Do Homebuyers Value Energy Efficiency? Evidence From an Information Shock*

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Abstract

We study the housing market response to a country-wide policy that mandated the provision of energy efficiency information with all marketing material at the time of listing. Using the near universe of housing sales in England and Wales, we match in the energy efficiency status of the property from Energy Performance Certificates data. We develop a conceptual framework that makes clear the key channels through which the policy may impact house prices – an information-driven salience channel and a market valuation channel. We provide causal evidence of homebuyers' willingness to pay for a higher energy rated property, documenting a 1-3% premium to a higher energy efficiency rating at the national level, and a 3-6% premium in the London market. We explore a set of key margins along which homebuyers can respond, ruling out as explanations both a consumption channel and an information channel. We conclude that the elevated EPC-rating premiums are driven by a market valuation channel, a conclusion for which we provide empirical support. Such a conclusion is of key policy importance, as it suggests market-facing energy efficiency regulations can increase demand for more energy efficient housing, even in absence of any discernible demand-side consumption or information effects.

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

An increasingly warming earth represents one of the greatest global challenges today. Construction and operation activities related to the building sector accounted for almost 36% of global energy demand in 2020. Housing accounts for approximately 40% of global energy consumption and a third of greenhouse gas emissions (World Economic Forum, 2021). However, approximately two thirds of countries where building stocks are rising lack strict building codes (United Nations Environment Programme, 2021). Recent energy market shocks, accompanied by price hikes, rationing, and sanctions, have underscored the importance of energy efficiency in the housing sector (World Green Building Council, 2018). One of the five recommendations from the International Energy Agency to keep the global temperature rise within $1.5°C$ by 2030 is to double the rate of energy efficiency improvements (IEA, 2023).

The UK faces a challenge with regards to the energy efficiency of the housing stock. The UK has the largest stock of old houses in Europe (Sivarajah, 2021) – almost 31% of houses are built pre-1950.[1] Consequently, the housing sector in this country is more reliant on energy use than other European countries (Hodgkin and Sasse, 2022).

In this paper, we study the response of the housing market to a country-wide energy efficiency-based information disclosure policy. The policy 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, through the Housing Act 2004 and Energy Performance of Buildings (Certificates and Inspections) (England and Wales) Regulations (hereafter EPBR) of 2007. 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. Since the regulation came into effect, domestic properties across England and Wales have been assessed by accredited energy assessors and scored in a consistent manner, with assessment based on an exhaustive list of criteria, which serve as inputs into an energy efficiency score function.[2] The EPC ratings are categories based on these scores.

EPCs are aimed at increasing information on energy efficiency of properties, thereby introducing market forces to incentivize energy enhancing improvements via retrofitting in order to improve energy efficiency of properties. However, under the EPBR 2007, the information on EPCs were not readily available to buyers in the home-buying process. The market response to the original regulation of 2007 was tepid, and compliance with the regulations was poor (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,

[1] The median energy efficiency rating band of UK houses is D (Office for National Statistics, 2021). As we show in Figure B3, older properties are typically less energy efficient.

[2] We cover the construction of the EPC scores in greater depth in Appendix C.

there was no requirement for this to be prominent or 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.[3] 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). The policy we study in this paper – the EPBR 2011 amendment (hereafter "the policy", or "the amendment") – was a response to the shortcomings of the original regulations.

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 key elements – a valuation term and an inattention term. The valuation term makes clear that homebuyers may value energy efficiency ratings for two reasons. First the consumption value of a better rating e.g., lower energy bills, warm glow effect from lower carbon emissions. Secondly, a perceived valuation effect, whereby forward-looking homebuyers account for the benefit of a better EPC-rated property on resale. The inattention term, which builds on the work of DellaVigna (2009), highlights the role of attribute-specific salience for homebuyers.

Using this framework, we make clear the two distinct channels through which the policy may influence EPC rating premiums. The first channel is a salience channel: given the increased salience of EPC rating information due to the policy, the amendment represents a positive shock to the salience of energy efficiency. The second channel is a market valuation channel – 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 houses with a better EPC rating. We use the framework to guide our interpretation of our core empirical findings, and later rely upon it to test potential mechanisms through which the policy may have influence EPC rating premiums.

