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Information disclosure and the valuation of energy efficiency in housing markets

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Information Disclosure and the Valuation of Energy Efficiency in Housing Markets*

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Abstract

We study the housing market response to a national disclosure policy that mandated the prominent display of energy efficiency information at listing. The policy altered the timing and prominence of information that was already available on request, providing a sharp test of whether the design of disclosure matters independently of its content. Using the near-universe of housing transactions in England and Wales with a flexible generalized difference-in-differences specification, we estimate willingness-to-pay premiums for more energy-efficient properties of 1–3% nationally and up to 6.5% in London. Information salience is a key channel: buyers respond to the efficiency rating made prominent at listing, but not to detailed energy information in the same certificate, equally available before and after. Observed premiums exceed the present value of energy savings, pointing to an investment component alongside consumption value. Disclosure design reshapes equilibrium valuation in a major asset market, with direct implications for climate policy.

Keywords— Hedonic Price Models, Energy Performance Certificates, Real Estate

JEL Codes— R38, Q48, K32

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1 Introduction

The carbon content of housing is among the largest and most persistent sources of global emissions: housing accounts for approximately 40% of global energy consumption and a third of greenhouse gas emissions (World Economic Forum, 2021), and yet two thirds of countries where building stocks are rising lack strict building codes (United Nations Environment Programme, 2021). Recent energy market shocks have sharpened the salience of this issue, and doubling the rate of energy efficiency improvements in the building sector is one of the five recommendations from the International Energy Agency for keeping the global temperature rise within 1.5°C by 2030 (IEA, 2023). Housing is also the single largest asset in most household portfolios in developed economies, transacted infrequently and at stakes large enough to shape household wealth for decades.

In this paper we study how the design of information disclosure – the timing and prominence with which information is presented – reshapes valuation in the housing market, and through it, the market rewards to energy efficiency. We study a national reform in England and Wales that required homeowners to prominently display the energy efficiency rating of the property with all marketing material when placing their home on the market. This was (and still is) typically done through providing the front page of the property’s Energy Performance Certificate (hereafter EPC) with all marketing material for the property sale. The policy mandated that the energy efficiency information was prominently displayed at the outset of the buying process, and thus (i) a property’s energy efficiency credentials were highly visible to all potential buyers and (ii) the salience of energy efficiency in general was heightened during the selling process.

Energy Performance Certificates were first introduced in the UK in 2007, when it became mandatory for sellers to provide prospective buyers with a valid EPC.¹ However, the original regulation did not require this information to be prominently displayed at the outset of the selling process, and compliance was limited (Ministry of Housing, Communities & Local Government, 2020). The 2011 amendment addressed this directly: it altered the design of disclosure without altering the underlying information set. The same EPC was available before and after the reform; what changed was when and how prominently the rating was presented to prospective buyers.

In order to guide our interpretation of the key empirical findings, and to better understand the potential underlying mechanisms, we develop a conceptual framework that captures the key aspects of the policy. Based on a hedonic house price model, our framework conceptualizes the value of a property as the sum of all housing- and area-based attributes of the property multiplied by an attribute-specific hedonic weight. The hedonic weight comprises two elements – a valuation term and an inattention term. The valuation term highlights that homebuyers may value energy efficiency ratings for two reasons. First, there is a consumption component, reflecting lower expected energy bills or a potential warm-glow benefit from reduced carbon emissions. Second, there is an investment component, whereby forward-looking homebuyers account for the expected resale value of a better EPC-rated property. The inattention term, which builds on the work of DellaVigna (2009), captures the role of attribute-specific salience

¹We cover the institutional background in detail in Section 2.1, and the construction of the EPC scores in Appendix C.

for homebuyers.

Using this framework, we distinguish four channels through which the policy may influence EPC rating premiums. The first is a saliency channel: by increasing the prominence of EPC rating information at the outset of the buying process, the amendment represents a positive shock to the salience of energy efficiency. The second is a consumption channel, which builds on salience: the effect of the salience shock will be larger for households that derive greater consumption value from a more energy-efficient home, for example through lower expected energy bills or reduced carbon emissions. Third, the policy may operate through a market valuation channel: in tighter housing markets, energy information salience can be amplified in equilibrium, leading to larger observed premiums. Finally is an investment channel, whereby forward-looking buyers place greater weight on the expected resale value of a better EPC-rated property. We use the framework to guide our interpretation of the empirical findings and to structure the mechanism tests that follow.

In the empirical analysis, we begin by estimating the house price effects of the EPBR 2011 amendment. We assemble the near universe of housing transactions in England and Wales and match each sale to the property’s energy efficiency rating at the time of transaction. Using these data, we estimate a hedonic house price model with a regression-adjusted difference-in-differences (DD) specification. We focus on properties rated B, C, or D within a one-year window around the implementation of the policy.²

Our regression specifications are highly flexible across both space and time, consistent with best practice in DD applications within hedonic house price models (Kuminoff et al., 2010; Kuminoff and Pope, 2014; Bishop et al., 2020). We define housing markets at the local authority district level and allow the valuation of housing characteristics to vary across districts in order to respect the law of one price (Bishop et al., 2020). We further allow the hedonic price function to shift between the pre- and post-policy periods, mitigating conflation bias whereby changes in the willingness to pay for energy efficiency are confounded with changes in the underlying price function (Kuminoff and Pope, 2014; Banzhaf, 2021). This framework allows us to interpret the DD estimates as changes in the willingness to pay for EPC ratings induced by the policy.

To interpret the DD estimates causally, we rely on two core assumptions: parallel trends across EPC categories and stability in group composition across periods. We present placebo DD estimates from pre-policy years, graphical evidence on pre-treatment price trends, and event study estimates that show no differential pre-trends. We also document balance in observable characteristics across rating groups in the pre- and post-periods.

We extend the baseline analysis in two directions. First, we estimate dynamic treatment effects using an event study specification, which allows us to trace the evolution of EPC rating premiums and assess whether initial price responses persist or attenuate as markets adjust. Second, we use our conceptual framework to discipline a series of mechanism tests designed to distinguish between competing explanations for the policy-induced premiums. We compare observed price premiums to the present value of energy cost savings, test whether buyers place greater weight on detailed energy attributes contained in the full EPC, and examine how policy

²EPC scores range from 0 to 100 and are divided into categories from A to G. A-rated properties are the most energy efficient and G-rated properties the least. The three categories we analyze account for 71% of all properties. See Figure B1 for the distribution.

effects vary with housing market pressure and expected duration of ownership. Together, these analyses allow us to assess the relative importance of the saliency, consumption, investment, and market valuation channels.

In our empirical analysis, we document significant premiums for higher EPC-rated properties. Following the policy, homebuyers pay 3.1% more for a B-rated property and 1.3% less for a D-rated property, relative to the base category of C. We also uncover substantial heterogeneity across regions. The London housing market stands out, with willingness to pay for energy efficiency approximately twice as large as at the national level: in London, we estimate a 6.5% premium for B-rated properties and a 3% penalty for D-rated properties.

We next examine the dynamic evolution of these effects using an event study specification. At the national level, the premium for B-rated properties rises following the policy and remains elevated over the subsequent years, while D-rated properties exhibit a persistent penalty. In London, by contrast, the initially large B-rating premium attenuates over time. This pattern is consistent with stronger medium-run supply responses in the London market, suggesting that the observed price effects reflect equilibrium adjustments to both demand- and supply-side forces.

Guided by our conceptual framework, we then examine the mechanisms underlying these premiums. We find evidence consistent with an important role for salience: the policy appears to have increased the weight that buyers place on EPC ratings at the point of sale. We also document stronger effects where energy-efficient properties are locally scarce, consistent with the market valuation sub-channel. Comparing observed premiums to the present value of energy cost savings, we show that in most settings the premium substantially exceeds the discounted value of private and social energy benefits, pointing to a positive investment component alongside consumption value. Premiums are larger in housing markets under greater valuation pressure, where investment motives are strongest, reinforcing the importance of the investment channel.

The evidence indicates that the policy operates through four same-signed channels: increased salience, a consumption value from energy savings, forward-looking investment considerations, and amplification in tighter housing markets. From a policy design perspective, this multi-channel structure is a strength. The presence of several reinforcing mechanisms makes the policy robust, as valuation effects need not depend on any single behavioral margin. As we document in Section 2.3, policies that stimulate demand for higher EPC-rated properties indirectly stimulate demand for lower carbon emissions.

Our study makes three contributions. First, we contribute to the literature on how information disclosure and salience shape economic decisions. Prior work shows that making information more visible or easier to process can affect outcomes in settings such as crime risk (Linden and Rockoff, 2008), school quality (Hussain, 2022; Greaves et al., 2021; Hastings and Weinstein, 2008), health-care report cards (Dranove et al., 2003), restaurant hygiene (Jin and Leslie, 2003), infrastructure risk (Herrnstadt and Sweeney, 2022), and energy efficiency decisions (He et al., 2022; Fisman et al., 2023). We extend this literature by studying a national disclosure reform in a high-value asset market. Housing transactions are infrequent, financially consequential, and embedded in local market equilibrium. By examining both the immediate and dynamic responses to the policy, we provide evidence on how information shocks operate in a setting where valuation effects can propagate through broader market forces.

Second, we contribute to the growing literature on the impact of energy performance certificates on housing markets. Much of the early work in this area was correlational (Fuerst et al., 2015; Jensen et al., 2016; Fuerst et al., 2020). More recent studies exploit policy variation to identify causal effects, including evidence from a localized disclosure reform in Austin, Texas (Myers et al., 2022; Cassidy, 2023) and an instrumental variables approach in the Netherlands (Aydin et al., 2020). We complement this literature by providing causal evidence from a national reform in England and Wales, estimated within a flexible hedonic difference-in-differences framework. Beyond documenting price effects, we trace their dynamic evolution and use a structured conceptual framework to assess the mechanisms through which disclosure influences valuation. In doing so, we provide evidence not only on whether energy efficiency is capitalized into house prices, but on how and under what market conditions such capitalization arises.³

Our third contribution relates to environmental policy design. We show that a market-facing disclosure reform can meaningfully alter housing market valuations, and that these effects arise through multiple, reinforcing channels. This multi-channel structure is an important feature of the policy: valuation effects do not depend on a single behavioral margin, but instead reflect the combined roles of salience, consumption value from energy savings, forward-looking investment considerations, and market valuation dynamics. In this sense, disclosure-based instruments can complement price-based approaches to reducing carbon emissions, such as emissions trading schemes or carbon taxation (Hintermann and Zarkovic, 2020; Asen, 2021). By demonstrating how an information-based reform reshapes equilibrium outcomes in a large asset market, our findings contribute to the broader discussion of how regulatory and market-based instruments interact in climate policy.

The rest of the paper proceeds as follows. In Section 2 we outline the institutional setting of our study, and establish the policy relevance of the topic by documenting both the extent, and consequences, of the carbon content of housing in England and Wales. In Section 3 we develop a conceptual framework that we will use to interpret the key findings of our analysis. In Section 4 we present our empirical specification. We present our core results on the impact of the policy on homebuyers WTP for better EPC-rated properties in Section 5. In Section 6 we consider the mechanisms at play that drive our key findings. Section 7 concludes.

2 Institutional Setting

2.1 Energy Performance Certificates and the EPBR 2011 Amendment

Energy Performance Certificates were introduced in the UK on 1 August, 2007 by the Housing Act 2004 and EPBR 2007.⁴ With this regulation, it became mandatory for sellers or landlords to provide any prospective buyer or tenant with a valid EPC at the earliest opportunity. Moreover, landlords were obliged to commission an EPC before their properties were marketed for sale and

³Additional work examines property owner responses to energy efficiency policies (Comerford et al., 2018; McAllister and Nase, 2019), and recent research studies the effects of energy price shocks across the UK (Fetzer et al., 2022).

⁴This law was implemented in response to the EU Directive 2002/91/EC. For further details on the relation between EU Directives and UK legislation, and for more context on the institutional background to the setting of our study, see Appendix C.

to obtain the EPC within a maximum of 28 days by reasonable efforts.⁵

The EPBR 2011 amendment – the key regulatory policy we study in this work – came into force on 6th April, 2012, when a copy of the front page of the EPC *had to be* enclosed with all marketing materials of rental or sales properties. This meant that when one viewed a property online, the EPC would be prominent on the webpage. If one viewed a property in person, the front sheet of the EPC would be presented. Prior to the EPBR 2011 amendment, this was not the case. Instead, EPCs were available to all prospective buyers or tenants on request, but disclosure of EPCs was not mandatory at the outset of the selling process. Specifically, the 2011 amendment stated that landlords must obtain an EPC for all commercial or residential sales and lettings properties and include the first page of the certificate with all printed and electronic property particulars. At a minimum, in case the energy efficiency rating or the front page of the certificate were not included in all advertisement, a fine of £200 could be charged per advertisement.

It is noteworthy that the amendment was required at all. This reflects that the market response to the original regulation of 2007 was insufficient and that the level of compliance needed to be improved (Ministry of Housing, Communities & Local Government, 2020). This was almost certainly due to the fact that although homeowners were mandated to supply potential buyers with an EPC, there was no requirement for this to be prominent and salient at the start of the process (Ministry of Housing, Communities & Local Government, 2012b). Thus for many buyers, the EPC may well have come right before sale was finalized. This is too late for the information on the building’s energy efficiency to be priced in by the market (Ministry of Housing, Communities & Local Government, 2020, 2012a; Shepherd, 2012).⁶ The 2011 amendment addressed this directly.

2.2 Data and Sample Selection Criteria

Data We use two core datasets in our empirical work. The first is the Land Registry Price Paid data which covers almost every house sale in England and Wales.⁷⁸ Key variables we obtain from this data are sales price, final sale date, full address and some limited housing characteristics (indicators for whether the property is a leasehold, if the property is a new-build, as well as property type).

Second, we use the dataset “Energy Performance of Buildings Data: England and Wales”.⁹ These data are available from 2008 and include considerably more information on the property, including number of rooms, floor area, building age and a host of other property information. The data also provide us with information on the energy performance rating of the house, the

⁵An exemption would have applied only if the building in question were to be demolished.

⁶As a result, the government was concerned that the EPCs were provided too late in the housing sale process for buyers to react to this information and could in effect be delayed until right before the sale or rental contract (Department for Communities and Local Government, 2010). In a consultation process in 2010, over 90% of respondents agreed that energy performance certificates should be made available earlier in the process (Department for Communities and Local Government, 2010).

⁷Source: <https://www.gov.uk/government/statistical-data-sets/price-paid-data-downloads>, HM Land Registry.

⁸The Land Registry list reasons for the minority of sales that are not registered at <https://www.gov.uk/guidance/about-the-price-paid-#data-excluded-from-price-paid-data>.

⁹Source: <https://epc.opendatacommunities.org/>, Energy Performance of Buildings Register.

date of inspection and full address of the property.

We merge these two datasets to yield a combined dataset with house price, property characteristics, and energy efficiency information for the property.¹⁰ We are able to match EPC data to the vast majority of house sales during our sample period (86.8%).

