	*0.627*	*0.627*	*0.625*
Sample size	*1,996*	*1,996*	*1,996*

The asterisks show significance levels. *p = 0.05, **p = 0.01 and ***p = 0.001. Complete results are shown in Appendix 4.

2.4 Conclusion about EPCs and PRS sale prices

The private rented sector has been identified as a key sector for energy efficiency improvements due to its size and structural characteristics. An important prerequisite for successful upgrading of the rental stock is that energy efficiency levels are reflected in property values.. Individual price components can be analysed with a hedonic regression model.

Consistent with prior expectations, physical property characteristics in the form of the number of bedrooms, floor area, dwelling type and vintage class are shown to be important in determining sale prices. Similarly, the hedonic analysis shows a clear price premium for properties located in neighbourhoods with good socio-economic profiles in terms of income level, employment rate, quality of schooling, crime rate, housing services and living environment. Not surprisingly, there is also a strong relationship between the sale price and the location of the dwelling, with dwellings located in urban areas achieving a significant price premium.

As for the pricing effects of EPC ratings, roperties labelled B/C are found to transact at a price premium of 4.7-4.9% per square metre, and they command a price appreciation of 5.6% per square metre, relative to comparable D-rated properties sold. In contrast, a price discount of 9-11% is found for the lowest rated dwelling in the F/G category, relative to the reference category of EPC D. Although they do not appear to influence the appreciation rate, the overall energy efficiency scores are found to be positively linked to sale price.

While the above findings suggest that buy-to let properties that are labelled with higher energy performance achieve higher prices, a number of important caveats remain. Hedonic regressions are sensitive to omitted variable bias and endogeneity problems. Despite recent advances in the era of Big Data, complete dataset including information on the state of the decoration, quality of the kitchen, bathroom, technical equipment etc. remains leusive, particularly for a large and representative sample. It would be valuable if, in future research, comparable micro-data were studied to investigate the causal relationship between energy efficiency and prices by analysing changes in observed or perceived energy efficiency features in the same dwelling units over time. More so, as the hedonic regressions applied in this study do not control for the general state of the properties, follow-up studies examining properties in terms of physical characteristics such as new kitchens, bathrooms or the general quality of the property are warranted.

3. Market rents and EPC ratings in the PRS

The second part of this study examines the relationship between rents and EPCs in England using the hedonic pricing model to control for key rental determinants. The results detailed below indicate that rental dwellings with favourable energy efficiency ratings achieve a small but significant price premium on monthly rent. This price effect may be due to energy cost savings in energy-efficient dwellings as well as additional benefits of energy efficiency features such as enhanced thermal comfort or image benefits. A separate estimation of the empirical relationship between time-on-market and energy efficiency rating is found to be inconclusive but provides moderate support for the hypothesis that energy-efficient dwellings rent out more quickly.

As established in the first part of this report, buy-to-let investors appear to be willing to pay a price premium when purchasing properties with favourable EPC ratings. Given the fundamental link between capital values and rental rates, important insights about the underlying investment rationale in the rental market can be gathered from studying the price effect of energy efficieny on rental prices and time-on-market. Given that the private rental market in England has fewer regulations than many comparable countries, landlords and tenants can freely negotiate terms (Bracke, 2015). The listed rental prices and the resulting marketing period are thus the result of genuine market mechanisms and less prone to be the effect of non-market interventions as may be the case in more regulated housing markets.

3.2 Previous studies on energy efficiency and rents

Empirical studies examining the capitalisation of energy efficiency in the private rented sector are rare. The apparent gap in the literature is not surprising, given the inherent shortage of good quality data. The more established literature in the commercial property sector has typically relied on valuation-based data or asking rent data to show a significant and positive link between energy efficiency ratings and office or retail rents. Despite this, investors in the residential rental market are likely to be different from investors in commercial buildings in the absence of easily accessible information on the energy efficiency of buildings (Kok and Kahn, 2014). Empirical literature emerging from the private rental market has up until now been very limited. Quality concerns and suitability of available data sources are often cited limitations and there is no clear consensus on the scale of the price effect of energy efficiency. Yet, case studies from Sweden, Germany and Ireland all report a positive relationship between energy efficiency ratings and residential rents.

- Zalejska-Jonsson (2014) uses a Swedish database that includes occupants living in green and conventional multi-family buildings to show a green premium of 5% of total rent in green buildings. However, environmental certificates are found to have a negligible effect on renting decisions.
- Similarly, Hyland et al., (2013) adopt a Heckman`s selection technique to investigate the effect of energy efficiency ratings on Irish residential property values and rents. They report that relative to D-rated properties, A-rated properties have a green sale price premium of 11% and a green rent premium of 1.9%. Interestingly, not only does this study suggest a positive relationship between energy efficiency ratings and rental and sale prices, but it also suggests that buyers exhibit a stronger willingness to pay for energy efficiency than tenants.

- Cajias and Piazolo (2013) also find a rent premium of 1.7% in the German market.
- In related research, Kholodilin and Michelsen (2014) examined the residential rental market in Berlin and found that energy efficiency savings are generally capitalised into rental prices.
- Earlier, Rehdanz (2007) arrived at similar conclusions in their study of German housing markets.

3.3 Data and Descriptive Statistics

As was the case with the sales transactions sample, information on rents and dwelling characteristics was obtained from HomeCo Internet Property Ltd. This property search engine provides wide-ranging quality data containing rent asking prices for hundreds of thousands of residential properties in the UK. In preparing the data, efforts were made to ensure that each dwelling included in the final sample had both an on-market date and an off-market date. According to the data providers, this increased the likelihood of the asking rents in the sample matching the transacted rents. The sample used in this study contains rental prices of 5,300 properties which were advertised for rent in the period of 2011-2015, along with the corresponding information on property location, type, size, number of bedrooms and vintage class. Socio-economic information from the census and the IMD index were also added to the final data sample, along with information on energy performance ratings obtained from the EPC register.

A brief review of the descriptive statistics in the sample reveals a number of notable points. Figure 3 illustrates that the average monthly rental rates in England exhibit marked persistent differences, with listed rental prices in the South, particularly in hotspots in and around the capital, being priced significantly higher than rental properties in the North. For example, the most expensive neighbourhoods (as defined by the LSOA) in London command average monthly rental prices of up to £3,000.