Sample Selection We restrict our analysis to properties with EPC ratings of B, C and D, which comprise over 70% of the properties in our matched EPC-transaction sample.¹¹ We do not consider new-build properties, as the EPC distribution for these properties is completely different to the existing housing stock. We drop properties with multiple inspections in the run-up to a sale in order to rule out sellers gaming the EPC rating system by “shopping around” for better ratings, which reduces the sample by 1%.

Our primary estimation sample contains sales in a one-year window around the Amendment, running from 6 April 2011 - 5 April 2013. The primary rationale for this restriction is to limit supply-side responses to the Amendment, thereby enabling us to isolate the demand-side response. We consider a wider time frame for our event study analysis, which we discuss in Section 5.3.¹²

Using our main estimation sample, Table 1 presents summary statistics for the key variables in our analysis.

Table 1: Summary Statistics

	England and Wales		London	
	Mean	Standard Deviation	Mean	Standard Deviation
Sale Price (£s)	222,649	230,477	400,063	483,723
EPC Category:				
B Rating	0.02	0.16	0.05	0.21
C Rating	0.31	0.46	0.32	0.47
D Rating	0.67	0.47	0.63	0.48
Property Type:				
Detached	0.23	0.42	0.03	0.18
Semi-Detached	0.29	0.45	0.13	0.33
Terraced	0.30	0.46	0.31	0.46
Flat	0.18	0.39	0.53	0.50
Leasehold	0.23	0.42	0.54	0.50
Construction Year	1959	41	1941	47
Number of Rooms	4.55	1.63	3.86	1.59
Total Floor Area (m ²)	89.17	40.51	81.29	40.03
Main Fuel is Gas	0.90	0.30	0.89	0.31

Notes: Time Period: 6 April 2011 - 5 April 2013.

¹⁰Details on the data and merging process is included in appendix C.

¹¹Figure B1 presents the distribution of EPC ratings in our matched data. A-rated properties are so rare that we do not use these. Properties rated E-G evolved with different time trends in the pre-period, hence given that we are using difference-in-differences, we consider properties rated B-D.

¹²Pre/post status is assigned based on final sale date rather than listing date. The typical listing-to-completion period in England and Wales is 8–12 weeks, short relative to the one-year estimation window on each side of the reform date, so any resulting misclassification affects only a small share of post-period observations and attenuates our estimates toward zero. The sensitivity analysis in Appendix B.4.1 – which restricts the sample to transactions where the EPC inspection was lodged before the EPBR 2012 amendment date – uses the inspection date as a proxy for marketing date and yields virtually identical results (Tables B1 and B2).

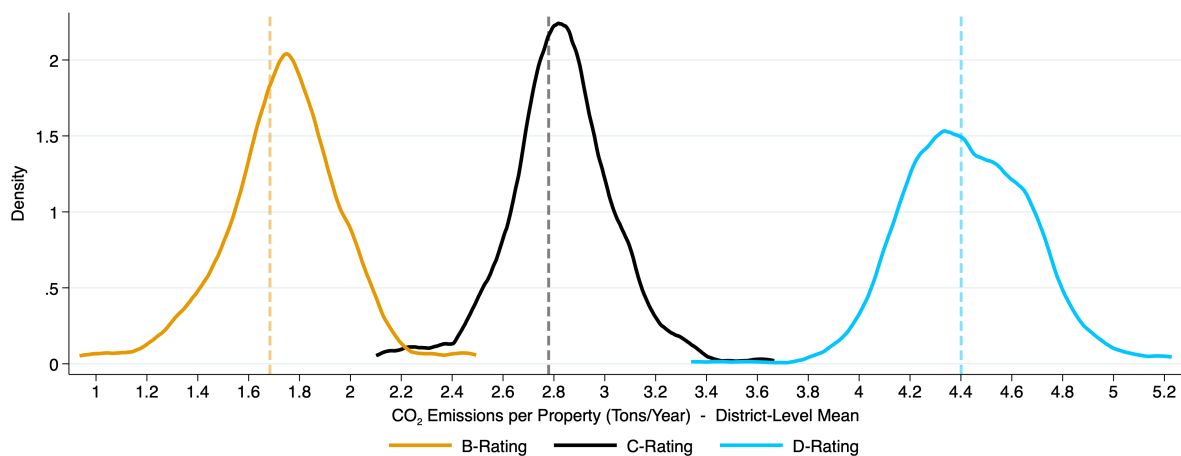
2.3 Motivating the Importance of Energy Efficiency in Housing

The 2011 amendment we study is a disclosure reform, but its policy relevance rests on the carbon footprint of the housing stock that the rating system describes. This subsection takes stock of that footprint and of how homebuyers valued high-emissions attributes in the run-up to the policy. The aim of this exercise is threefold. First, we quantify the extent of carbon emissions of the housing stock in England and Wales. Second, we present a measure of the societal implications of these emissions and conduct a simple simulation experiment to gauge the impact of energy efficiency improvements. Third, we highlight that in the run-up to the EPBR 2011, homeowners valued the housing attributes that were associated with higher, not lower emissions.

Motivating Evidence 1: EPC Categories are Closely Linked to Carbon Emissions

We first present the distribution of district-level mean carbon emissions across EPC rating categories in Figure 1. The figure highlights that EPC ratings meaningfully correlate with the carbon emissions of the housing stock in England and Wales – higher rated properties emit considerably less CO₂, the primary gas contributing to global warming. Compared to B-rated mean emissions, C-rated properties emit 65% more carbon, and D-rated properties emit 161% more carbon. In order to mitigate the carbon impact of housing, improving the energy efficiency of properties plays a critical role.

Figure 1: Higher EPC-Rated Properties Emit Considerably Less Carbon



Notes: Data used: matched housing transaction-EPC data for 6 April 2010-5 April 2012. The figure shows the distribution of district-level mean carbon emissions by EPC categories. The vertical lines represent the country-wide EPC-category mean carbon emissions.

Motivating Evidence 2: The Social Cost of Poor Energy Efficiency in Housing is Substantial

Next, we provide a measure of the negative externality that the carbon content of housing in England and Wales imposes on the global scale. Specifically, using data for the two years prior to the amendment, we calculate (i) the proportion of property sales in each EPC rating category and (ii) the mean carbon emission per property in each rating category. Next, using data on the entire private housing stock in the country, we construct the number of houses in each category, based on the assumption that pre-amendment housing transactions are

informative of the EPC-rating distribution of the housing stock as a whole. With these statistics at hand, we can calculate an estimate of the rating-specific total carbon emissions for England and Wales (Column (3)). We then translate these emissions into a measure of the social cost of carbon, using recent work by Rennert et al. (2022) that considers the social cost of carbon.¹³ The calculations provided in Column (4), Table 2, specifically in the final rows, show that the annual carbon emissions from the private housing stock in England and Wales is associated with an annual social cost of carbon exceeding £12 billion (\$15 billion), with the housing in the EPC rating range B-D that we consider in this work contributing over half of this cost.

In Columns (5)-(7) we simulate the equivalent carbon emissions for the housing stock under the counterfactual that each property improves their EPC rating by one grade, e.g., a C-rated property moves to a B-rating. Column (8) presents the difference between the actual and counterfactual social costs of carbon. Under this simulation, we find that – for a single year of carbon emissions – improving the energy efficiency of the private housing stock in England and Wales would lead to an annual reduction of the social cost of carbon to the tune of £4.2 billion (\$5.5 billion). Once again, the housing stock in the B-D range contributes the lion’s share of this reduction. These statistics underscore the urgency for government policy that can improve the energy efficiency of the housing stock in England and Wales.

Table 2: The Social Cost of Housing-Based Carbon in England and Wales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Actual			Counterfactual			
EPC Rating	Private Residential Housing Stock	Mean CO ₂ Emissions (Tons per Year)	Total CO ₂ Emissions (Million Tons per Year)	Social Cost of Carbon (£Million per Year)	Mean CO ₂ Emissions (Tons per Year)	Total CO ₂ Emissions (Million Tons per Year)	Social Cost of Carbon (£Million per Year)	SCC Difference (£Million per Year)
B	1,409,869	1.7	2.38	302	.56	.79	100	202
C	4,559,558	2.8	12.7	1,611	1.7	7.79	989	622
D	7,802,150	4.4	34.2	4,348	2.8	21.8	2,766	1,582
E	4,495,556	6.6	29.6	3,752	4.4	19.8	2,512	1,240
F	1,369,880	9.7	13.2	1,675	6.6	9.07	1,152	524
G	327,364	11	3.61	459	9.7	3.14	398	61
Total: B-G			95.7	12,147		62.4	7,918	4,229
Total: B-D			49.3	6,261		30.4	3,856	2,405

Notes: The counterfactual calculations here simulate the reduction in carbon emissions from a one rating CO₂ emissions improvement. All EPC ratings are included in the calculations, with the exception of A-rated properties, which account for only .024% of properties in our sample. Social cost of carbon (Rennert et al. 2022, preferred estimate): £126.94 per tCO₂ (2012 GBP), obtained by converting \$185 from 2020 USD to GBP using the 2020 average Spot exchange rate from Bank of England exchange rate data, and then deflating this value from 2020 GBP to 2012 GBP using the Bank of England inflation calculator. Housing stocks statistics are the average housing stock in the two pre-policy fiscal years. The carbon emission statistics are based on our sample of housing transactions for properties sold in the two years prior to the policy.

Motivating Evidence 3: Homeowners Value Attributes with High Carbon Emissions

As a final piece of motivating evidence, we explore how key housing characteristics correlate with

¹³Rennert et al. (2022) report a preferred mean social cost of carbon of \$185 per metric ton of CO₂, expressed in 2020 USD. We convert from 2020 USD to GBP using the 2020 average Spot exchange rate from Bank of England exchange rate data, and then deflate this value from 2020 GBP to 2012 GBP using the Bank of England inflation calculator.

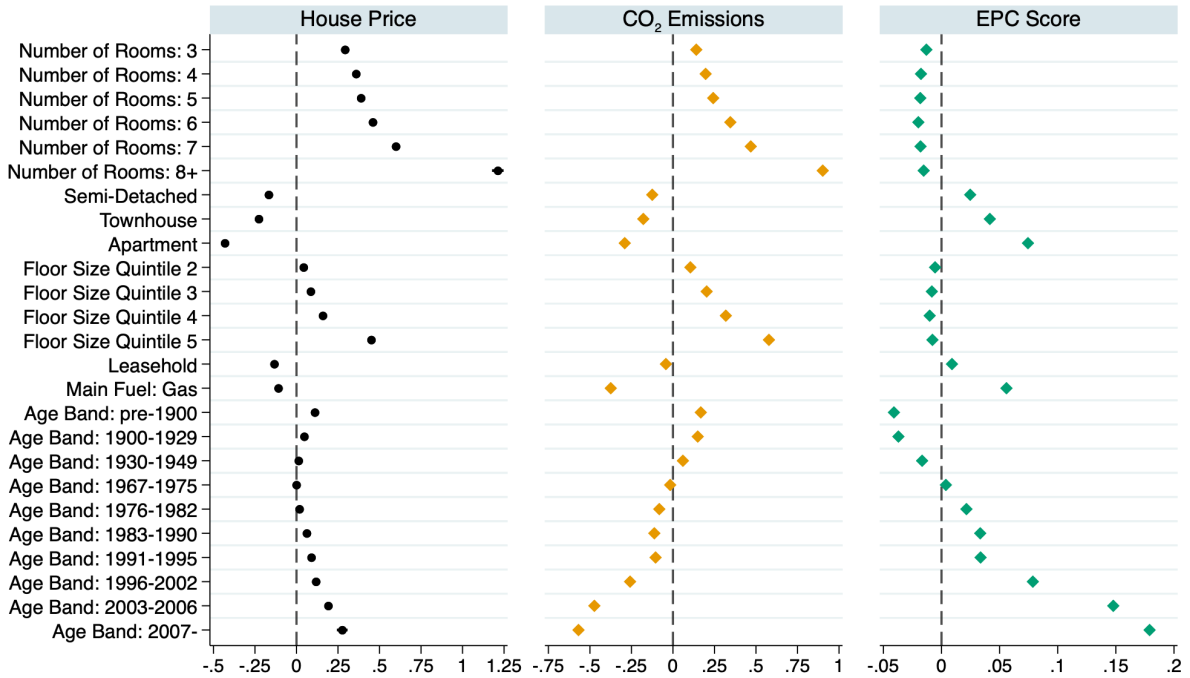
sales price, CO₂ emissions, and energy efficiency. We do so for the year prior to the policy. We estimate a regression specification of the form:

$$y_{pt} = X_p' \beta + \sum_{w=1}^W \tau_w (Wider\ Neighborhood_w \times time_t) + \pi_{r \times t} + \theta_n + \epsilon_{pt} , \quad (1)$$

where X_p is a vector of property characteristics including a dummy for leasehold, a dummy for gas being the main fuel, property type dummies, quintiles of floor area of the property, number of habitable rooms categories and categories for construction year bands. $\pi_{r \times t}$ captures month-by-year regional shocks to house prices, τ_w accounts for wider neighborhood trends in house price determinants, θ_n is a neighborhood fixed effect and captures local unobservables and ϵ_{pt} is an error term. Here y_{pt} is either (i) house price, (ii) CO₂ emissions, or (iii) the energy efficiency score of the property.

We present parameter estimates for key housing characteristics in Figure 2 for the three outcomes based on the full set of properties in England and Wales.

Figure 2: Key Housing Attributes Move Prices and EPC Scores in Different Directions



Notes: Estimation sample: 6 April 2011 - 5 April 2012. Each point is the resulting coefficient from Equation (1) for each category. To present all estimates on a common scale, the estimates here are proportional estimates based on the mean of the outcome. Lines represent 95% confidence interval for robust standard errors". We represent house price estimates with black, CO₂ emissions estimates in orange, and EPC score estimates with green.

The estimates tell a striking story – almost across the board, the housing attributes that homebuyers value – larger homes, more rooms, the oldest of homes, detached houses – are also correlated with higher CO₂ emissions, and thus lower energy efficiency. This evidence suggests that without energy efficiency-related housing-based policy, such as the one we study in this paper, homebuyers are unlikely to choose more energy-efficient properties.

The evidence we provide in this section makes clear both the carbon emission differentials

across EPC ratings and the societal consequences of these differentials. The simulation evidence provides motivating evidence for the importance that energy efficiency-focused policies can play in mitigating the carbon-based impact of housing in developed countries. The final piece of motivating evidence highlights the importance of policy interventions that target energy efficiency in the housing market – the status quo is for homeowners to value attributes of properties that correlate negatively with energy efficiency.

3 Conceptual Framework

In this section we present a simple framework to make clear the channels through which the EPBR 2011 amendment could change how households respond to EPC ratings. A key feature of the amendment is that it altered the design of information disclosure – the timing and prominence of the EPC at the point of sale – rather than the underlying information set, which was available on request from 2007 onwards. The framework we develop below is organized around this distinction.

Through the lens of a hedonic pricing model, individual i 's valuation of a given property p is given by the weighted sum of its attributes, such that $V_{ip} = \sum_j \omega_{ij} a_j$, where ω_{ij} is the weight individual i gives to attribute j , and a_j is the value of the attribute j in house p . Under this framework, the price premium for any attribute will be given by $\partial V_{ip} / \partial a_j = \omega_{ij}$.

Focusing on EPC ratings, and taking expectations over the distribution of homebuyers and properties we can write $E[\omega_{ij} | j = EPC_k]$, which is the estimated premium for the EPC category k , relative to C-rated properties, our base category. To link this framework with our empirical approach we define $\hat{\omega}_{EPC}^t = E[\omega_{ij} | j = EPC_k, t]$ as the estimated premium (weight) for the EPC category k in a given period t . We can then write our DD estimator as $\hat{\beta}_{EPC_k} = \hat{\omega}_{EPC_k}^1 - \hat{\omega}_{EPC_k}^0$.

To better understand how the EPBR 2011 amendment may affect the premium associated with EPC ratings, we rewrite our equation for V_{ip} , decomposing the hedonic weight ω_{ij} into two distinct terms:

$$V_{ip} = \sum_j \underbrace{(\alpha_{ij} + \gamma_i \tilde{v}_j)}_{\text{Valuation Term}} \underbrace{(1 - \theta_i(s_j))}_{\text{Inattention Term}} a_j. \quad (2)$$

The first component – the valuation term – represents the valuation given by the individual to a given attribute and comprises two parts. First, α_{ij} is the utility the individual receives from consuming a house with an attribute a_j .¹⁴ Take for example, a property with a swimming pool ($a_{\text{pool}} = 1$).¹⁵ $\alpha_{i,\text{pool}}$ represents how much the individual enjoys having a house with a pool.

Second, given that a property is also an investment (Bailey et al., 2019; Glaeser and Gyourko, 2018; Iacoviello and Neri, 2010), $\gamma_i \tilde{v}_j$ is the perceived valuation of a property with attribute a_j . $\tilde{v}_j$ is the present value of a common perception of the market value of the attribute, and $\gamma_i \geq 0$ is the relative weight the individual places on the investment component of the property with respect to the consumption value. For instance, if the property has a pool, the individual has an estimation of how much the pool could add to the total house value if she sells it in the

¹⁴To take into account the fact that consumption of a given attribute expands over the period that a person lives in the property, one can understand α_{ij} as the discounted present value of the consumption.

¹⁵Given the climate, pools are not common in properties in England and Wales. We chose this example to highlight the distinct elements homebuyers face when viewing a property with a pool – it may provide a very high (idiosyncratic) consumption value, but is unlikely to yield much of an investment value.

future. If $\gamma_i \leq 1$ individual i gives the same or more weight to consumption than investment. When $\gamma_i > 1$ the homebuyer considers the investment value of the attribute as relatively more important than the consumption value.

The second component of the weight – the inattention term – builds on DellaVigna (2009)’s definition of limited attention. In this case, $\theta_i(s_j) \in [0, 1]$ represents the degree of attention individual i gives to the attribute j , where $\theta_i(s_j) = 0$ represents full attention and $\theta_i(s_j) = 1$ total inattention. The level of attention depends on the salience of the attribute, denoted as s_j , with $\partial\theta_i/\partial s_j \leq 0$. Notice that the salience of j is common to all individuals but the resulting attention depends on each individual. For example, more sophisticated or experienced buyers may pay more attention to all features by, for instance, collecting more information. Certain features of homebuyers may lead them to pay greater attention to specific attributes. For instance, although school quality information is available to everyone, homebuyers with school-age children will pay more attention to this information than homebuyers without children.¹⁶

3.1 Model Predictions

Based on this simple conceptual framework, we can express the 2011 EPBR amendment as two distinct shocks. This approach yields four channels through which the policy may differentially impact housing valuations for properties with different EPC ratings.

Saliency Channel First, given the increased salience of EPC rating information due to the policy, the amendment represents a positive shock to the salience of energy efficiency. In our framework, the result of this shock will be:

$$\frac{\partial\omega_{i,EPC}}{\partial s_{EPC}} = -(\alpha_{i,EPC} + \gamma_i\tilde{v}_{EPC})\frac{\partial\theta_{i,EPC}}{\partial s_{EPC}} \geq 0 \quad (3)$$

Equation 3 thus represents the saliency channel. The positive effect of the salience shocks aligns with the findings of Chetty et al. (2011), Bordalo et al. (2013) and Caplin and Dean (2015).

An insight from Equation 3 relates to the valuation assigned to more energy-efficient homes. This reveals important sources of heterogeneity associated with the saliency channel, and yields two distinct sub-channels.¹⁷

Consumption Sub-Channel The first sources of heterogeneity from Equation 3 relates to the consumption value placed on more efficient homes. Specifically, where $\alpha_L < \alpha_H$, if homebuyer L expects less consumption gains than house buyer H (savings in the electricity bill, for example), then:

$$\left| \frac{\partial\omega_{i,EPC}|\alpha_L}{\partial s_{EPC}} \right| < \left| \frac{\partial\omega_{i,EPC}|\alpha_H}{\partial s_{EPC}} \right|. \quad (4)$$

This represents the consumption sub-channel. The saliency shock will have a larger effect on the valuation for homebuyers that expect a larger consumption gain from buying a more efficient

¹⁶Adida et al. (2020) and Singhal (2022) also show that individuals pay different attention to the same information in different scenarios.

¹⁷The two sub-channels are effectively second-order channels. If the saliency channel is inactive, these sub-channels will also remain dormant.

household.¹⁸

Market Valuation Sub-Channel Similarly, if $\tilde{v}_{EPC}^L < \tilde{v}_{EPC}^H$ —that is, if the local market value associated with energy efficiency is higher for property H than for property L —then:

$$\left| \frac{\partial \omega_{i,EPC} | \tilde{v}_{EPC}^L}{\partial s_{EPC}} \right| < \left| \frac{\partial \omega_{i,EPC} | \tilde{v}_{EPC}^H}{\partial s_{EPC}} \right|. \quad (5)$$

The saliency shock is therefore amplified when the local market places a higher premium on energy efficiency.

Investment Channel Finally, the fact that the EPC is now so prominent in sales marketing material could be understood as an increase in the perceived market value of properties with a better EPC rating:

$$\frac{\partial \omega_{i,EPC}}{\partial \tilde{v}_{EPC}} = \gamma_i (1 - \theta_i(s_{EPC})) \geq 0 \quad (6)$$

We label this final mechanism the investment channel. This channel highlights how the policy affects the valuation for more efficient households via the increased perceived valuation of the property at resale.

Both Equation 5 and Equation 6 underscore the role of investment value in shaping housing market dynamics and policy effects. However, they capture distinct mechanisms. The investment channel (Equation (6)) reflects a policy-induced signal to the market: energy-efficient homes are more valuable assets. On the other hand, Equation (5) shows that the saliency channel becomes stronger when the perceived investment value of energy efficiency is higher.

Policy Implications of a Multi-Channel Policy As our framework highlights, the policy can shift the premium for more efficient homes through four distinct, same-signed channels. The framework disciplines each channel with a separate empirical test, drawing on different sources of variation in the data. In Section 6 we implement these tests and find supporting evidence for each of the four channels, together with informative nulls on specific margins within the consumption and market valuation sub-channels. From the standpoint of policy design, this multi-channel structure is an attractive feature of the EPBR 2011 amendment. A policy that shifts valuation through several reinforcing margins does not rely on any single behavioral response: even if one channel is weak in a given market or population, others may still operate.

¹⁸We note that the consumption channel is effectively a second-order channel, based on the existence of the (first-order) saliency channel. If the saliency channel does not exist, then neither can the consumption channel.

4 Empirical Specification

Our empirical approach takes the form of a hedonic house price model, using a regression-adjusted difference-in-differences (DD) specification as follows:

$$\begin{aligned}
 Price_{pt} = & \sum_{k \neq C}^K \alpha_k Category_k + \sum_{k \neq C}^K \beta_k (Post_t \times Category_k) \\
 & + \sum_{\tau=0}^1 \sum_{d=1}^D (District_d \times 1[Post_t = \tau] \times X_p' \gamma_{d\tau}) \\
 & + \sum_{w=1}^W \tau_w (Wider Neighborhood_w \times time_t) + \pi_{r \times t} + \theta_n + \epsilon_{pt} , \tag{7}
 \end{aligned}$$

where $Price_{pt}$ is the sale price of property p , sold in period t (measured at the month-level). We choose to model prices in levels as opposed to log-transformed prices given recent work detailing the pitfalls of the log-transformation when implementing a DD design (McConnell, 2023). $Category_k$ denotes EPC rating category k , $Post_t$ is a dummy for properties sold post-EPBR 2011 amendment, and β_k are our parameters of interest. These are the DD parameters. We conceptualize the EPBR 2011 amendment as both (i) an information shock regarding the energy efficiency ratings of properties and (ii) a market-wide salience shock to the notion of energy efficiency as a key property attribute. Against this backdrop, we interpret our DD estimates as capturing the information shock-induced willingness to pay (WTP) of households for a higher EPC-rated property within a more energy efficiency aware market. X_p is a vector of property characteristics including a dummy for leasehold, a dummy for gas being the main fuel, property type dummies, quintiles of floor area of the property, number of habitable rooms categories and categories for construction year bands. $\pi_{r \times t}$ captures month-by-year regional shocks to house prices, τ_w accounts for wider neighborhood trends in house price determinants, θ_n is a neighborhood fixed effect and captures local unobservables and ϵ_{pt} is an error term. The treatment occurs at the household-level and we implement a repeated cross-sectional DD approach, hence we use heteroskedasticity-robust standard errors throughout (Abadie et al., 2023).

We specify the housing market as a local authority district (hereafter district). The local authority district is the core level of local government in England and Wales. Property taxes are collected at the district-level, and it is districts that provide key local public goods such as social care, schools, and waste collection. Districts are also the level at which school admissions policies are organized. We interact the vector of housing characteristics, X_p , with district dummies in order to respect the “law of one price function” (Bishop et al., 2020). This allows the valuation of key property characteristics to vary across local housing markets, which allows for a great deal of flexibility, as there are 347 districts in our sample.¹⁹

We allow the coefficients on all housing characteristics to differ in the pre and post periods, thereby allowing the hedonic price function to shift post-policy. We do so in order to avoid conflation bias (Kuminoff and Pope, 2014; Banzhaf, 2021). Given this flexibility, the regres-

¹⁹There are 348 districts in total in England and Wales – we omit the Isles of Scilly due to data limitations.

sion specification in (7) is, in the nomenclature of Kuminoff et al. (2010), a generalized DD estimator.²⁰

4.1 Identification

The key identifying assumption underpinning our empirical approach is that properties with different EPC ratings experience common house price trends. Taking into account the recent critique of canonical pre-trends testing made by Roth (2022), we provide a battery of evidence using multiple approaches in support of parallel trends in our setting.

We first implement a set of placebo DD regressions. We shift all key dates one year back in time, and re-estimate Equation 7. We do not estimate any significant placebo DD parameters for either England and Wales combined (Appendix Table A1), or for the London region (Appendix Table A2). Next we inspect the trends in house prices across the three EPC rating categories in the two years prior to the implementation of EPBR 2011 (Appendix Figure A1). We cannot reject the null of equality of trends in any case. Finally, we later present event study estimates in Figure 3. In addition to allowing us to trace the dynamic effects of the policy on house prices, these graphs also highlight an absence of differential pre-trends across EPC categories. This provides further support for the parallel trends assumption. Taken together, the evidence we present here is strongly supportive of parallel trends in house prices across the different EPC categories under consideration.

Given that we are using repeat cross-sectional data for our empirical analysis, we also provide evidence for a second identifying assumption – that the composition of EPC category groups are stable across the pre and post periods. In order to assess the stability of groups over time, we present the results from a series of balance tests in Appendix Table A3 for England and Wales, and Appendix Table A4 for London. In both cases, we find strong support for stability of group composition in our sample period. This is most easily seen by viewing the bottom row of Appendix Table A3 and Appendix Table A4, where we present the p -values from a joint test of balance across all control variables.

5 The Value of Energy Efficiency Information

In this section, we present the core difference-in-differences estimates of the policy’s impact on EPC premiums. We begin with country-wide results and then turn to London, where housing market conditions differ markedly from the national setting. We assess the stability of the estimates across alternative specifications and examine dynamic treatment effects. In Section 6, we interpret these patterns through the channels outlined in Section 3.

5.1 Country-Wide Results

We present the DD parameter estimates from Equation (7) in Column (7) of Table 3. The six preceding columns report estimates from progressively less stringent specifications, allowing us to assess parameter stability as we (i) increase the resolution of the spatial fixed effects and (ii) introduce local time trends at different spatial levels.

²⁰As Kuminoff et al. (2010) note: “the generalized DID estimator appears to be the best suited to hedonic estimation in panel data. The interactions between time dummies and housing characteristics control for changes in the shape of the equilibrium price function over time; the spatial fixed effects control for omitted variables in each time period”.

In Column (1), we define the housing market at the Travel To Work Area (TTWA) level – analogous to Commuting Zones in the US—include TTWA fixed effects – and omit local time trends. Under this specification, B-rated properties sell for 5.4% more and D-rated properties for 1.3% less than comparable C-rated properties in the post period, where the magnitudes are calculated as $(\text{Rating} \times \text{Post})/\bar{Y}_{C,PRE}$ at the base of Table 3.

Table 3: DD Estimates from Introduction of EPC certificates – England and Wales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating $\times$ Post	11,308** (4,432)	8,555** (4,147)	6,183* (3,501)	6,200* (3,216)	6,238* (3,215)	6,373** (3,085)	6,509** (3,117)
D Rating $\times$ Post	-2,778** (1,092)	-2,691*** (1,003)	-2,987*** (817)	-2,649*** (770)	-2,653*** (770)	-2,617*** (774)	-2,603*** (778)
$\bar{Y}_{C,PRE}$	207958	207958	207958	207958	207958	207958	207958
(B Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	.0544**	.0411**	.0297*	.0298*	.03*	.0306**	.0313**
(D Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	-.0134**	-.0129***	-.0144***	-.0127***	-.0128***	-.0126***	-.0125***
Spatial FEs	TTWA	District	District	Wider NH	Wider NH District	NH	NH
Local Time Trends							Wider NH
X Interactions	TTWA $\times$ Post $\times$ X	TTWA $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X
Adjusted R^2	.458	.559	.69	.737	.737	.759	.76
Observations	702,360	702,360	702,362	702,362	702,362	702,266	702,266

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. Eicker-Huber-White standard errors in parentheses. The dependent variable in all regressions is the house price in £.

Columns (2) and (3) increase the spatial resolution of the fixed effects and redefine the housing market from TTWA to district, which alters the X -interaction structure. These changes reduce the B-rating premium but leave the D-rating penalty largely unchanged, suggesting that highly efficient properties are unevenly distributed across housing markets. Moving from Column (3) to Column (7) has little effect on either DD estimate.

Column (7) presents our baseline specification, which includes neighborhood fixed effects, neighborhood-specific time trends, and district-by-period-by- X interactions for all controls. This specification absorbs fine-grained spatial sorting and allows for differential local price trajectories across neighborhoods and districts. The stability of the DD estimates under these controls indicates that the premium is not driven by time-invariant location differences or differential local trends. Under this specification, B-rated properties command a 3.1% premium and D-rated properties a 1.3% penalty relative to C-rated properties in the post period.