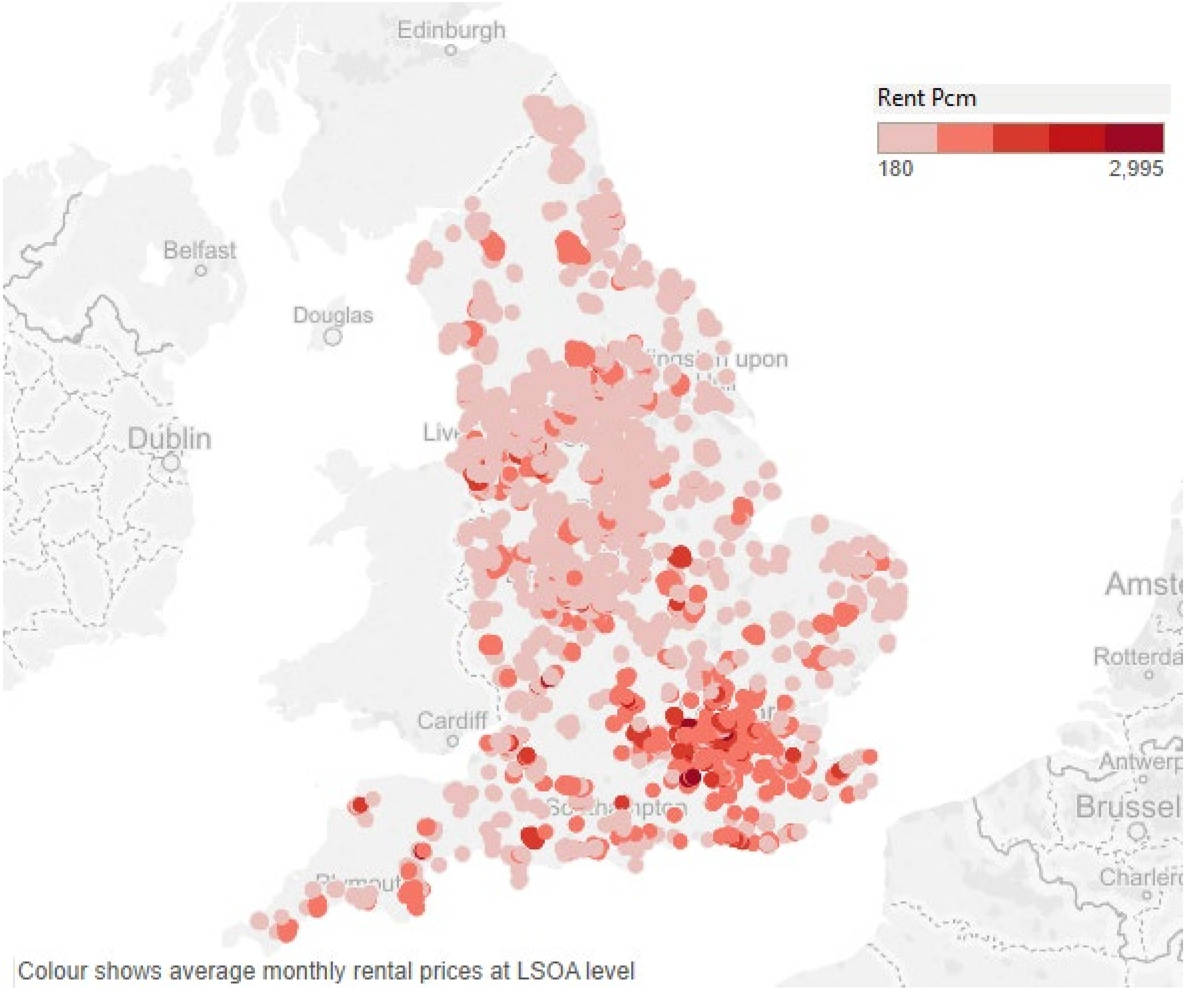

Figure 3 Average monthly rental prices (Each dot represents an LSOA in England with lighter colours indicating lower rents and vice versa).

Considering the number of days between when a property is first listed and when it is taken off the market as a result of a transaction, the North-south divide in monthly rental prices appears to be reversed. Figure 4 illustrates that, on average, marketing periods are highest in neighbourhoods in the North and relatively low in neighbourhoods in the Southeast and London. This difference in rental rates and marketing periods between the North and South of England is historically linked to macroeconomic differences in employment levels and economic activity, as well as London's unique prominence as the financial capital of the world. The descriptive statistics illustrated in the maps are therefore consistent with a priori expectations derived from general market statistics.

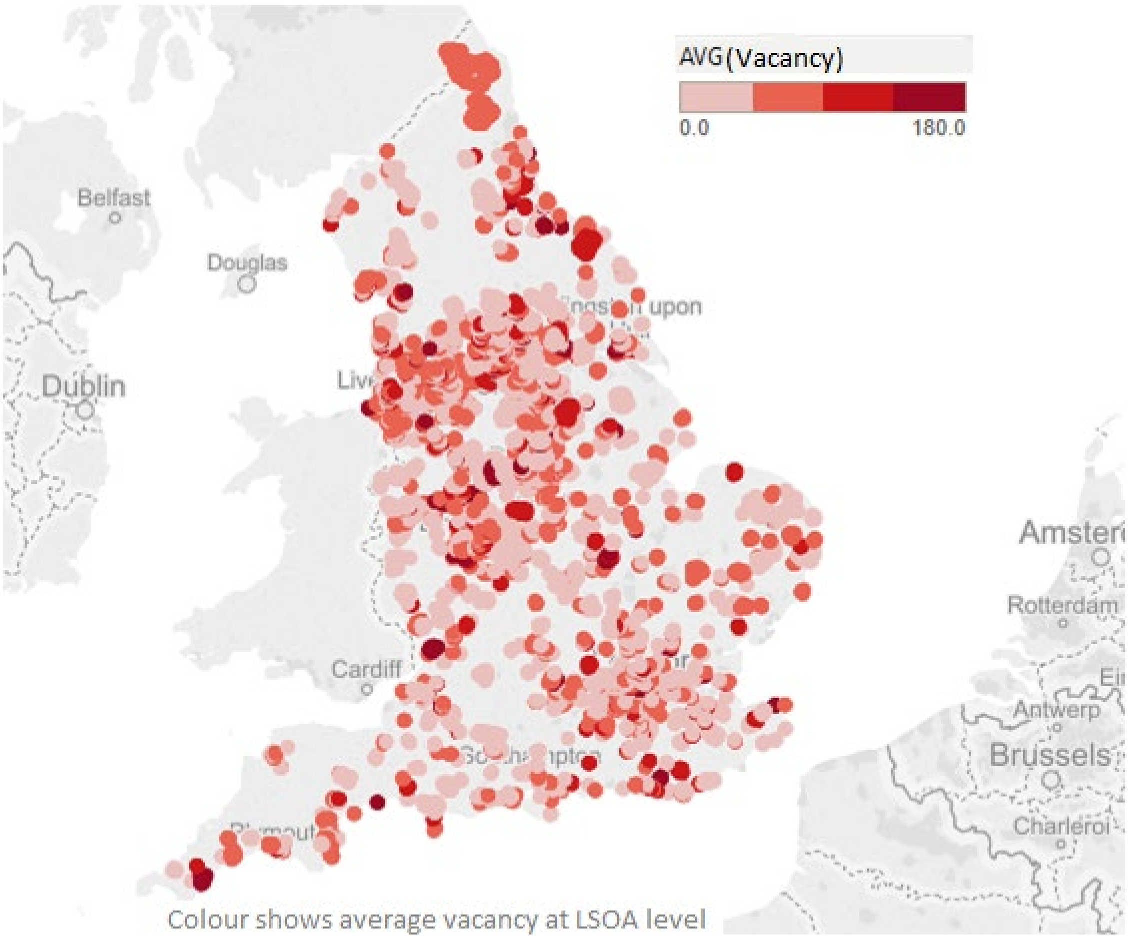

Figure 4 Average time-on-market (difference between listing date and off-market date) at the LSOA level in England. (Each dot represents an LSOA in England with lighter colours indicating shorter time on market and vice versa).

Appendices 5 and 6 provide detailed descriptive statistics of the categorical variables in the sample. The sample largely consists of flats and terraced houses, two property types that are dominate in the UK private rental stock. Approximately 13% of the observations in the sample are missing information on vintage class, but properties are otherwise evenly distributed across the many vintage classes. Over 60% of the properties contain two bedrooms, with less than 2% containing 5 bedrooms or more. Houses in Multiple Occupation, a niche sub-market, are excluded from the sample to reflect the broader private rented market in England. To the extent that these physical features, largely determined at the time of construction, contribute favourably to the desirability of the rental unit, their expected effects on monthly rents are positive (Allen et al., 1995). Similarly, a multitude of location and neighbourhood-specific attributes linked to socio-economic outcomes may impact a property's desirability and hence rents. The majority of the properties in the sample (86.35%) are located in urban settlements. This is consistent with the proportion of flats and terraced houses in the sample, as well as the spread of private rented properties in England as they are, by and large, predominantly located in urban areas close to key amenities. In terms of socio-economic area characteristics, as measured by the Indices of Multiple Deprivation (IMD), the descriptive statistics reveal that properties in the sample are spread evenly across the different levels of deprivation, with approximately 6% being in the lowest deprivation level of 1. The spread of the observations in the sample over the Government Office Regions of England is also statistically desirable. For example, considering the highly populated regions with a large rental sector, approximately 21% of the properties in the sample are located in the Northwest, 20% are in Yorkshire, 14% are in West Midlands, and 8% are in Greater London. This suggests that the sample delivers a good portrait of the rental market in England. Considering the variable of interest, in line with the national average, 34% of the properties in the sample are in the D-rated category. There is, however, a clear shortage of A-rated properties (only 1 observation in the sample) and G- rated properties (less than 1% in the sample). In this study, for practical reasons, the sole A-rated property in the sample is excluded and F- and G-rated properties are clustered together.

Estimation Strategy

Similar to the previous section on transaction prices, a rental unit is a multidimensional good and a hedonic pricing estimation can be applied to recover implicit prices which can be used to compare the marginal valuation of the many attributes of housing.

The implicit prices are estimated by regressing rental values on the various hedonic chacteristics of the rental unit:

$$Log\ R_{it} = \beta_0 + \beta_1 \sum_{j=1}^{J} Propert`s\ physical\ characteristics_i + \beta_2 \sum_{j=1}^{J} Location\ characteristics + \beta_3 \sum_{j=1}^{J} Neighborhood\ profile_{it} + \beta_4 \sum_{j=1}^{J} EPC\ rating_{\ it} + \epsilon_{it.}$$

The dependent variable is the natural logarithm of the asking rent per square metre in GBP, indexed by property i (cross-sections) and time t. The log-linear specification is the preferred functional form as it mitigates the effect of extreme values and it also facilitates interpretation of the coefficient as average percentage premiums. Previous emprical studies on rental determinations provide no conclusive list of variables for inclusion in the hedonic model. To isolate the effect of the environmental certificate on rent, the focus is on housing units' physical characteristics on the basis of dwelling type, number of bedrooms, square footage and vintage class, as well as neighbourhood characteristics captured by the English IMD. These area characteristics at the LSOA level include the quality of schooling, quality of the living environment, crime rate, health provision, income levels, employment rate, public housing and services available and level of urbanisation. β is a vector of parameters to be estimated, and it captures the marginal effect each attribute (z) of the rental unit has on the rental price:

$$\frac{\partial z_k}{\partial R_i} = \beta_n \qquad (5)$$

ϵ_{it} is a random composite error term, assumed to be independent across observations and normally distributed with a mean of zero and a constant variance of σ2. The independent variable of interest is the vector of energy effiency ratings, which controls for the energy performance rating of the rented property.

Regression Results and Discussion

The empirical estimates in Table 3 provide a detailed description of rental prices as a function of their determinants, with the effect of any omitted variables being compounded into either the error term or the intercept. A number of diagnostic and robustness checks were undertaken, ensuring consistent estimation. For each of the models of Table 3, the dependent variable is the natural log of the monthly rent per square metre. Each model explains a relatively large proportion of the variation in the rent price as indicated by the adjusted R-squared. In Models 1 and 2, the full sample is used to estimate the implicit price effects of various hedonic factors understood to drive rental prices.

Key results of rental analysis:

- **The hedonic models explain a relatively large proportion of the variation in the rent price as indicated by the adjusted R-squared.**
- **Semi-detached rental properties achieve between 9% and 11% lower rental prices relative to detached properties**
- **Terraced properties trade at a discount of 15-18% and flats at a discount of 8-12%, in comparison to detached homes.**
- **The model confirms that more recent vintage and an urban location confer a rental premium**
- **Similarly, higher socio-economic status and lower deprivation scores increase the average rent of an area.**
- **Regarding EPC effects, A/B-rated units are found to command a green rent premium of approximately 5.2-5.3% relative to D-rated properties.**
- **C-rated rental units achieving a premium between 4.6% and 4.8%**
- **These premiums are found to be greater for a flat-only sample**
- **A rent discount of approximately 6% is found for units in the lowest EPC category of F/G in one of the specification.**
- **Correlation of EPC ratings with unobserved factors may cause model estimates to overstate or understate the 'true' values.**