5.2 London-Specific Estimates

We next estimate region-specific responses to the EPBR 2011 amendment, to gauge regional heterogeneity. Appendix Figure B4 highlights substantial regional variation in these responses. The London region exhibits particularly large treatment effects, both in absolute and proportional terms, motivating a London-specific estimation of Equation (7). We report these results in Table 4.

Table 4: DD Estimates from Introduction of EPC certificates – London Only

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating $\times$ Post	40,450** (16,966)	30,005* (15,811)	24,993* (13,499)	22,314* (12,256)	22,244* (12,250)	22,854* (11,760)	22,769* (11,909)
D Rating $\times$ Post	-16,101** (7,060)	-13,437** (6,401)	-11,577** (5,075)	-9,763** (4,800)	-9,830** (4,794)	-11,140** (4,947)	-10,867** (4,991)
$\bar{Y}_{C,PRE}$	350839	350839	350839	350839	350839	350839	350839
(B Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	.115**	.0855*	.0712*	.0636*	.0634*	.0651*	.0649*
(D Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	-.0459**	-.0383**	-.033**	-.0278**	-.028**	-.0318**	-.031**
Spatial FEs	TTWA	District	District	Wider NH	Wider NH District	NH	NH
Local Time Trends							Wider NH
X Interactions	TTWA $\times$ Post $\times$ X	TTWA $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X
Adjusted R^2	.297	.446	.641	.696	.696	.717	.718
Observations	93,602	93,602	93,595	93,595	93,595	93,582	93,582

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. Eicker-White standard errors in parentheses. The dependent variable in all regressions is the house price in £.

As in Table 3, coefficient magnitudes shift when moving from coarse to finer spatial controls, but stabilize in the more demanding specifications. In the baseline London specification, B-rated properties command a 6.5% premium and D-rated properties incur a 3.0% penalty relative to C-rated properties in the post period, measured as (Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$. These effects are approximately twice the magnitude of those estimated at the national level. Importantly, these larger magnitudes arise under an equally demanding specification, with neighborhood fixed effects, neighborhood-specific trends, and rich district-by-period interactions with control variables. The larger London premium therefore emerges within the same empirical framework, under an equally demanding specification.

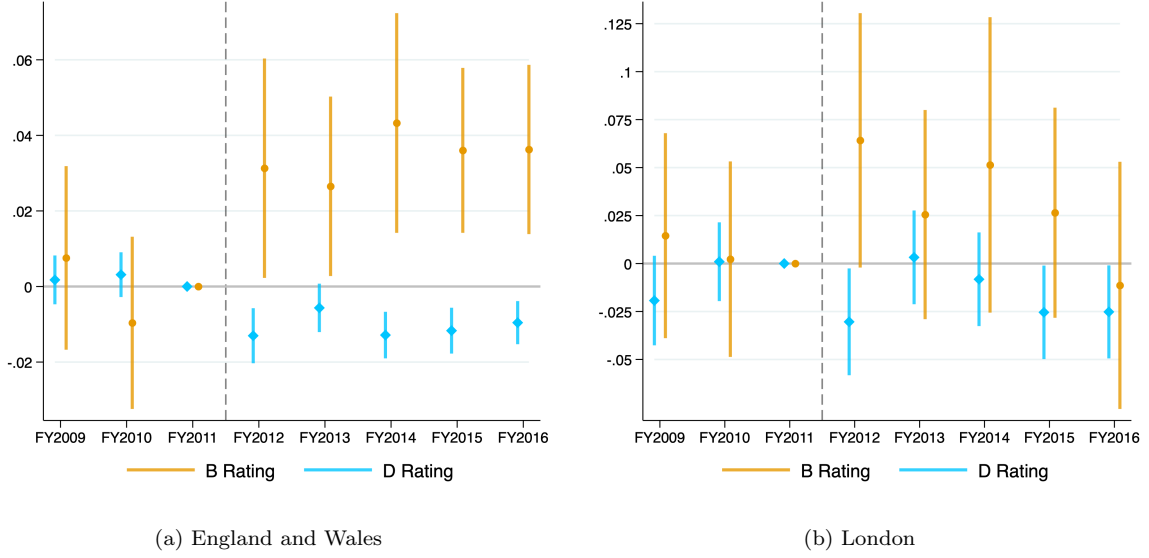
In Section 6, we examine the mechanisms underlying this spatial variation.

5.3 Dynamic Treatment Effect Estimates

A key feature of our baseline DD specification is the short temporal window around the implementation of the EPBR 2011 amendment, which limits the scope for supply-side adjustment. If, following the policy, homeowners anticipate a sustained premium for more energy-efficient properties, differential supply responses across the EPC distribution may emerge over time. It is therefore informative to examine dynamic treatment effects, recognizing that event-study coefficients capture equilibrium price responses that reflect both demand- and supply-side forces.

$$\begin{aligned}
Price_{pt} = & \sum_{k \neq C}^K \alpha_k Category_k + \sum_{\substack{e=-3, \\ e \neq -1}}^5 \left[\sum_{k \neq C}^K \beta_k (ET_e \times Category_k) + \sum_{d=1}^D (District_d \times ET_e \times X'_p \gamma_{de}) \right] \\
& + \sum_{w=1}^W \tau_w (Wider Neighborhood_w \times time_t) + \pi_{r \times t} + \theta_n + \epsilon_{pt} ,
\end{aligned} \tag{8}$$

Figure 3: Event study results



Notes: We present point estimates and 95% confidence intervals for the dynamic DD terms, using the specification outlined in Equation (8).

where all terms are as defined in Equation (7), with the exception of ET_e , which denotes event time. We create event time to match the introduction of the legislation, hence $ET_e = -1$ coincides perfectly with our DD-based pre-period (6 April 2011-5 April 2012), $ET_e = 0$ coincides with our post period (6 April 2012-5 April 2013), and so on.²¹ As in Equation (7), we allow covariates to vary flexibly by event time and district, thereby mitigating conflation bias and preserving the law of one price. We present the resulting dynamic DD parameters in the form of event study plots in Figure 3.

The event study graphs show no evidence of differential pre-trends across EPC categories. This provides additional evidence in support of the identifying assumptions underlying our empirical specification, complementing the results in Table A1, Table A2, and Figure A1.

We next examine post-policy dynamics in Figure 3(a). At the national level, the B-rating premium rises in the immediate post period and remains elevated thereafter, while D-rated properties exhibit a persistent penalty of opposite sign. The relative stability of these coefficients over time indicates that any supply-side adjustment was insufficient to offset the initial increase in demand for more energy-efficient properties. One interpretation is that the national premium, while economically meaningful, was not large enough to generate a substantial supply response capable of eroding the equilibrium price differential.

Figure 3(b) reveals a different pattern for London. The coefficients for D-rated properties fluctuate over time, consistent with evolving demand- and supply-side responses. The most salient feature is that the initially large B-rating premium attenuates over time and is no longer present in the medium run. One interpretation consistent with this pattern is that the sizeable

²¹Our extended sample period starts with the 2009 fiscal year (6 April 2009-5 April 2010) – the first full year of data we have. The extended sample period ends with the 2016 fiscal year (6 April 2016-5 April 2017). We choose this endpoint so as to avoid picking up other housing market-based legislation changes that came into effect in 2018. This is a conservative choice, as these changes affect directly G- and F-rated properties, which we do not consider.

initial premium induced a stronger supply response in London, which subsequently compressed the equilibrium price differential.

Appendix Figure B5 provides suggestive evidence on this margin by reporting the relative supply of B- and D-rated properties over time, using C-rated properties as the reference group. The relative supply of B-rated properties increases both nationally and in London, with a sharper rise in London. These patterns are consistent with a supply response that contributes to the medium-run compression of the London B-rating premium. A similar equilibrium logic appears in the literature on the 1980s and 1990s rise in the college wage premium, when increases in relative supply coincided with rising premiums as demand shifted even more strongly (Katz and Murphy, 1992; Card and Lemieux, 2001; Goldin and Katz, 2008; Autor et al., 2008).

6 Mechanisms

Having documented a rise in the premium for better-rated properties post-Amendment, we now turn to investigate the mechanisms that underpin these enhanced energy efficiency premiums. The model we develop in Section 3.1 makes clear that the policy can impact property valuations via four different channels. We assess the empirical evidence on mechanisms through the lens of this model.

6.1 Hard-to-Observe Attributes and the Saliency Channel

The policy we study in this paper mandated that the front page of the EPC was to be included in all advertising material for the sale of a property, at the time of sales listing. This front page (see Figure C2 for an example front page) provides information on the EPC rating of the property, and some additional information on the costs and benefits for a subset of potential retrofit upgrades. The full EPC contains more detailed information on a variety of key dimensions of the energy efficiency of the property, many of which are hard to observe, and thus plausibly represent new information for homebuyers.²² The saliency of this extended set of information was *not* directly increased due to the Amendment – it was available before the policy and after, but the full EPC was not made more prominent post-Amendment. Only the information on the front page. This is the sense in which the Amendment changed the design of disclosure rather than the information set itself, and the front-page-versus-full-EPC contrast we develop below provides a direct test of whether this distinction matters for housing market valuation.

This differential, Amendment-induced shift of the front-page matter provides a test for the saliency channel we outline in Section 3.1. The policy increased the salience of the EPC rating, but did not increase the salience of other energy-related information contained in the full EPC. If the saliency channel is operative, we should observe a post-policy change in the valuation of EPC ratings but no corresponding change for these other features. To test this, we estimate a variant of Equation (7), where we replace the EPC ratings with one of three sets of features of

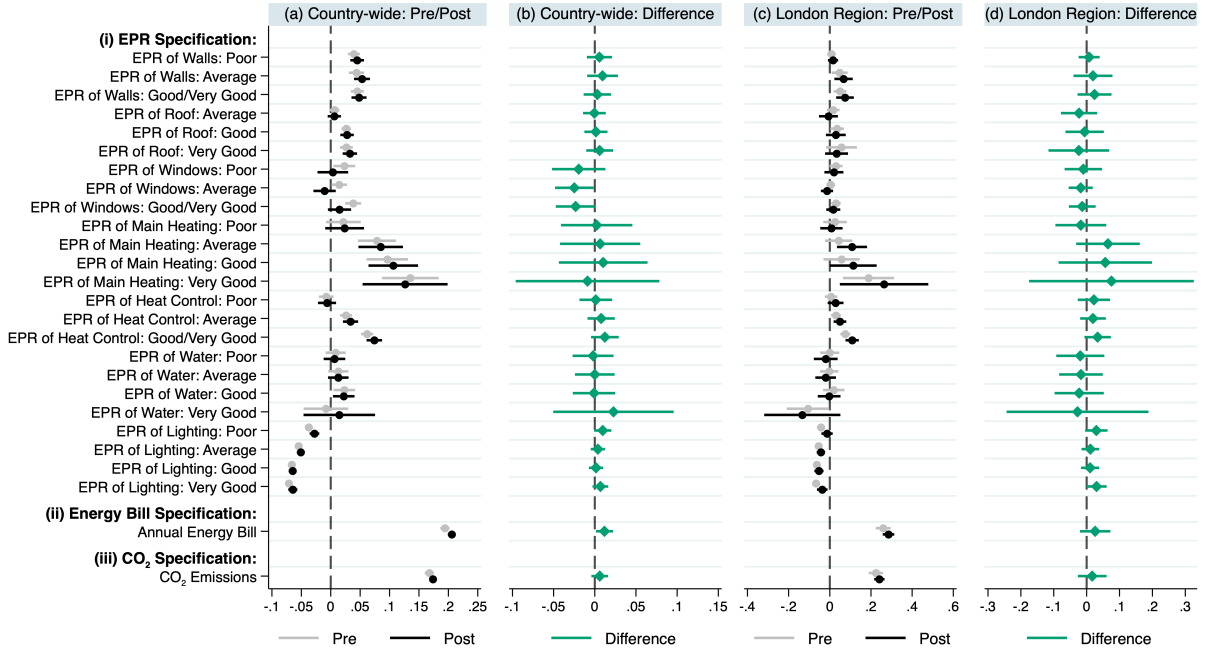
²²This includes a set of feature-specific energy performance ratings for the property, as well as information on energy costs and carbon emissions of the property. The full EPC provides ratings of the energy performance for the following property features: the walls, the roof, windows, main heating, main heating control, hot water, lighting, floor, and secondary heating if present. See Figure B6 for an example from an EPC. In absence of an EPC, this information would be extremely difficult to ascertain.

the property, indexed by f . This leads to a series of equations of the form:

$$Price_{pt} = F'_{fp}\alpha_f + Post_t \times F'_{fp}\beta + \sum_{\tau=0}^1 \sum_{d=1}^D (District_d \times 1[Post_t = \tau] \times X'_p\gamma_{d\tau}) + \sum_{w=1}^W \tau_w(Wider\ Neighborhood_w \times time_t) + \pi_{r \times t} + \theta_n + \epsilon_{pt} \text{ for } f = (1, 2, 3). \quad (9)$$

For the first set of features, $F_{1p} = EPR_p$, a vector of all the key feature-specific energy performance ratings (EPR) presented in the full EPC.²³ In the second specification, $F_{2p} = EB_p$, the annual energy bill estimate (EB), calculated by the energy assessor based on the energy performance of the property. In the final specification $F_{3p} = CO_{2,p}$, the estimated carbon emission of the property on inspection. All other terms are as discussed in Section 4. For the three separate specifications, we present the key feature-specific rating coefficients, and 95% confidence intervals, in Figure 4 below. In panels (a) and (c) we present the corresponding point estimates

Figure 4: Valuing Specific Housing Characteristics



Notes: EPR stands for Energy Performance Rating. Energy performance rating of key features of the property (e.g., walls, roof) are displayed in the full EPC, but are not presented on the first page that accompanies the marketing material.

and 95% confidence intervals for all key feature-specific ratings in the pre- and post-periods for the country as a whole and the London region respectively. The pattern of estimates is similar for both the country-wide and London-specific samples. In panels (b) and (d) we present the pre-post difference in how homebuyers value these hard-to-observe attributes of the property. These pre-post differences correspond to our estimates of β in Equation (9). For specification 1 – the feature-specific ratings specification – we do not observe any key differences across the two periods. For the second and third specifications, we observe a similar pattern. The core

²³The base category for each feature-specific performance rating is “very poor”, unless “very poor” is too infrequent, in which case we combine “very poor” and “poor” as the base category.

message we take away from these results is that salience matters. We document a large and significant change in the valuation of EPC ratings – aspects of the property made salient by the Amendment. We document no change in the valuation of hard-to-observe aspects of the property that was not made salient by the policy – information on which was available both pre- and post-Amendment. The results of specification 2 highlight that the policy does not lead homeowners to meaningfully change how they factor in energy costs of the property. The results of specification 3 show that homebuyers are not differentially internalizing the carbon emission of the property in the post-policy period.

These null findings are particularly interesting when viewed against the backdrop of both our conceptual model and our core results. The policy raised the salience of the EPC rating of the property. Accordingly, in Section 5, we document a robust and statistically significant market response – in the post-period homebuyers pay a larger premium for higher rated properties. Although the full EPCs also contain information on the energy performance of specific features of the properties, as well as the energy costs and carbon emissions of the property, this wider information set is *not made salient by the policy*. It is only the EPC rating of the property that the policy makes more salient. We interpret the absence of price responses to any of the other energy efficiency-based characteristics listed in the full EPC as clear evidence of the importance of the saliency channel.