Depending on the specification, semi-detached rental properties achieve between 9% and 11% lower rental prices relative to detached properties (the reference category). Terraced properties trade at a discount of 15-18% and flats at a discount of 8-12%, in comparison to detached homes. Next, the number of bedrooms coefficient suggests that, holding all else equal, one additional bedroom increases the monthly rental price by approximately 10-13 % per square metre. The negative but significant relationship between the rental price and floor area reflects that the rental price per square metre for the larger properties is likely to be slightly lower than that of much smaller ones. The coefficients of the dummy variables which measure the vintage class of the properties in the sample are increasingly negative but inconclusive as most of these coefficients are statistically insignificant. With properties built after 1995 as the reference category, properties built between 1930 and 1949 achieve 5-7% lower rental prices per square metre, and properties built between 1967 and 1982 transact at a discount of 4-5% per square metre. These physical characteristics are found to be important determinants of rental price in previous empirical studies (Guasch and Marshall, 1985). Furthermore, depending on the specification, there is a significant rental price premium of 4-8% associated with rental units located in urban places. In terms of local amenities and socio-economic factors affecting the rental prices of the dwellings in the sample, a number of notable observations can be made.

When the different domains of the English IMD are separately controlled for, a percentage increase in each of the factors of income score, quality of education, employment score and living environment is found to increase rental price by approximately 0.02%. A single level improvement in the crime decile is also associated with a 15% increase in rental price per square metre. A 1% improvement in the overall socio-economic profile of the neighbourhood as measured by the IMD index entails a 0.02% increase in rental price per square metre. This is consistent with previous studies on the importance of neighbourhood characteristics in influencing rent levels (see Kain and Quigley, 1970; Davies, 1977; DiPasquale and Wheaton, 1992; and Potepan, 1996). The final set of control variables in Table 3 relate to regional and time fixed effects variations in the sample. Turning to the price effects of EPC ratings, B-rated units are found to command a green rent premium of approximately 5.3% relative to D-rated properties. This is closely followed by C-rated rental units achieving a premium of 4.9% of rent per square metre. Interestingly, when the aggregated IMD score is controlled for as opposed to its individual constituent indicators, a rent discount of approximately 6% is found for units in the lowest EPC category of F/G. This discount is markedly lower than the corresponding discount (11%) found for F/G rated properties in sales transactions. The difference may be attributable to additional regulatory risks affecting this lowest rated group of dwellings which may require substantial upgrades to remain legally eligible as PRS properties. These concerns are likely to have been affected landlords particularly towards the end of our study period when new legislation on minimum EPC requirements were under debate.

Allen et al. (1995) argue that hedonic price functions may not be identical across property types since the structural parameters determining rent levels of flats are likely to be different for other property types. Drawing on this insight, and given the large share of flats in the sample, a separate hedonic estimation was conducted to investigate this assumption. In Models 3 and 4, the statistical significance and the relative magnitudes and signs of the coefficients for the control variables resemble those of the full sample. However, two notable control variables which appear to vary across the two samples are vintage class and tenure. For flats built before 1900, a significant and positive price effect is found relative to those built post-1995. This is perhaps not surprising as these rental units are likely to be houses converted into flats and renovated in recent years. A divergent result is also found for the price effects of EPCs for the flats-only sample. Using band D as the reference category, the pattern of price effects reveals a significant positive rental premium of 8.7% for B -rated rental units and 7.8% for C-rated units. In each case, this amounts to a 3-4% higher rental price in comparison to the rental price of A, B and C rated rental units contained in the larger sample of all property types. No significant price discount is found for the lowest F/G rated flats in the sample. In Model 4, when the logarithm of the energy efficiency score, rather than the band, is used as the independent variable, a 1% increase in the energy efficiency score produces a 0.12% increase in the rental price per square metre for flats, a slightly higher figure in comparison to estimate for the full sample, perhaps highlighting the higher proportion of energy costs and consequently energy savings on total rent in flats compared to other property types.

Table 3 Energy rating and rental price: hedonic estimations

Dependent variable: *log of monthly rent per square metre*	Model 1 (full)	Model 2 (full)	Model 3 (flats only)	Model 4 (flats only)
EPC band B	**0.053*****		**0.087*****	
EPC band C	**0.049*****		**0.078*****	
EPC band D	**Reference**		**Reference**	
EPC band E	-0.030		-0.029	
EPC band F/G	-0.057*		-0.021	
EPC rating score (log)		**0.09*****		**0.122*****
Floor area in m2 (log)	0.76***	0.76***	0.76***	0.77***
IMD -score (log)	0.020***	0.020***	0.022***	0.022***
Rural area pop < 10k – sparse	0.041***	0.041***	0.071***	0.075***
Tenure (Freehold)	-0.00	-0.00	-0.080*	0.078*
Vintage era fixed effects	Yes	Yes	Yes	Yes
Property type fixed effects	Yes	Yes	Yes	Yes
Quarterly fixed effects	Yes	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes	Yes
Adjusted R-squared (model fit)	*0.61*	*0.61*	*0.71*	*0.71*
Sample size	*4,135*	*4,135*	2,344	2,344

The asterisks show significance levels. *p = 0.05, **p = 0.01 and ***p = 0.001. Complete results are shown in Appendix 7.

Finally, Table 4 reports the results for the time on market, defined as the number of days between making a letting advert available online and removing the advert, against the full set of control variables. It is, however, apparent that the explanatory power of the models is generally low and that the majority of the coefficients in both the full sample and the flats-only sample are not statistically significant. This is not surprising as the amount of rental units listed for rent affects the marketing period of the rental unit. Previous theoretical studies also report that, although the physical characterises of the rental unit are important, time on market varies systematically with factors such as tenant mobility (Guasch and Marshall, 1985). This implies that additional determinants of the marketing period are unaccounted for in the estimation of the coefficients. Despite being inconclusive, two interesting observations emerge. Firstly, the negative coefficient of the rent level indicates that rental units with relatively higher listed rental prices are likely to stay listed for longer, with the caveat that the equilibrium rent level is assumed to be set exogenously but landlords can deviate from this equilibrium by setting asking rents too high or too low which will in turn affect time on market. Secondly, in Model 1, A/B-rated rental units are predicted to achieve a statistically significant 36% lower time-on-market in comparison to those in the lowest EPC category of F/G. The remaining coefficients of energy efficiency bands and the energy efficiency score are statistically insignificant.

Table 4 Energy rating and time-on-market: hedonic estimations

Dependent variable: *log of time-on-market in days*	Model 1 (full)	Model 2 (full)	Model 3 (flats only)	Model 4 (flats only)
EPC band B	**-0.36***		**-0.26**	
EPC band C	**-0.20**		**-0.13**	
EPC band D	**-0.05**		**0.029**	
EPC band E	**-0.26**		**-0.32**	
EPC band F/G	**Reference**		**Reference**	
EPC rating score (log)		**0.178**		**0.155**
Monthly rent (log)	-0.181*	-0.181*	-0.274	-0.30*
IMD -score (log)	0.059*	0.058*	0.065	0.067
Rural area pop < 10k – sparse	-0.096	-0.096	-0.27**	-0.28**
Tenure (Freehold)	-0.00	-0.01	0.110	0.077
Vintage era fixed effects	Yes	Yes	Yes	Yes
Property type fixed effects	Yes	Yes	Yes	Yes
Quarterly fixed effects	Yes	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes	Yes
Adjusted R-squared (model fit)	0.02	0.02	0.03	0.02
Sample size	4,072	4,072	2,305	2,305

The asterisks show significance levels. *p = 0.05, **p = 0.01 and ***p = 0.001. Complete results are shown in Appendix 8.

3.4 Summary on EPCs and rents in the PRS

A demonstrable link between achievable PRS rents and energy efficiency levels is crucial for landlords to have a monetary incentive for investing in the energy efficiency of their investment properties. The results of the empirical analysis confirm that energy efficiency features, as measured by the EPC rating, exert a small but significant influence on quoted rental prices.

Although a number of caveats apply when interpreting the results of this analysis, there are statistically significant price premiums for rental units in the B category (approximately 5.3%) and C category (approximately 4.9%), relative to units in the average D category. For rental units in the lowest category of F/G, there appears to be a price discount in the order of magnitude of around 6%. Considering a flats-only sample, the relative price effects are somewhat higher, with a 8.7% premium for A/B-rated flats and 7.8% for C-rated flats compared to D, while no significant discount is found for F/G-rated flats. A model of time-on-market against similar control variables yields inconclusive results but there is some, albeit weak, evidence of a negative relationship between time-on-market and energy efficiency rating, i.e. more energy efficient dwellings may tend to lease up more quickly.

3 Overall conclusions

Although a fair amount of criticism has been levelled at the accuracy of EPC ratings in the past, this study presents some empirical evidence that the housing market, both in the sales and rental sectors, is responding to this information and the increased transparency regarding the expected energy performance of a dwelling, even if the information is subject to limitations and inaccuracies and estimates of price effects are imperfect. The analysis of sale prices and rents is based on a large number of price determinants which provide us with a 'best guess' of the true effects of EPC ratings. However, in the absence of important information on the state of repair at the point of sale or expected future maintenance costs, the statistically inferred premiums and discounts presented in this study are to be considered rough estimates rather than exact measurements.

More research is required to determine the most cost effective ways of improving the accuracy of EPCs. In the review of EU-mandated legislation upon the UK's exit from the European

Union, retaining EPCs or a similar mandatory energy efficiency rating appears to be an important step in maintaining and increasing transparency and awareness with regard to energy performance of dwellings in the housing transaction market. Nevertheless, amendments to the current EPC regime may be considered. Apart from improving the accuracy of the ratings, the 10-year validity period of the EPC could be reviewed to determine if a shorter period might ensure that the ratings reflect both the current state of the property and the current standard of energy efficiency levels.

Overall, consistent with the empirical evidence on drivers of sustainable energy saving investments in the housing market, the results provide empirical evidence on the importance of energy efficiency ratings for pricing decisions in the PRS. Although the data set used in this study is at a granular level and provides insights into the price drivers of rental units in general and pricing of energy efficiency in particular, it does not allow conclusions to be drawn on the expected rent increase following an energy efficiency retrofit. It would be instructive to use comparable micro-data over time to study the effects before and after retrofits. For example, as per regulatory requirements in England, starting in 2018, rental units with an EPC rating below E will be legally excluded from the rental market. This government intervention is likely to stimulate energy efficiency retrofits for poorly rated rental units across England. An obvious concern with this policy is the rent affordability implications of upgrading the lowest performing segment of the stock which may disproportionately be occupied by lower income households. However, landlords' efforts to recoup energy efficiency investments from tenants via higher rents are likely to be severely limited in the low-income sector of the market. While it is beyond the scope of this study to ascertain if and to what extent these vulnerable households may suffer adverse effects from policy-induced energy efficiency upgrades, careful statistical monitoring of the PRS and future deliberations on suitable policies to mitigate any such effects are indicated.

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Appendices

Appendix 1: Overview of selected studies on energy efficiency capitalisation in the housing market.

Studies:	Methodology	Country	Results
Amecke (2012)	Standard Hedonic model	Germany	Energy performance certificates have a limited effect on purchasing decisions
Berry et al., (2008)	Standard hedonic Model.	Australia	A, B or C rated properties command premiums of 10%, 5.5% and 2.2% relative to properties rated D
Brounen and Kok. (2011)	Heckman`s two-step estimation (FGLS)	Netherlands	Building with a green label sells at a premium of 3.6 % relative to otherwise comparable houses with a non-green label
Cerin et al., (2014)	Standard hedonic model	Sweden	Energy rating does not on average contribute to the market price premium of a house
Chen et al., (2014)	Standard Hedonic model	Taiwan	Price Premium exists for green features but premium for green label is insignificant
Davis et al., (2015)	Standard Hedonic model	Northern Ireland	A small but positive relationship between energy performance and sale prices
Deng and Quigley (2012)	Standard Hedonic Model and Fixed effect	Singapore	Substantial economic returns to green buildings in Singapore.
Fuerst et al., (2015)	Standard Hedonic Model	England	14% premium of the highest band of energy ratings relative to lowest band
Fuerst et al., (2016)	Standard Hedonic Model	Wales	18.5% and 4% for A/B rated and C rated buy-to-let properties and no significant discount for lower-rated properties.
Hyland et al., (2013)	Standard Hedonic model	Ireland	A-rated property receives a price premium of 11%, and a B-rated property increases the price by 5.8% relative to a D rated property.
Högberg (2013)	Standard Hedonic Model	Sweden	Home buyers take into account the information available in the EPCs which entail a price premium.
Jensen et al., (2016)	Standard Hedonic Model	Denmark	Energy performance rating of properties play an important role in relation to sale price
Kok and Kahn (2014)	Standard Hedonic Model and Propensity score Matching to a lesser extent.	USA	Green price premiums of 2-4 %
Yoshida and Sugiura (2010)	Standard Hedonic Model	Japan	Green residential buildings trade at a price discount of 5.5%
Zheng et al., (2012)	Standard Hedonic Model	China	Significant price premia for 'green' properties in the Chinese housing market

Appendix 2: Descriptive statistics for key variables (n = 2,202)