6.2 Does Local Supply Matter for EPC Premiums?

We next consider a test of the market valuation sub-channel. This necessarily proceeds Section 6.1, as if the primary saliency channel is dormant, so too are the second-order sub-channels. Our test here is founded on the observations that when (i) energy efficiency is valued and (ii) highly efficient properties are locally scarce, then all else equal, local scarcity of efficient properties should amplify the policy-induced increase in the valuation of B-rated properties. To operationalize this idea, we first create (for every property in our main estimation sample) a series of property-specific measures that capture aspects of the energy efficiency of other properties that were sold in the same neighborhood up to one year prior to the reference-property sale date. These local measures thus capture a time-varying measure of the local supply of energy-efficient properties in the period when homebuyers would be searching for properties in the locale of each reference property. We then estimate a triple-difference variant of Equation (7) where the third difference is one of three property-specific measures of the energy efficiency in the wider neighborhood in the run-up to the sale date – the proportion of B-rated properties, the proportion of D-rated properties, and the mean EPC score of properties sold in reference area and time period. To ease interpretation and comparison across the third differences, we center and studentize these three measures. We present the results in Table 5.

At the national-level, we do not find strong evidence in support of the market valuation sub-channel. For London, however we do. For all three measures of local supply of more energy-efficient properties we document a strong response for the premium paid for a B-rated property. The results in Column (4) highlight that when there are more B-rated properties on the market in the wider neighborhood, homebuyers pay a smaller premium for a B-rated property. This

Table 5: DDD Estimates – Local Supply Of More Energy-Efficient Properties

	(1)	(2)	(3)	(4)	(5)	(6)
	England and Wales			London		
	Proportion B-Rated	Proportion D-Rated	Mean EPC Score	Proportion B-Rated	Proportion D-Rated	Mean EPC Score
B Rating DDD	-2,875 (1,833)	1,710 (2,069)	-5,731** (2,719)	-10,752* (6,385)	14,234* (7,823)	-17,754* (9,913)
D Rating DDD	-390 (552)	275 (547)	751 (659)	608 (2,878)	-2,671 (3,089)	3,880 (3,785)
$\bar{Y}_{C,PRE}$	207958	207958	207958	350839	350839	350839
B Rating DDD/ $\bar{Y}_{C,PRE}$	-.0138	.00822	-.0276**	-.0306*	.0406*	-.0506*
D Rating DDD/ $\bar{Y}_{C,PRE}$	-.00188	.00132	.00361	.00173	-.00761	.0111
Third Difference: Mean	.0601	.417	60.5	.0728	.393	60.7
Third Difference: SD	[.0883]	[.11]	[5.05]	[.109]	[.11]	[5.46]
Observations	702,265	702,265	702,265	93,582	93,582	93,582

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. Eicker-White standard errors in parentheses. The dependent variable in all regressions is the house price in £.

DDD effect does not wipe out the post-Amendment gains to B-rated properties in London, but rather mitigates these gains. We see a reverse pattern in Column (5) for mechanical reasons – if there are proportionately more D-rated properties, this likely means fewer B-rated properties.

These results implicitly provide support for the saliency channel – the market valuation sub-channel operates via this primary channel. The results also highlight the importance of an investment response to the EPBR 2011 Amendment. That this response should be markedly stronger in London – where the private rental sector plays a larger role than at the national level – is not surprising.²⁴

6.3 Capitalization of Energy-Related Savings

As we outline in Section 3, the policy-induced premiums we estimate may reflect distinct components of the valuation term in our model. In particular, Equation (2) decomposes the hedonic weight on the EPC rating into a consumption component, $\alpha_{i,EPC}$, and an investment component, $\gamma_i \tilde{v}_{EPC}$. In this section, we assess whether the observed post-policy premiums can be accounted for by the consumption component alone. Under the null hypothesis that the investment channel is inactive ($\gamma_i = 0$), the premium associated with a more energy-efficient property should not exceed the present value of expected reductions in private energy expenditure, and, to the extent that households internalize environmental externalities, the present value of monetized carbon emission reductions.

We present the results of this cost-benefit comparison in Table 6. The policy-induced premiums represent the additional price paid for a better-rated property in the post-policy period. We compare these premiums to two present-value measures of energy-related benefits. First, private benefits in the form of lower energy bills. Second, the social benefit of lower carbon emissions. For a homebuyer concerned only with private savings, the relevant comparison is

²⁴According to 2011 Census data for England and Wales, the private rented sector accounted for 18.0% of all households. In contrast, Greater London had a substantially higher proportion of households in the private rented sector at 26.4% in the same year, reflecting a notably greater concentration of investor-owned properties relative to the national average. (Greater London Authority Intelligence Unit and Office for National Statistics, 2013)

Column 1 versus Column 2. For a homebuyer who fully internalizes the social benefit of reduced carbon emissions, the relevant comparison is Column 1 versus Column 4.

Table 6: The Costs and Benefits of More Energy Efficient Properties

	(1)	(2)	(3)	(4)
		Private Benefits	Social Benefits	
	Policy-Induced Price Premium	Energy Bill Reduction	Reduced Carbon Emissions	Bills + Carbon Reduction
England and Wales				
From D to C	2,603	2,340	1,703	4,042
From C to B	6,509	968	559	1,527
London				
From D to C	10,867	2,264	1,629	3,893
From C to B	22,769	1,137	661	1,798

Notes: Policy-Induced Price Premiums from tables 3 and 4. For the cost of carbon reductions, we use the regression-adjusted difference between B and C, and C and D properties, in the one year prior to the EPBR policy. We multiply these carbon emission differences by the social cost of carbon value, (Rennert et al., 2022). We first convert from USD to GBP using the 2020 average Spot exchange rate from Bank of England exchange rate data, and then deflate this value from 2020 GBP to 2012 GBP using the Bank of England inflation calculator. For energy bill savings we follow an analogous strategy, using the regression-adjusted difference between B and C, and C and D properties as inputs into the present value calculation. The present value is computed using the sum of annual energy savings and the monetized carbon emission reductions over the average tenure (14 and 13 years for England and Wales, and London respectively) that we observe in the Price Paid data, and an interest rate of 0.5%.

Two key findings emerge from this exercise. First, energy-related savings are economically meaningful in all settings we consider. The present value of lower energy bills—and, where relevant, carbon emission reductions—is non-trivial in magnitude. In the national D- to C-rating comparison, the private energy bill savings closely approximate the estimated premium, consistent with near full capitalization under the consumption channel.

Second, in all other cases, the observed premium for a better-rated property substantially exceeds the present value of energy-related benefits, even under the assumption of full internalization of carbon emission reductions. This divergence is particularly pronounced in the London market. Within the structure of Equation (2), this implies that the consumption component $\alpha_{i,EPC}$ is insufficient to account for the full magnitude of the premium. The comparison is therefore inconsistent with the null that $\gamma_i = 0$ in these settings.

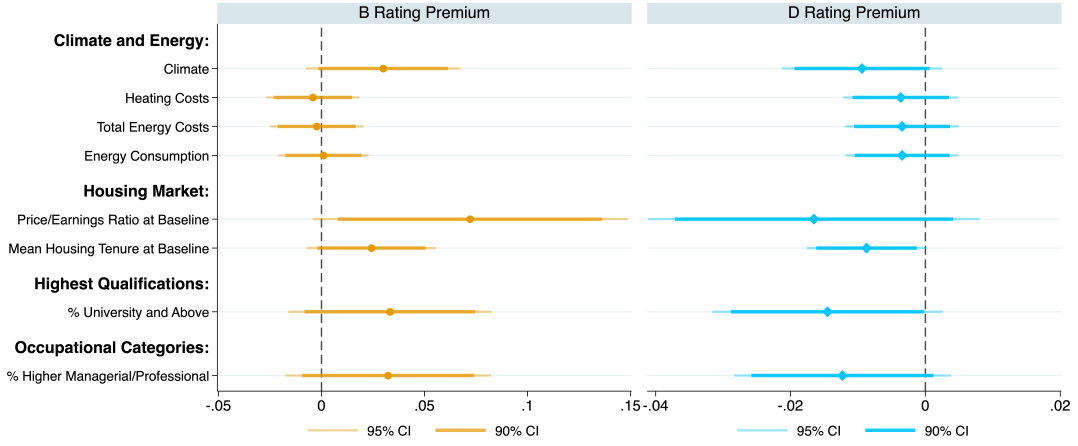
These magnitudes imply that observed premiums over-capitalize energy-related savings. While the consumption component is economically relevant, it is insufficient to account for the estimated post-policy premiums. The remaining wedge between the present value of energy-related benefits and the observed premium therefore reflects a positive investment component, $\gamma_i \tilde{v}_{EPC}$, which is particularly large in the London property market.

6.4 Heterogeneity Analysis by Area Characteristics

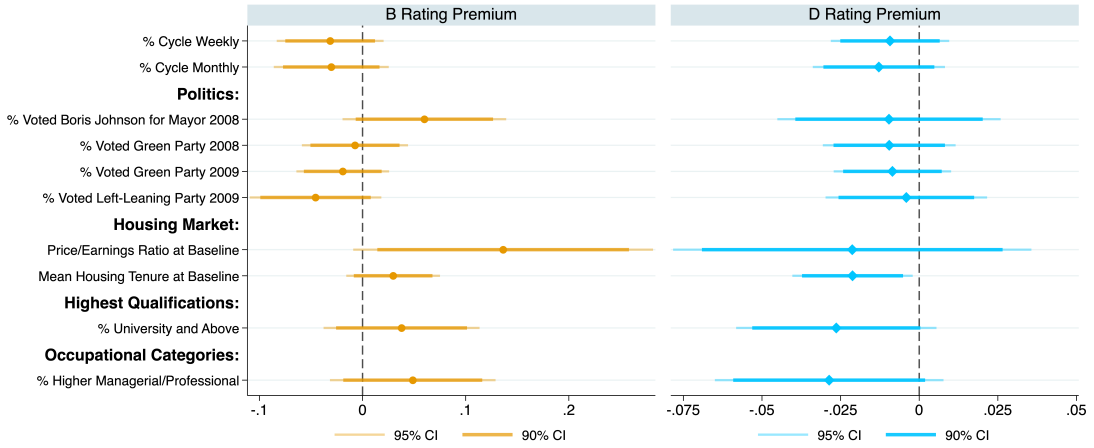
We complete the section exploring mechanisms by considering the extent to which our DD estimates vary with area-specific attributes. We do so in a manner consistent with our theoretical model. To implement this approach, we estimate a modified, triple-difference (DDD) version of Equation (7), whereby we interact our DD terms with a third, district-level variable. Each row of the coefficient plots presented in Figure 5 relates to a separate DDD regression. To ease comparison across specifications, we center and studentize all attributes for this analysis.

We discuss these heterogeneity results in turn through the lens of the saliency, consumption, and investment channels of the model.

Figure 5: Housing Market Characteristics Yield the Only Statistically Significant DDD Estimates



(a) DDD Estimates – Country-Wide



(b) DDD Estimates – London

Notes: The figures present point estimates, 90% and 95% confidence intervals (respectively in bold and light). Districts are population-weighted. We center and studentize the third-difference-relevant variables to present the coefficients on a single scale. As we are comparing across districts with different price levels, we normalize the area-specific DD estimates by the average house price for C-rated properties (the base category) in the area prior to the EPBR 2011 amendment. Additional data used in Figure 5a includes climate data (source: HadUK-Grid, Met Office), data on the housing stock (source: Department for Levelling Up, Housing & Communities for England, and StatsWales for Wales), data on earnings (source: Annual Survey of Hours and Earnings (ASHE)), and data on qualifications and occupation (source: Census 2011, nomis). For the London-specific analysis in Figure 5b, additional data include information on transport and politics (source: London Datastore).

Saliency Channel For London, we can further probe the saliency channel using borough-level measures of how “green” or liberal the local population is, which enter as the third-difference variables in Figure 5. According to our conceptual framework, climate-conscious homebuyers are more likely to have paid close attention to EPC ratings prior to the Amendment (i.e., $(1-\theta) \approx 1$). Under the saliency channel, Equation (3) implies that the impact of the policy should be smaller as $(1-\theta)$ approaches 1 before the policy, because the EPC provides less new information to this group. We therefore use district-level cycling propensity and voting patterns as proxies

for baseline attention to energy efficiency. The DDD estimates provide no evidence that policy effects are larger in greener or more liberally-minded boroughs in terms of how local inhabitants value EPC ratings. This absence of differential responses indicates that borough-level variation in environmental preferences does not systematically amplify or attenuate the saliency effect.

Consumption Sub-Channel We first examine heterogeneity in baseline housing tenure. Areas with longer average tenure exhibit larger policy-induced EPC premiums in the DDD estimates shown in Figure 5a. Within our framework, a longer expected duration of residence increases the present value of energy savings, corresponding to a higher α . The stronger effects in high-tenure areas are therefore consistent with the consumption channel.

We also exploit climatic variation across England and Wales. Average 30-year temperatures vary by approximately $3.2^{\circ}C$ ($5.7^{\circ}F$) across districts,²⁵ generating cross-sectional differences in heating demand. Following Equation (4), colder climates should imply $\alpha_{\text{cold}} > \alpha_{\text{warm}}$ and thus stronger policy effects. The DDD estimates do not support this prediction: coefficients are small and, if anything, opposite-signed. Interactions with local energy consumption similarly yield no statistically significant differentials. Climate-related variation therefore does not systematically amplify the policy-induced EPC premium.

Investment Channel We next consider heterogeneity in local housing market pressure. EPC premiums are larger in areas with higher house price-to-earnings ratios in both the country-wide and London-specific DDD specifications. Such areas plausibly attract more investment-oriented buyers, corresponding to a higher γ in our framework. Consistent with Equation (6), the stronger effects in high price-to-earnings areas provide clear support for the investment channel.

We also examine two measures of socioeconomic status: (i) the share of residents with higher education and (ii) the proportion employed in professional occupations. If higher socioeconomic status proxies for a larger investment component, policy-induced premiums should be stronger in such areas. The DDD estimates display a consistent but statistically insignificant directional pattern: the EPC premium is more positive for B-rated homes and more negative for D-rated homes in higher-SES areas. While imprecise, this pattern is consistent with a larger investment component in those markets.

6.5 A Multi-Channel Interpretation of the Policy Effects

Section 6 has examined the extent to which the policy-induced EPC premium operates through the channels articulated in Section 3.1. In our framework, the valuation weight on the EPC rating can be expressed as $\omega = (\alpha + \gamma\tilde{v})(1 - \theta)$, where θ captures attention, α the consumption value of energy efficiency, and $\gamma\tilde{v}$ the investment component reflecting the perceived market value of energy efficiency. The preceding subsections have investigated empirical support for each of these margins.