Continuous variables	Mean	Std. Dev.	
Price (P1)	127,860	258,666	
Price (P2)	172,662	358,311	
Compound annual growth rate (%)	4.47%	6.70%	
Total floor area (m2)	80	35	
Energy efficiency rating	59	14	
Categorical variables	**Categories**	**Frequency**	**% of total**
Dwelling type	Detached	221	10.04%
	Flat	213	9.67%
	Semi-Detached	583	26.48%
	Terrace House	1,185	53.81%
Tenure	Freehold	1,820	82.65%
	Leasehold	382	17.35%
Vintage class of dwelling	Missing	275	12.49%
	Before 1900	326	14.80%
	1900–1929	491	22.30%
	1930–1949	187	8.49%
	1950–1966	152	6.90%
	1967–1975	115	5.22%
	1976–1982	100	4.54%
	1983–1990	155	7.04%
	1991–1995	112	5.09%
	1996–2002	158	7.18%
	2003–2006	111	5.04%
	2007 onwards	20	0.91%
Number of bedrooms	Missing	65	2.95%
	0	1	0.05%
	1	143	6.49%
	2	929	42.19%
	3	768	34.88%
	4	225	10.22%
	5	48	2.18%
	5 +	22	1.30%
Energy efficiency band	A	0	0.00%
	B	48	2.18%
	C	526	23.89%
	D	942	42.78%
	E	546	24.85%
	F	107	4.86%
	G	33	1.50%
Urban/Rural indicator	Urban	1,782	80.93%
	Rural	420	19.07%
IMD decile where IMD-1 is the most deprived 10% of LSOA	Missing	116	5.27%
	IMD-1	179	8.13%

IMD-2	201	9.13%
IMD-3	195	8.86%
IMD-4	227	10.31%
IMD-5	238	10.81%
IMD-6	221	10.04%
IMD-7	197	8.95%
IMD-8	218	9.90%
IMD-9	212	9.63%
IMD-10	198	8.99%

Appendix 3: Energy rating and price: hedonic estimations

Dependent variable: logarithm of price per square metre	(1)	(2)	(3)
EPC band B/C	**.047***	**.049****	
EPC band D	**Reference**	**Reference**	
EPC band E	**-0.008**	**-0.019**	
EPC band F/G	**-.11****	**-.09****	
EPC rating score (logarithm)			**.09*****
Floor area in m2 (logarithm)	-.609***	-.637***	-.640***
Number of bedrooms	.124***	.128***	.128***
Detached	Reference	Reference	Reference
Semi-detached	-.203***	-.218***	-.213***
Terraced House	-.325***	-.322***	-.314***
Flat	-.177***	-.203***	-.197***
Tenure (Freehold)	.121***	.121***	.131***
Vintage class = Missing	0.024	-0.015	-0.03
Vintage class = Pre 1900	0.023	0.009	-0.022
Vintage class = 1900-1929	-.088*	-0.081	-.102*
Vintage class = 1930-1949	-0.072	-.097*	-.111**
Vintage class = 1950-1966	-.190***	-.152***	-.168***

Vintage class = 1967-1975	-.111*	-.114*	-.129**
Vintage class = 1976-1982	-0.017	-0.037	-0.052
Vintage class = 1983-1990	-0.021	-0.036	-0.050
Vintage class = 1991-1995	0.005	0.007	-0.009
Vintage class = 1996-2002	-0.006	-0.019	-0.023
Vintage class = Post 2002	Reference	Reference	Reference
Rural area pop < 10k – sparse	-.061**	-.041*	-.040*
Purchased brand new	0.0218	0.0123	0.009
IMD -2012/2013 score (logarithm)		.299***	.299***
Income level score (logarithm)	.024**		
Employment level score(logarithm)	.031***		
Education and schooling quality score (logarithm)	.019*		
Crime decile	-.046***		
Health level score (logarithm)	.026***		
Barriers to housing and services score (logarithm)	.016*		
Living environment score (logarithm)	0.010		
Constant	8.848***	9.449***	9.127***
Quarterly fixed effects	Yes	Yes	Yes
Regional fixed effects	Yes	Yes	Yes
Adjusted R-squared	0.568	0.625	0.627
Sample size	2,202	2,202	2,202

*p = 0.05, **p = 0.01 and ***p = 0.001

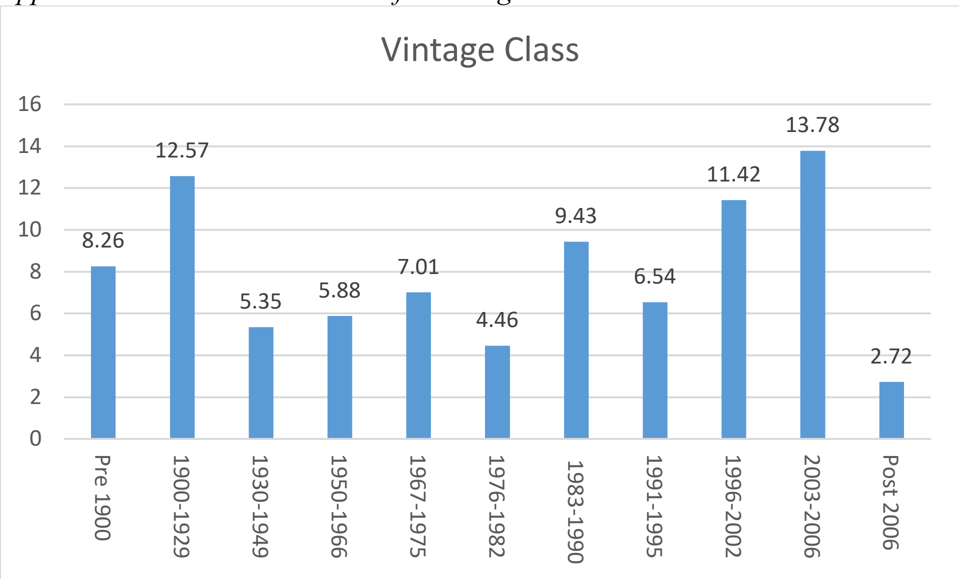
Appendix 4: Energy rating and price growth: repeat sales estimations