The evidence across subsections maps naturally onto the components of the valuation term. Section 6.1 provides support for the saliency channel, consistent with a reduction in θ and an increase in attention to EPC ratings following the policy. Section 6.2 documents stronger effects where energy-efficient properties are locally scarce, supporting the market valuation sub-

²⁵The district encompassing the English Lake District has the lowest 30-year average temperature of $8.5^{\circ}C$, while the City of London has the highest at $11.7^{\circ}C$.

channel. Section 6.3 shows that while energy savings are economically meaningful, the observed premiums frequently exceed the present value of private and social energy benefits, indicating over-capitalization and a positive investment component, $\gamma\tilde{v}$. Finally, the heterogeneity analysis in Section 6.4 demonstrates that premiums are amplified in areas with longer average tenure, consistent with the consumption channel, and in areas with higher price-to-earnings ratios, consistent with the investment channel. Climatic variation and several socioeconomic proxies do not systematically amplify policy effects.

Collectively, the evidence across Section 6 documents empirical support for each of the four channels articulated in the framework: the saliency channel via the front-page-versus-full-EPC contrast in Section 6.1, the market valuation sub-channel via local supply heterogeneity in London in Section 6.2, the investment channel via both the wedge between observed premiums and the present value of energy savings in Section 6.3 and the amplification in high price-to-earnings markets in Section 6.4, and the consumption sub-channel via tenure heterogeneity in Section 6.4. Two informative nulls discipline the interpretation of this evidence: the market valuation sub-channel is not detected at the national level, and the consumption sub-channel is not amplified by climatic variation across districts. Each of these tests draws on a distinct source of variation in the data.

From the standpoint of policy design, this multi-channel structure has a clear implication. A policy that shifts valuation through several distinct margins does not rely on any single behavioral response. Even if one channel is weak in a given market or population, others may still operate. As discussed in Section 3.1, this makes the EPBR 2011 amendment a robust policy instrument.

7 Conclusion

In this paper we examine how the design of information disclosure shapes valuation in a high-stakes asset market. The EPBR 2011 amendment in England and Wales required that the energy efficiency rating of a property be prominently displayed at listing, altering the presentation of information that was already available on request. We develop a simple framework in which the hedonic weight on energy efficiency comprises a valuation term and an inattention term, and use this framework to structure the empirical specification and to interpret the resulting price effects.

With a generalized difference-in-differences specification that allows the hedonic price function to shift across space and time, we estimate the policy-induced change in willingness to pay for EPC ratings. We document a statistically and economically significant increase in the premium for higher-rated properties. Nationally, B-rated homes command a premium of approximately 3% relative to C-rated homes, while D-rated properties incur a penalty of roughly 1-1.5%. In London, where housing market conditions are tighter, the initial premium is approximately twice as large. We find no evidence of differential pre-trends. Nationally, the premium persists; in London, it attenuates in the medium run, consistent with stronger supply-side adjustment in equilibrium.

Each of the four channels articulated in the framework finds empirical support in our setting: salience, consumption value from energy savings, forward-looking investment considerations, and

market-specific amplification. Each is identified through a test drawing on a distinct source of variation in the data. Two informative nulls discipline the interpretation: the market valuation sub-channel is not detected at the national level, and the consumption sub-channel is not amplified by climatic variation across districts.

These findings have implications for disclosure-based policy in asset markets. Housing transactions are infrequent, financially consequential, and embedded in local equilibrium conditions. The EPBR 2011 amendment did not alter the underlying energy performance of the housing stock; it altered when and how energy efficiency entered the decision problem. Accordingly, the price effects we document reflect a change in valuation rather than a change in technology. Disclosure design – specifically, timing and prominence – can therefore alter equilibrium valuation in housing markets.

Our findings also speak to climate policy. Improving the energy efficiency of the housing stock requires not only technological progress and regulatory standards, but also demand-side incentives that shift relative returns to retrofit investment. By increasing willingness to pay for more efficient properties, disclosure reforms alter the market rewards associated with energy performance, and in this sense complement price-based approaches such as carbon taxation or emissions trading. This is a corollary of the main contribution: what the evidence most directly documents is that the design of information disclosure can generate persistent changes in equilibrium valuation in a major asset market.

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Appendix

A Support for the Identifying Assumptions

A.1 Parallel Trends

A.1.1 Placebo Regressions

In this section, we run placebo versions of our baseline specification – Equation (7) – where we shift all key dates one year back in time. Here the $Post_t$ term takes value zero for the period 6 April 2010-5 April 2011, and one for the period 6 April 2011-5 April 2012. We control for the same variables, and include the same fixed effects. The aim of this section is to check for pre-trends. The key assumption of the DD model is one of parallel trends, hence any significant coefficients here is a warning that this assumption is not met.

We do not estimate any significant placebo DD parameters for either England and Wales combined, or for the London region. We take this as the first piece of evidence in support of the parallel trends assumption holding.

Table A1: DD Estimates from Introduction of EPC certificates – England and Wales – Placebo

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating $\times$ Post	5,550 (3,458)	5,174 (3,246)	4,415 (2,729)	3,249 (2,530)	3,102 (2,530)	2,267 (2,362)	2,583 (2,328)
D Rating $\times$ Post	-650 (888)	-934 (805)	-719 (664)	-633 (616)	-588 (615)	-770 (622)	-629 (630)
$\bar{Y}_{C,PRE}$	208824	208824	208824	208824	208824	208824	208824
(B Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	.0266	.0248	.0211	.0156	.0149	.0109	.0124
(D Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	-.00311	-.00447	-.00344	-.00303	-.00282	-.00369	-.00301
Spatial FEs	TTWA	District	District	Wider NH	Wider NH	NH	NH
Local Time Trends					District		Wider NH
X Interactions	TTWA $\times$ Post $\times$ X	TTWA $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X
Adjusted R^2	.499	.595	.709	.752	.752	.774	.775
Observations	642,181	642,181	642,179	642,179	642,179	642,010	642,010

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. Eicker-White standard errors in parentheses. The dependent variable in all regressions is the house price in £.

A.1.2 Graphical Evidence of Parallel Trends

Figure A1 shows the pre-trends in residualized house prices for the pre-policy period of 6 April 2010-5 April 2012. In order to residualize the data, we run the following regression, and then

Table A2: DD Estimates from Introduction of EPC certificates – London Only – Placebo

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating $\times$ Post	12,870 (13,231)	9,541 (12,307)	2,941 (10,156)	2,079 (9,303)	1,435 (9,297)	621 (8,664)	1,873 (8,441)
D Rating $\times$ Post	623 (5,384)	-1,762 (4,789)	-1,173 (3,704)	-1,578 (3,426)	-1,400 (3,415)	-2,027 (3,565)	-1,203 (3,629)
$\bar{Y}_{C,PRE}$	349173	349173	349173	349173	349173	349173	349173
(B Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	.0369	.0273	.00842	.00595	.00411	.00178	.00536
(D Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	.00178	-.00505	-.00336	-.00452	-.00401	-.0058	-.00344
Spatial FEs	TTWA	District	District	Wider NH	Wider NH District	NH	NH
Local Time Trends							Wider NH
X Interactions	TTWA $\times$ Post $\times$ X	TTWA $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X
Adjusted R^2	.33	.486	.671	.721	.721	.739	.741
Observations	86,910	86,910	86,903	86,903	86,903	86,881	86,881

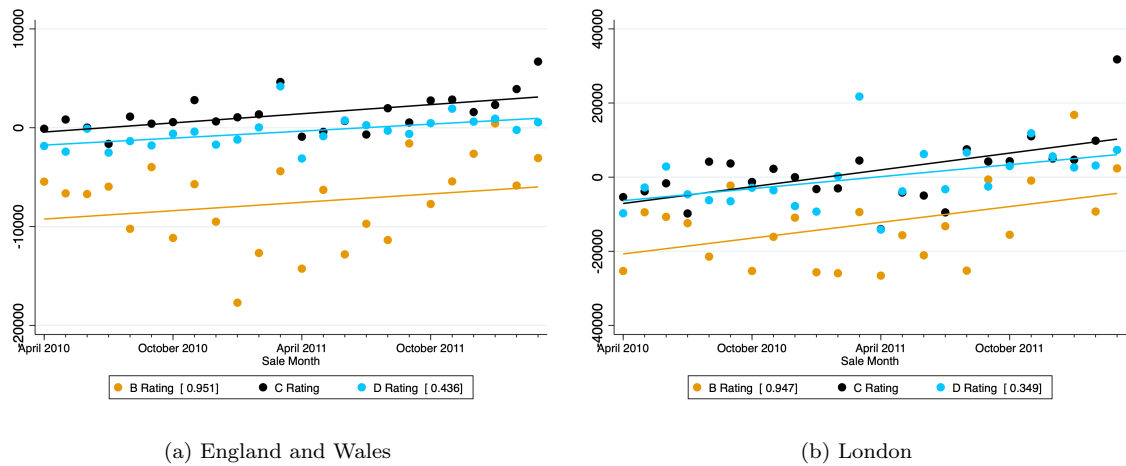
Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. Eicker-White standard errors in parentheses. The dependent variable in all regressions is the house price in £.

extract the residuals.

$$Price_{pt} = \sum_{d=1}^D (District_d \times X_p' \gamma_d) + \sum_{w=1}^W \tau_w (Wider Neighborhood_w \times time_t) + \theta_n + \epsilon_{pt}, \quad (10)$$

The p -value presented in the legend of each graph is based on a test of equality of trends in the pooled data (i.e. testing the trends for B and D rated properties against category C properties). The large p -values reinforce the visual patterns, confirming that the trends in house prices between EPC ratings groups are indeed parallel in the run-up to the policy change in April 2012.

Figure A1: Pre-trends



Notes: The p -values presented in square brackets in the legend of both graphs is based on a test of equality of trends between the control rating category (C) and the treatment categories (B and D) using pooled, transaction-level data. Period: 6 April 2010-5 April 2012

A.2 Stable Group Composition

In order to use difference in differences with repeat cross-sectional data, we also require stability of the composition of the groups across time. If treatment group composition varies over time, the DD estimator will not identify the ATT, but rather some other parameter (Blundell and Dias, 2009) – we will conflate compositional changes with the ATT.

In order to assess the stability of groups over time, we present the results from a series of balance tests in Table A3 for England and Wales, and Table A4 for London. In this analysis, we account for spatiotemporal variables, but not property characteristics. We do so to account for the fact that properties with different rating categories will not be randomly distributed across areas, and that different areas may experience different housing market cycles. We do not want to conflate these spatiotemporal factors with property characteristics.

Of the 78 balance tests we present, 5 are significant at the 5% level. Given that $5/78=.064$, we ascribe this to sampling error, and conclude that the group composition is stable for both England and Wales, and London.

Table A3: Balance Tests - England and Wales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Control Group			Treatment Groups					
	Category C			Category B			Category D		
	Pre Period	Post Period	<i>p</i> -value: Differ- ence	Pre Period	Post Period	<i>p</i> -value: Differ- ence	Pre Period	Post Period	<i>p</i> -value: Differ- ence
Sample Size	109,402	106,689		9,554	7,829		227,077	242,611	
Property Type:									
Detached	.191 (.00531)	.168 (.00544)	[.0286]	.0139 (.00344)	.0112 (.00411)	[.72]	.255 (.00379)	.261 (.00355)	[.402]
Semi-Detached	.235 (.00564)	.238 (.00579)	[.811]	.0335 (.0056)	.0207 (.00652)	[.282]	.322 (.00427)	.322 (.004)	[.964]
Terraced	.293 (.00627)	.309 (.00644)	[.219]	.0841 (.0121)	.106 (.0143)	[.408]	.305 (.00399)	.311 (.00374)	[.419]
Apartment	.281 (.00506)	.286 (.00519)	[.611]	.868 (.0124)	.862 (.0147)	[.82]	.118 (.00257)	.106 (.00241)	[.0159]
Leasehold	.326 (.00539)	.328 (.00553)	[.8]	.881 (.0127)	.879 (.015)	[.956]	.162 (.00294)	.153 (.00275)	[.0958]
Building Age	1,976 (.42)	1,975 (.432)	[.14]	1,999 (.749)	2,000 (.876)	[.774]	1,950 (.334)	1,950 (.313)	[.249]
Floor Size:									
Quintile 1	.272 (.00636)	.273 (.00653)	[.966]	.543 (.0293)	.448 (.0346)	[.133]	.157 (.0035)	.157 (.00328)	[.994]
Quintile 2	.199 (.00603)	.223 (.00619)	[.0485]	.23 (.0275)	.272 (.0325)	[.491]	.194 (.00393)	.192 (.00368)	[.75]
Quintile 3	.169 (.00556)	.183 (.00572)	[.211]	.111 (.0211)	.112 (.0248)	[.991]	.216 (.00407)	.212 (.00382)	[.591]
Quintile 4	.163 (.00557)	.153 (.0057)	[.373]	.0795 (.0199)	.076 (.0235)	[.935]	.224 (.00419)	.223 (.00392)	[.9]
Quintile 5	.197 (.00561)	.168 (.00575)	[.0115]	.0355 (.0153)	.0928 (.0182)	[.0856]	.209 (.00391)	.216 (.00366)	[.314]
Number of Rooms	4.35 (.0234)	4.28 (.024)	[.0985]	2.96 (.0504)	3.02 (.0597)	[.611]	4.69 (.0142)	4.72 (.0133)	[.297]
Main Fuel is Gas	.886 (.00428)	.89 (.00438)	[.661]	.664 (.0247)	.696 (.0291)	[.543]	.917 (.00223)	.919 (.00209)	[.571]
Joint Test			[.337]			[.855]			[.866]

Notes: Means and standard errors (in parentheses) are shown. *p*-values are based on OLS regressions with Eicker-Huber-White standard errors. We do not control for any household-level characteristics in the balance test regressions, but we do account for the following spatiotemporal variables: Neighborhood Fixed Effects, Wider Neighborhood Time Trends and Region-by-Month-by-Year Fixed Effects.