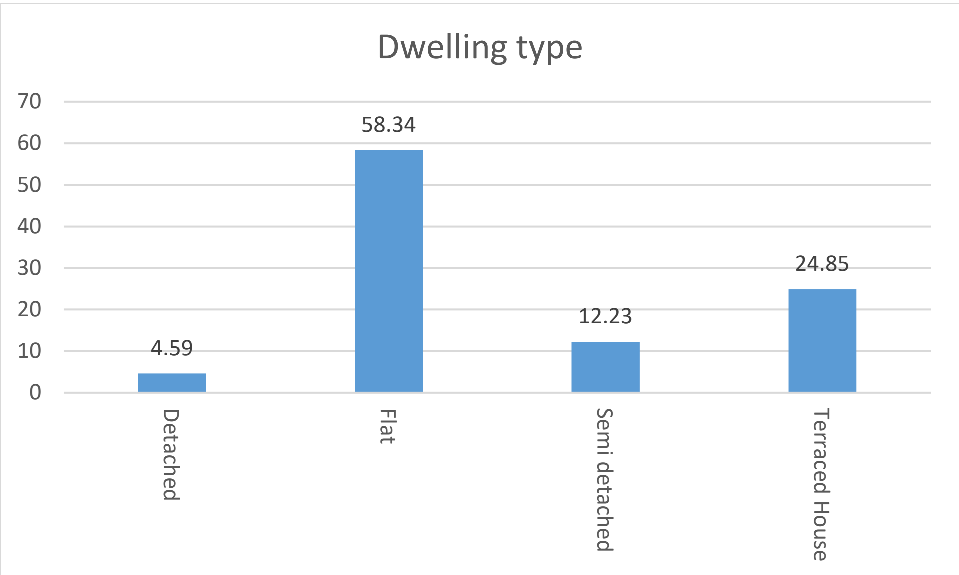
Dependent variable: log of change in price per square metre	(1)	(2)	(3)
EPC band B/C	**.056****	**.056****	
EPC band D	**Reference**	**Reference**	
EPC band E	**-0.022**	**-0.022**	
EPC band F/G	**0.03**	**0.03**	
EPC rating score (logarithm)			**0.007**
Regional price Index	1.05***	1.05***	1.05***
No of bedrooms	-.254***	-.254***	-.255***
Semi/Detached House	Hold-out	Hold-out	Hold-out
Flat	.154***	.154***	.156***
Terraced House	.070***	.070***	.075***
Tenure (Freehold)	0.030	0.030	0.026
Vintage class = Missing	-0.031	-0.031	-0.023
Vintage class = Pre 1900	Reference	Reference	Reference
Vintage class = 1900-1929	-0.044	-0.044	-0.045
Vintage class = 1930-1949	-.078*	-.078*	-0.069
Vintage class = 1950-1966	0.046	0.046	0.055
Vintage class = 1967-1975	-0.026	-0.026	-0.019
Vintage class = 1976-1982	0.064	0.064	0.081
Vintage class = 1983-1990	.089*	.089*	.105**
Vintage class = 1991-1995	-0.022	-0.022	-0.005
Vintage class = 1996-2002	-0.043	-0.043	-0.005
Vintage class = 2003-2006	-0.065	-0.065	-0.021
Vintage class= Post 2006	-0.019	-0.019	0.024
Purchased brand new	-.114**	-.114**	-.107**
Rural area pop < 10k – sparse	.058**	.058**	.057**
IMD score 2015 (logarithm)	-0.021	-0.021	-0.022

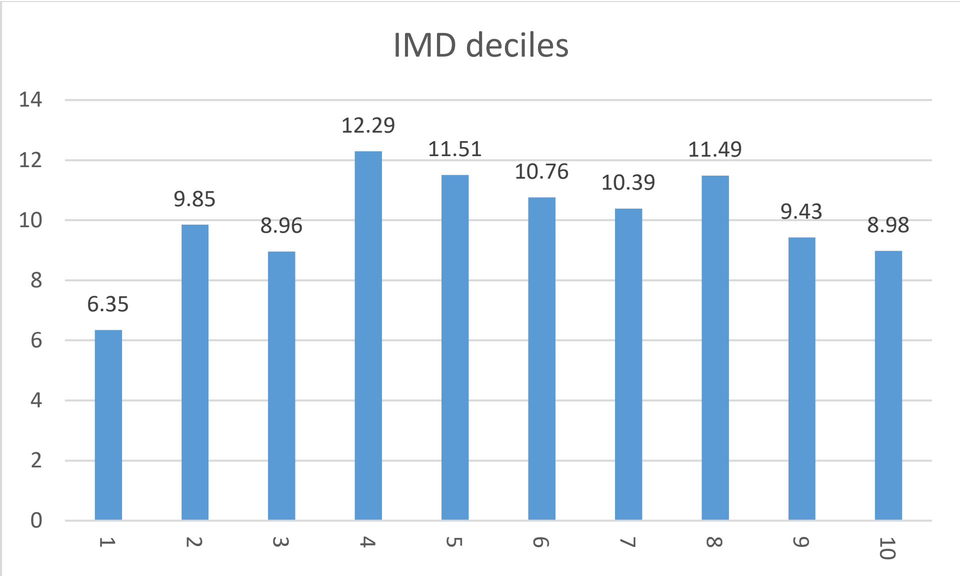
IMD score 2007 (logarithm)		0.0006	0.0005
Constant	-3.594***	-3.598***	-3.619***
Quarterly fixed effects	Yes	yes	yes
Regional fixed effects	Yes	yes	yes
Adjusted R-squared	0.627	0.627	0.625
Sample size	3,992	3,992	3,992

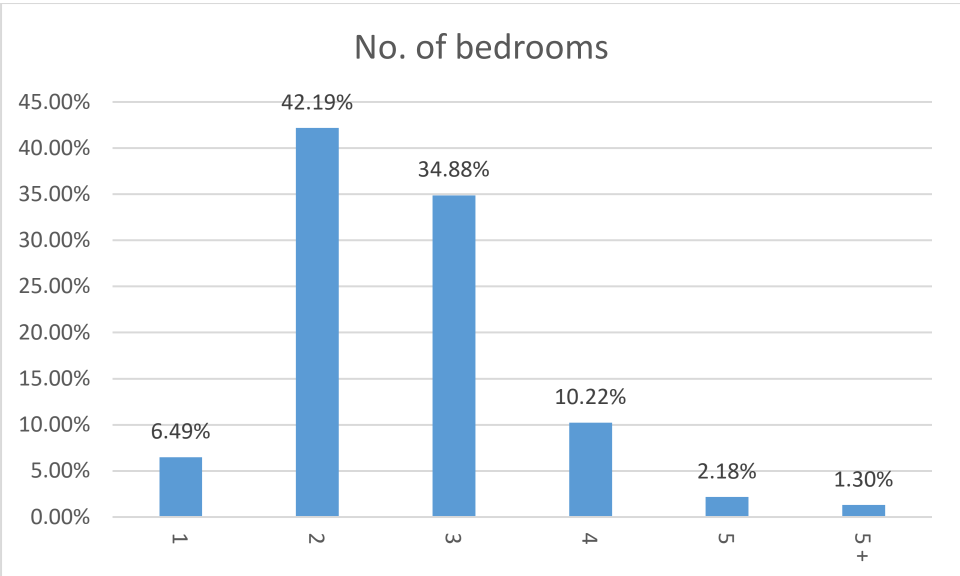
The asterisks indicate significance levels. *p = 0.05, **p = 0.01 and ***p = 0.001

Appendix 5: Distribution charts of dwelling characteristics









Appendix 6: Descriptive statistics of the categorical data in the sample (n = 4,702).