Table A4: Balance Tests - London

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Control Group			Treatment Groups					
	Category C			Category B			Category D		
	Pre Period	Post Period	<i>p</i> -value: Differ- ence	Pre Period	Post Period	<i>p</i> -value: Differ- ence	Pre Period	Post Period	<i>p</i> -value: Differ- ence
Sample Size	15,210	14,928		2,290	2,008		28,831	30,470	
Property Type:									
Detached	.0136 (.00406)	.0273 (.00421)	[.0924]	.00137 (.000546)	.00147 (.000626)	[.847]	.0427 (.00526)	.0394 (.00498)	[.744]
Semi-Detached	.0455 (.00662)	.0556 (.00678)	[.444]	.00362 (.000778)	.00316 (.000784)	[.61]	.181 (.0101)	.167 (.0095)	[.462]
Terraced	.188 (.0134)	.224 (.0137)	[.179]	.00566 (.0146)	.0217 (.0162)	[.6]	.363 (.0126)	.401 (.012)	[.119]
Apartment	.753 (.0142)	.693 (.0145)	[.0347]	.989 (.0146)	.974 (.0163)	[.61]	.413 (.0122)	.393 (.0116)	[.386]
Leasehold	.76 (.0139)	.711 (.0142)	[.0796]	.982 (.0116)	.986 (.013)	[.847]	.419 (.0123)	.414 (.0116)	[.846]
Building Age	1,960 (1.55)	1,959 (1.58)	[.859]	1,995 (1.39)	1,993 (1.49)	[.398]	1,926 (1.09)	1,929 (1.03)	[.205]
Floor Size:									
Quintile 1	.28 (.018)	.289 (.0183)	[.789]	.349 (.046)	.355 (.0502)	[.946]	.132 (.00985)	.159 (.00938)	[.154]
Quintile 2	.243 (.017)	.244 (.0173)	[.961]	.225 (.0501)	.28 (.0547)	[.597]	.175 (.0116)	.181 (.011)	[.775]
Quintile 3	.172 (.0154)	.215 (.0157)	[.159]	.227 (.0505)	.186 (.055)	[.692]	.208 (.0121)	.191 (.0114)	[.452]
Quintile 4	.155 (.015)	.135 (.0152)	[.502]	.155 (.0485)	.0997 (.053)	[.582]	.253 (.0127)	.218 (.012)	[.149]
Quintile 5	.151 (.0147)	.116 (.0149)	[.241]	.0434 (.0334)	.0789 (.0367)	[.611]	.232 (.0125)	.251 (.0118)	[.424]
Number of Rooms	3.37 (.0498)	3.37 (.0508)	[.987]	2.7 (.09)	2.68 (.0993)	[.9]	4.18 (.0437)	4.2 (.0415)	[.847]
Main Fuel is Gas	.82 (.0141)	.84 (.0143)	[.473]	.705 (.0428)	.605 (.0466)	[.261]	.94 (.00572)	.931 (.00545)	[.459]
Joint Test			[.237]			[.984]			[.318]

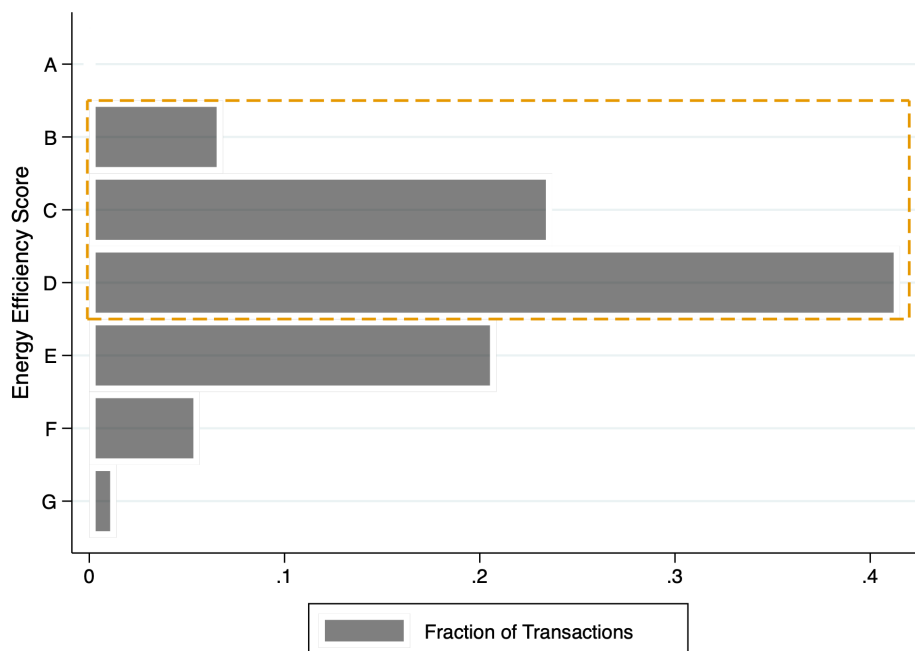
Notes: Means and standard errors (in parentheses) are shown. *p*-values are based on OLS regressions with Eicker-Huber-White standard errors. We do not control for any household-level characteristics in the balance test regressions, but we do account for the following spatiotemporal variables: Neighborhood Fixed Effects, Wider Neighborhood Time Trends and Region-by-Month-by-Year Fixed Effects.

B Summary Statistics and Ancillary Results

B.1 Additional Summary Statistics

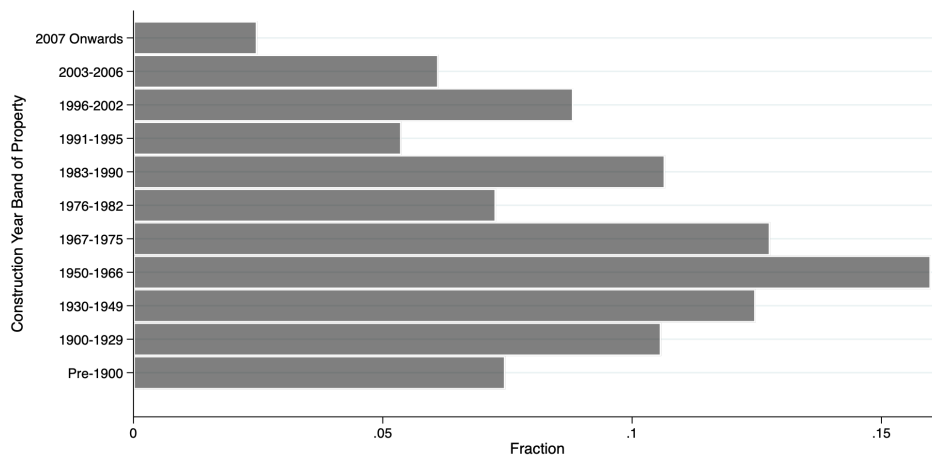
Figure B1 presents the distribution of EPC scores during our sample period.

Figure B1: EPC Rating Distribution



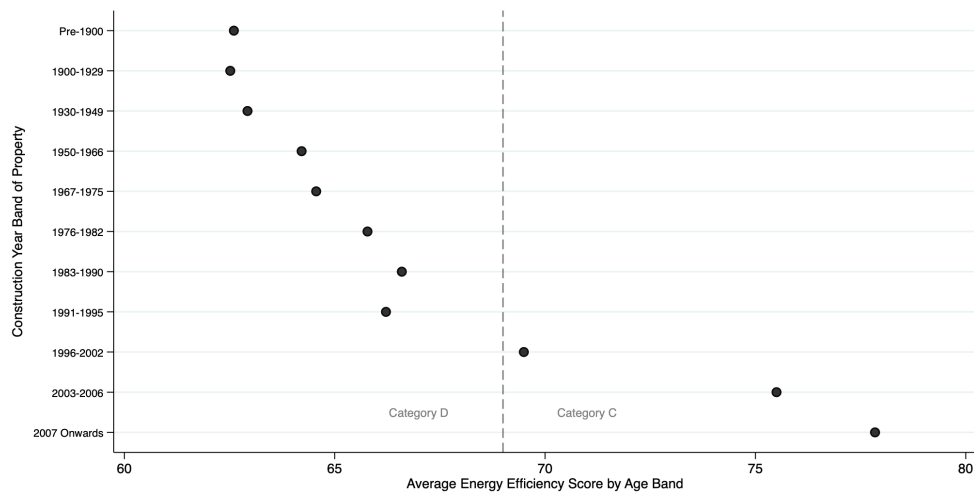
The UK has an older housing stock than many other European countries. Figure B2 presents the distribution of property age during our sample period. Figure B3 documents the consequence

Figure B2: Building Age Bands



of this relatively old building stock. For each age band, we present the average EPC score for properties sold during our sample period.

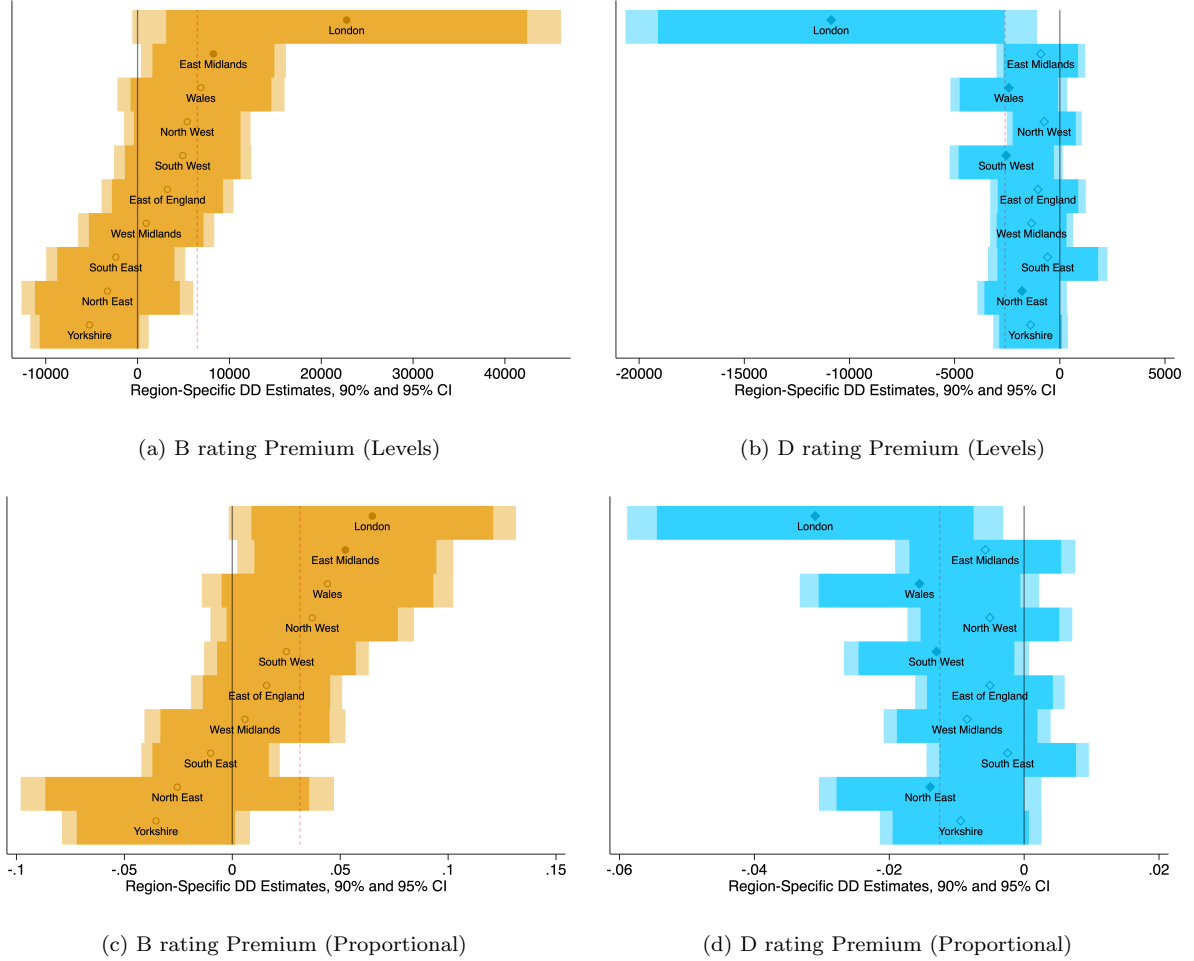
Figure B3: Energy Efficiency Score by Age Bands



B.2 Region-Specific DD Estimates

Given that our data spans all of England and Wales, we next explore regional variation in the response to the policy. We estimate a variant of Equation (7) on a region-by-region basis. We present the resulting DD coefficient estimates in Figure B4 below. London is a stand-out region

Figure B4: Region-specific DD estimates

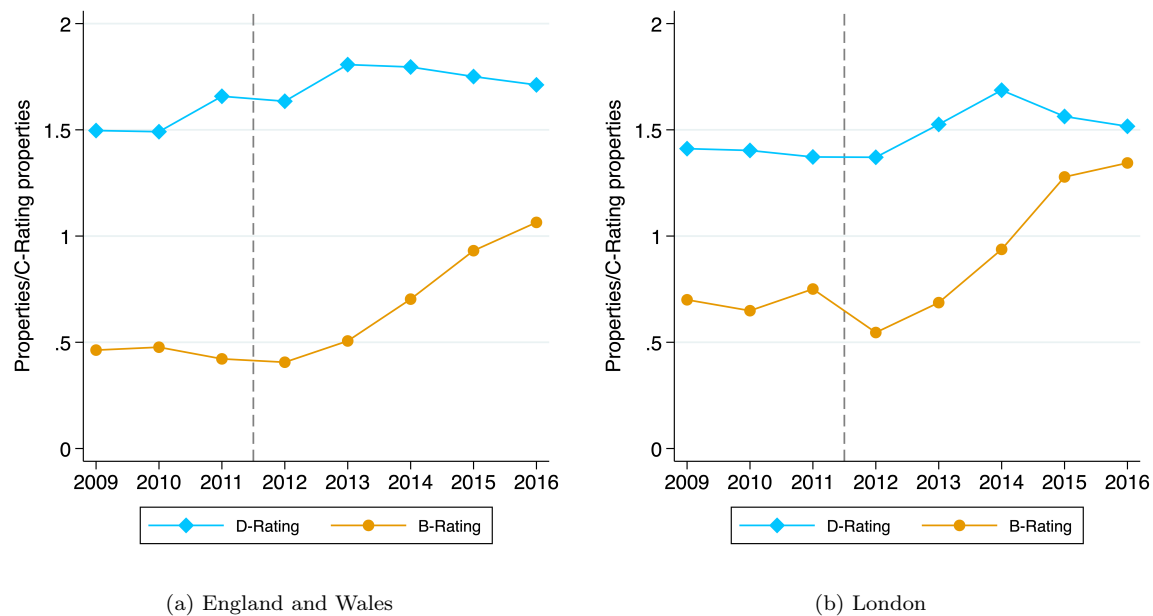


Notes: The figure presents point estimates from a region-specific variant of Equation (7), as well as 90% and 95% confidence intervals (respectively transparent and opaque). The proportional estimates replicate the levels estimates, dividing the parameter estimates by the region-specific C-rating mean price in the pre-period.

for at least two reasons. First, the sheer magnitude of the estimated DD parameters. Second, London is the only region with statistically significant DD estimates for both B and D ratings. This is not just a power-related artifact of London's size – other regions are larger in terms of transaction volume, or of a similar size.

B.3 Dynamic Supply-Side Responses

Figure B5: Relative Supply of Properties by Rating Class over Time



Notes: We use all properties that required an EPC inspection to sell the property, and received a rating in the B, C, or D category between fiscal years 2009 and 2016. The figure illustrates the relationship between the number of D-rated (and B-rated) properties relative to C-rated properties in each fiscal year.

B.4 Sensitivity Analysis

B.4.1 Sensitivity Analysis – EPBR 2012

The EPBR 2012 amendment came into force on 9 January 2013. This amendment obviated the need for sellers to display the entire front page of the EPC in marketing material, but still required any marketing material to display the EPC letter rating and numerical score.²⁶ If we assume houses are marketed once the EPC inspection is lodged on the EPC register, we find that only 1.19% of post-period transactions in our main sample are marketed after the introduction of the 2012 amendment. In the analysis below we repeat our core analysis, but remove sales in the post period where the EPC inspection was lodged on or after January 9 2013. As we are working with a repeat cross section DD specification, we are ever mindful of the need to impose symmetric restrictions in both periods. Hence, in addition to the sample restriction we note for the post period, we additionally remove pre-period transactions where the EPC inspection was lodged on or after January 9 2012. We present the results of this sensitivity analysis both for England and Wales in Table B1 and for London in Table B2. None of our core results change.

Table B1: DD Estimates from Introduction of EPC certificates – England and Wales

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating $\times$ Post	11,944*** (4,457)	8,974** (4,172)	6,314* (3,502)	6,270* (3,219)	6,304* (3,218)	6,408** (3,093)	6,594** (3,125)
D Rating $\times$ Post	-2,737** (1,101)	-2,617*** (1,012)	-2,973*** (826)	-2,675*** (780)	-2,681*** (780)	-2,638*** (785)	-2,657*** (791)
$\bar{Y}_{C,PRE}$	208032	208032	208032	208032	208032	208032	208032
(B Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	.0574***	.0431**	.0303*	.0301*	.0303*	.0308**	.0317**
(D Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	-.0132**	-.0126***	-.0143***	-.0129***	-.0129***	-.0127***	-.0128***
Spatial FEs	TTWA	District	District	Wider NH	Wider NH	NH	NH
Local Time Trends					District		Wider NH
X Interactions	TTWA $\times$ Post $\times$ X	TTWA $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X
Adjusted R^2	.457	.558	.689	.736	.736	.758	.759
Observations	692,009	692,009	692,009	692,009	692,009	692,009	692,009

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. Eicker-Huber-White standard errors in parentheses. The dependent variable in all regressions is the house price in £.

²⁶Source: <https://www.legislation.gov.uk/ukxi/2012/3118/regulation/11/made>.

Table B2: DD Estimates from Introduction of EPC certificates – London Only

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating $\times$ Post	42,595** (17,073)	31,157* (15,916)	25,496* (13,497)	22,259* (12,263)	22,115* (12,257)	22,566* (11,792)	22,467* (11,934)
D Rating $\times$ Post	-15,615** (7,106)	-12,976** (6,452)	-11,142** (5,133)	-9,690** (4,866)	-9,751** (4,861)	-11,340** (5,021)	-11,225** (5,079)
$\bar{Y}_{C,PRE}$	351012	351012	351012	351012	351012	351012	351012
(B Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	.121**	.0888*	.0726*	.0634*	.063*	.0643*	.064*
(D Rating $\times$ Post)/ $\bar{Y}_{C,PRE}$	-.0445**	-.037**	-.0317**	-.0276**	-.0278**	-.0323**	-.032**
Spatial FEs	TTWA	District	District	Wider NH	Wider NH	NH	NH
Local Time Trends					District		Wider NH
X Interactions	TTWA $\times$ Post $\times$ X	TTWA $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X	District $\times$ Post $\times$ X
Adjusted R^2	.297	.445	.64	.695	.695	.716	.717
Observations	92,207	92,207	92,207	92,207	92,207	92,207	92,207

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. Eicker-White standard errors in parentheses. The dependent variable in all regressions is the house price in £.

B.5 Energy Performance Ratings Example

Figure B6: Feature-Specific Energy Performance Ratings from the EPC

Breakdown of property's energy performance

Features in this property

Features get a rating from very good to very poor, based on how energy efficient they are. Ratings are not based on how well features work or their condition.

Assumed ratings are based on the property's age and type. They are used for features the assessor could not inspect.

Feature	Description	Rating
Wall	Timber frame, as built, insulated (assumed)	Good
Roof	Pitched, 100 mm loft insulation	Average
Window	Fully double glazed	Average
Main heating	Boiler and radiators, mains gas	Good
Main heating control	Programmer and room thermostat	Average
Hot water	From main system	Good
Lighting	Low energy lighting in 24% of fixed outlets	Poor
Floor	Solid, no insulation (assumed)	N/A
Secondary heating	None	N/A

C Data Appendix

C.1 Details on Institutional Background

Within the EU the main directive to monitor energy performance of buildings is the Energy Performance of Buildings Directive (EPBD). Influenced by the Kyoto protocol, the first version of the directive (2002/91/EC) was implemented in December, 2002 (The European Parliament and the Council of the European Union, 2003). The objective of this directive was to foster improvement of energy efficiency of buildings allowing for the outdoor and local climatic conditions along with the indoor climatic requirement and budget constraints. This directive was later replaced by the EPBD Directive (2010/31/EU) which was implemented on 18th of June, 2010 (The European Parliament and the Council of the European Union, 2010). This directive requires energy performance certificates (EPC) to be displayed in the advertising for all real estate sales or rentals across the EU and it is the primary legal framework for improving housing energy efficiency in the EU (Committee on Industry, Research and Energy: European Parliament, 2021).²⁷ However the member states have implemented energy performance ratings requirements in different times. For example, Denmark was one of the first country to adopt the EPBD 2002 directive (Jensen et al., 2016), however brought in the mandatory disclosure of EPC ratings only in July 2012 (Thomsen et al., 2016). France has implemented the mandatory inclusion of EPC information in property marketing on 1st of January, 2011 (Bordier et al., 2016). In Germany the requirement to include energy performance ratings in advertisement came in effect on 2013 (Schettler-Köhler et al., 2016). The policy we study in this paper is not an isolated one, but similar policies have been implemented across Europe.²⁸ Crucially, the EPBR 2007 in the UK was implemented in response to the EPBD 2002 directive (Department for Levelling Up, Housing and Communities and Ministry of Housing, Communities & Local Government, 2007) and similarly EPBR 2011 was a response to the EPBD 2010.²⁹

At this point, it is important to note that EPCs are an intriguing hybrid of both a regulatory- and a market-based approach to improving the energy efficiency of buildings. The EPBR 2007 established the regulatory framework that mandated the provision of detailed energy efficiency information to potential buyers. The 2011 amendment was important in that the amended regulations required this information to be prominent and salient at the *start* of the home-buying process. With the regulatory framework in place, the market could respond to the new information – owners of energy efficient homes would be rewarded by the market, and owners of inefficient homes would be penalized. This created incentives for owners of energy inefficient properties to invest in energy efficient upgrades in their properties.

We now briefly detail the process of obtaining EPCs and the energy rating scales in the context of the UK. EPCs are required to contain information on property address, property type, date of inspection, certificate date and serial number, total floor area, as well as recommendations

²⁷There has been two major revisions to this amendment, i.e., Directive 2012/27/EU and Directive (EU) 2018/844, both on long term actions to renovate national building stocks in the member states.

²⁸It is important to note here that the EPBD 2010 directive provided a two year time frame in which member states needed to implement the laws (European Union Law, 2021), however member states in reality implemented this at different points in time and sometimes with regional responsibilities within the country (like Belgium) (Concerted Action: Energy Performance of Buildings, European Union, 2013).

²⁹Explanatory Note: <https://www.legislation.gov.uk/ukxi/2011/2452/made>

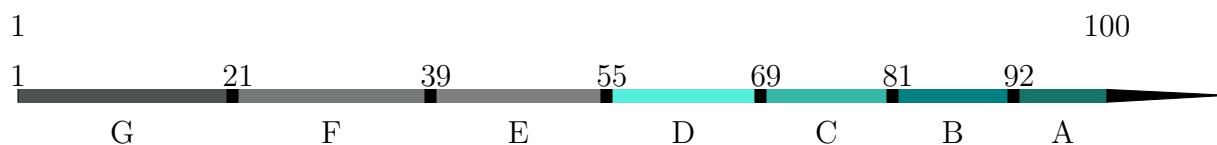


Figure C1: EPC Rating Categories and Underlying Scores

on ways to improve the property's energy efficiency. The energy assessment, which is a non-invasive procedure, is required to be performed by a qualified and accredited energy assessor. The assessor visits the property and notes the key characteristics such as boiler, cavity walls, floor insulation, radiator, heating, glazing of windows etc. These observations are used to calculate the rating of energy efficiency through a software program. This survey is paid for by the householder and costs (for a typical four bedroom house) approximately £60 -£120, depending on locations. The EPCs assign a number to the property ranging from 1-100, higher number denotes that the property is more energy efficient. The numbers are categorized in 7 scale ratings. The ratings range from A (most energy efficient) to G (least energy efficient). The scale below shows the relation between the EPC scores and rating scales. EPC regulations have been subjected to many criticisms and controversy as the procedure is non-invasive and often relies on the assessor's subjective judgements. Moreover, as improvements in listed buildings are often barred, it poses problems to rectify low EPC ratings.

Table C1: Time line of EPC regulations for England and Wales

2007	01 August: EPC mandatory for marketed sales of houses in a phased approach.
	06 April: All new-built homes require EPC upon completion.
2008	01 Oct: All home sales (including non-marketed), rentals, and non-domestic properties (built, rented or sold) require an EPC.
2009	10 August: Data quality improvement for register lodgement.
2010	21 May: Validity of EPC extended from 3 to 10 years.
2011	April: Change in EPC calculations where insufficient data is available for the building but not for the site.
2012	06 April: A copy of the first page of EPC has to be attached with all types of properties for marketing.
	09 Jan: Energy efficiency rating is mandatory at advertisement, first page need not be included. New provision for EPCs to include information about Green Deal plans, and that information also has to be stored on the EPB Register*.
2014	06 April: Allows data from the register to be disclosed to specific persons for particular purposes.
2015	April: Further changes to the disclosure requirements.
2016	June: Open access data from the register for greater transparency.
2017	April: Extending the list of data items that may be published online.
	01 April: Illegal to let (or renew lease) residential or commercial properties with EPC F or G. Domestic properties to reach EPC E by April 2020 and non-domestic by 2023.
2018	06 April: Changes to the disclosure requirements for statistical and research purposes.
2020	28 Dec: Inspections to include consideration of the air conditioning system to optimize performance under typical conditions.

Notes: This table shows the regulations for domestic and commercial properties and not public buildings. Consolidated with the key points from the UK statutory instruments from the The National Archives (2021) and Department for Levelling Up, Housing and Communities and Ministry of Housing, Communities and Local Government (2021). *It also combined and therefore revoked earlier amendments of 2007 (other phased amendments, not included here), 2008 (Oct), 2009, and 2010 together.

The EPB regulations of 2007 have been amended multiple times. For example, from 6th of April, 2008 all domestic and non-domestic properties for sale or rent (including new builds) were required to have an EPC. In 2010, the validity of EPCs were extended from 3 years to 10 years. The table above details the different regulations that came into force regarding EPC disclosure requirements in England and Wales from 2007. In one of the recent changes in 2018, it became illegal to rent or lease properties with F or G EPC ratings and guidelines were set for all domestic and non-domestic properties to improve their ratings to at minimum to E. The EPBR 2011 regulation that we study in this paper warranted a front page of EPC to be attached with all marketing materials of properties for sale or rent.³⁰ Figure C2 is such an example front page of EPC.

C.2 Details on data and matching

In our approach, we follow an extremely conservative approach to link these two databases. Given that the EPC data began to be released in 2008, we restrict our attention to the time range of 2008–2021. The key challenge to this data merging is that addresses are recorded in a non-standardized way across and within the two datasets. But especially more so in the EPC data as the addresses are entered by the energy assessors. In order to carry out the address standardization, we use three sets of addresses available in the price paid data - 1) address, 2) address with locality, 3) Primary Addressable Object Name (PAON- this field often has the entire address listed). There is existing evidence that addresses in the EPC register often are recorded with a lot of manual errors (Hardy and Glew, 2019). Consequently, we perform a series of text manipulations on the address fields of EPC dataset to reduce possibilities of misrecording of addresses. In order to treat the data correctly, we follow the address nomenclatures present in the price paid dataset. This included replacing all ‘apartment’ or ‘maisonette’ to ‘flat’ (inclusive of all cases), replacing for example, in both datasets uniformly ‘FIRST AND SECOND FLOOR FLAT’ to ‘FIRST FLOOR FLAT’, as well as some standard techniques of pre-processing text.

After this we parse and standardize addresses to create a fourth set of address fields for matching (Wasi and Flaaen, 2015). Moreover, we extract the numbers from the string addresses to make four sets of numbered addresses (addresses with one to four numbers) and isolate properties with house names as opposed to numbers. These processes give us address fields in the two datasets, which are similar (if not identical) and can be used for the matching techniques. After these text manipulations in both the raw files, we use the record linkage method (Wasi and Flaaen, 2015) to merge the two datasets.

We begin by separating houses with numbers from those with names and then conducting a merging process formed of four distinct blocks, the first three matching numbered properties and the final block matching named properties. The three numbered blocks differ according to the type of address variable we use, the degree of address standardization and the use of locality to aide differentiating between common addresses.

For the entire exercise, we use extremely conservative tolerance levels of 0.98 or more. We

³⁰It is important to note that homeowners also should have used all reasonable efforts to ensure the EPC is obtained within seven days of the marketing, in case a valid EPC for the property did not exist. Only in very limited cases a further 21 days are allowed to if despite all reasonable efforts EPC could not be obtained within seven days of marketing.

also give the highest weights to the address numbers (where present) and comparatively less weights to street names (due to high manual error possibilities). The entire matching process consists of 432 distinct stages and achieves a match rate of 86.8%.³¹

³¹Chi et al. (2021) take a slightly different approach to the matching of EPC to Land Registry data, first linking Land Registry data with Ordnance Survey data, and then linking the EPC database. The authors focus on the time period of 2011-2019, and achieve a match rate of a similar magnitude to ours – 79% of the full market sales.

Figure C2: An Example EPC Front Page

Energy Performance Certificate (EPC)



17 Any Street, District, Any Town, B5 5XX

Dwelling type: Detached house
Date of assessment: 15 August 2011
Date of certificate: 13 March 2012

Reference number: 0919-9628-8430-2785-5996
Type of assessment: RdSAP, existing dwelling
Total floor area: 165 m²

Use this document to:

- Compare current ratings of properties to see which properties are more energy efficient
- Find out how you can save energy and money by installing improvement measures

Estimated energy costs of dwelling for 3 years	£5,367
Over 3 years you could save	£2,865

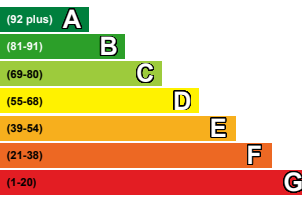
Estimated energy costs of this home

	Current costs	Potential costs	Potential future savings
Lighting	£375 over 3 years	£207 over 3 years	
Heating	£4,443 over 3 years	£2,073 over 3 years	
Hot water	£549 over 3 years	£222 over 3 years	
Totals:	£5,367	£2,502	

These figures show how much the average household would spend in this property for heating, lighting and hot water. This excludes energy use for running appliances like TVs, computers and cookers, and any electricity generated by microgeneration.

Energy Efficiency Rating

Very energy efficient - lower running costs



Not energy efficient - higher running costs

Current	Potential
49	76

The graph shows the current energy efficiency of your home.

The higher the rating the lower your fuel bills are likely to be.

The potential rating shows the effect of undertaking the recommendations on page 3.

The average energy efficiency rating for a dwelling in England and Wales is band D (rating 60).

Top actions you can take to save money and make your home more efficient

Recommended measures	Indicative cost	Typical savings over 3 years	Available with Green Deal
1 Increase loft insulation to 270 mm	£100 - £350	£141	✓
2 Cavity wall insulation	£500 - £1,500	£537	✓
3 Draught proofing	£80 - £120	£78	✓

See page 3 for a full list of recommendations for this property.

To find out more about the recommended measures and other actions you could take today to save money, visit www.direct.gov.uk/savingenergy or call 0300 123 1234 (standard national rate). When the Green Deal launches, it may allow you to make your home warmer and cheaper to run at no up-front cost.