Variable	Categories	Frequency	% of total
Dwelling type	Detached	216	4.59
	Flat	2,747	58.34
	Semi detached	576	12.23
	Terraced House	1,170	24.85
Vintage class	Missing	592	12.57
	Pre 1900	389	8.26
	1900-1929	592	12.57
	1930-1949	252	5.35
	1950-1966	277	5.88
	1967-1975	330	7.01

	1976-1982	210	4.46
	1983-1990	444	9.43
	1991-1995	308	6.54
	1996-2002	538	11.42
	2003-2006	649	13.78
	Post 2006	128	2.72
Number of bedrooms	0	1	0.02
	1	723	15.6
	2	2,790	60.21
	3	833	17.98
	4	219	4.73
	5+	69	1.46
EPC rating	A	1	0.02
	B	494	10.49
	C	1,666	35.38
	D	1,596	33.89
	E	739	15.69
	F	173	3.67
	G	40	0.85
IMD decile where 1 is the most deprived 10%	1	271	6.35
	2	420	9.85
	3	382	8.96
	4	524	12.29
	5	491	11.51
	6	459	10.76
	7	443	10.39
	8	490	11.49
	9	402	9.43
Urban/ rural indicator	10	383	8.98
	Urban	4,066	86.35
	Rural	643	13.65
Region	North East	197	4.18
	North West	946	20.09
	Yorkshire	942	20
	East Midlands	522	11.09
	West Midlands	647	13.74
	East of England	301	6.39
	London	385	8.18
	South East	436	9.26
	South West	333	7.07

Appendix 7: Energy rating and rental price: hedonic estimations (dependent variable: log of monthly rent per square metre).

	(1) Full sample	(2) Full sample	(3) Full sample	(4) Flats	(5) Flats
Log EPC			**.090*** **		**.122*** **
EPC = D vs.:					
A/B	**.052** **	**.053** **		**.087*** **	
C	**.046*** **	**.049*** **		**.078*** **	
E	**-0.026**	**-0.030**		**0.029**	
F/G	**-0.048**	**-.057***		**-0.021**	
Property type = Detached vs.:					
Semi-detached	-.092**	-.111***	-.107***		
Terraced House	-.150***	-.185***	-.177***		
Flat	-.083*	-.123***	-.112**		
Number of Bedrooms	.106***	.102***	.102***	.126***	.127***
Log floor area in m2	-.770***	-.759***	-.762***	-.765***	-.765***
Vintage class = post 1995 vs.:					
Missing	0.008	-0.003	-0.011	-.031*	-.033*
Pre 1900	-0.006	-0.023	-0.039	.134**	.130**
1900-1929	0.003	-0.015	-0.033	0.04	0.027
1930-1949	-.049*	-.065**	-.073**	0.007	-0.008
1950-1966	-0.040	-0.03	-.046*	0.010	0.004
1967-1975	-0.032	-.038*	-.053**	-0.021	-0.034
1976-1982	-.051**	-.042*	-.053**	-.054*	-.0601**
1983-1990	-.037*	-0.031	-.041*	-0.015	-0.024
1991-1995	-0.007	-0.011	-0.02	0.002	-0.009
Tenure freehold = yes	0.009	-0.002	0.000	-.080*	-0.078*
City or Urban area = yes	.081***	.041***	.041***	.071***	.075***
Log multiple derivation score		.020***	.0198***	.022***	.022***
Log income score	.025***				
Log education score	.023***				
Log employment score	.020***				
Log health score	0.006				
Crime decile	.015***				
Log barriers to housing score	-0.007				
Log living environment score	.019***				
Constant	4.530**	4.955***	4.604***	4.793***	4.330***
Quarterly fixed effects	yes	yes	yes	yes	yes
Regional fixed effects	yes	yes	yes	yes	yes
Adjusted R-squared	0.62	0.61	0.61	0.71	0.71
Sample Size	4,135	4,135	4,135	2,344	2,344

The asterisks indicate significance levels. *p = 0.05, **p = 0.01 and ***p = 0.001.

Appendix 8: Energy rating and time-on-market: hedonic estimations (dependent variable: log of time-on-market in days).

	(1) Full sample	*(2)* Full sample	*(3)* Flats	*(4)* Flats
Log EPC		**0.178**		**0.155**
EPC = F/G vs.:				
A/B	**-.356***		**-.260**	
C	**-.199**		**-.132**	
D	**-.047**		**.029**	
E	**-.255**		**-.318**	
Log Monthly Rent	-.181*	-.181*	-0.274	-.300*
Property type = Detached vs.:				
Semi-detached	0.205	0.178		
Terraced House	0.269	0.240		
Flat	0.222	0.193		
Number of Bedrooms	0.040	0.039	0.163	0.168
Log floor area in m2	0.094	0.090	0.048	0.051
Vintage class = post 1995 vs.:				
Missing	0.081	0.093	0.115	0.125
Pre 1900	-0.189	-0.162	0.129	0.131
1900-1929	-0.200	-0.197	-0.261	-0.257
1930-1949	-.267*	-0.241	-.428*	-0.391
1950-1966	0.146	0.161	0.065	0.060
1967-1975	-.263*	-0.232	-0.149	-0.125
1976-1982	-0.184	-0.155	-0.219	-0.224
1983-1990	0.035	0.061	0.043	0.050
1991-1995	-0.090	-0.049	-0.121	-0.086
Tenure freehold = yes	-0.005	-0.006	0.110	0.077
City or Urban area = yes	-0.096	-0.096	-.271**	-.280**
Log multiple derivation score	.059*	.058*	0.065	0.067
Constant	3.505***	3.208***	4.465***	4.262***
Quarterly fixed effects	Yes	yes	yes	Yes
Regional fixed effects	Yes	yes	yes	Yes
Adjusted R-squared	0.02	0.02	0.03	0.02
Sample Size	4,072	4,072	2,305	2,305

The asterisks indicate significance levels. *p = 0.05, **p = 0.01 and ***p = 0.001