In the empirical analysis, we first investigate the house price effects of the EPBR 2011 amendment. To do so we start with the near universe of all housing transactions in England and Wales, and match in information on the energy efficiency of the property at time of sale. With this data, we estimate a hedonic house price model, using a regression-adjusted difference-in-differences (DD) specification. We consider all matched transactions with an energy efficiency rating of B, C or D within a year window of the implementation of the policy.[4]

Our house price regression specifications are highly flexible across both space and time, in order to account for the current best practice when using DD specifications in a hedonic house price setting (Kuminoff et al., 2010; Kuminoff and Pope, 2014; Bishop et al., 2020). We specify the housing market as a local authority district. The local authority district (hereafter district)

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

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

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 all housing characteristics 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. In addition, 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 – an issue where the DD estimate conflates the willingness to pay for more energy-efficient properties with a change in the hedonic price function over time (Kuminoff and Pope, 2014; Banzhaf, 2021). Recent work by Banzhaf (2021) asserts the suitability of using a difference-in-differences approach with a hedonic house price model in order to study welfare effects of policy changes.

Against the backdrop of our conceptual framework, 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. In order to consider our estimates as the causal effects of the WTP for a higher EPC rating, we require two core assumptions to hold. First, the parallel trends assumption and second, that the composition of the groups we study are stable across our two time periods.[5]

We provide three pieces of evidence in support of the parallel trends assumption inherent in our DD approach – (i) placebo DD evidence from the years prior to the EPBR 2011 amendment implementation, (ii) we present the trends in house prices across the three EPC rating categories in the two years prior to the implementation of the amendment, and (iii) we implement the honest difference-in-differences approach of Rambachan and Roth (2023), in order to create worst-case treatment effect bounds for potential violations of the parallel trends assumption, based on pre-trends. Each piece of evidence provides support for the claim that the parallel trends assumption holds for our empirical specification in the sample period under consideration. In addition, with a series of balance tests, we present evidence that the composition of EPC category groups are stable across the pre and post periods.

In our empirical analysis, we document significant premiums to higher EPC-rated properties – once the information on ratings is visible and salient at the start of the buying process, homebuyers pay 3.1% more for a B-rated property, and 1.3% less for a D-rated property, relative to our base rating category of C. We note significant heterogeneity in willingness to pay for more energy efficient properties across the country, with the London region standing out as the housing market with particularly high valuation of energy efficiency. We proceed to focus on London, and document WTP estimates for energy efficiency that are approximately twice of the national average, specifically a 6.5% premium for B-rated properties and a 3% penalty for D-rated properties.

Using a variety of additional data sources, we estimate a series of triple-difference regressions, whereby we interact our DD term with a district level characteristic. These results not only allow us to explore the heterogeneity of our treatment effect estimates, they also enable us to form a better idea of the dimension upon which the WTP estimates vary in a substantive

[5]We require this second assumption as we use repeated cross-sectional data (Blundell and Dias, 2009).

manner. Examples of dimensions along which our DD estimates do not vary (i.e., the DDD term is economically and statistically insignificant) include the local climate, energy bill expenditure, as well as the political leaning of the area. The first two dimensions suggest that the increase in WTP for better EPC-rated properties is not being driven by energy-saving returns or due to homebuyers differentially pricing a better insulated property in colder areas of the country. Through the lens of our conceptual model, it suggests a limited role for the consumption value of more energy efficient properties. Local characteristics with which our DD terms do meaningfully vary are aspects of the housing market that relate to the expected time potential homebuyers will live in the property – the house price to earnings ratio of the district at baseline, and the baseline average of housing tenure in the area. These results suggest a role for the perceived valuation component from our conceptual framework – homebuyers have higher policy-induced WTP for better EPC-rated properties in areas where they expect to stay in the property over a longer time-horizon.

Next, we examine one potential explanation for our core findings – the information channel. Here, we use detailed information contained in the full EPC (but not present on the front page that is provided with all marketing material) on hard-to-observe energy-related characteristics of the property. We propose that by raising the salience of EPCs to homebuyers, the policy may have induced more potential buyers to read the full EPC. This includes information on feature-specific energy performance ratings (e.g., how energy efficient are the walls? What about the roof?), on expected energy bill expenditure, and on the carbon emissions of the property. We implement DD specifications of the same form that we use for our core analysis, but replace EPC ratings with these hard-to-observe attributes. If the WTP for these specific attributes changes meaningfully post-policy, we would interpret this as positive support for the information channel. We find no such support for the information channel.

The conclusion we draw from combining the insights we derive from our empirical analysis, specifically the heterogeneity analysis and our exploration of the information channel, is that the most likely explanation for the policy-induced rise in homebuyers' WTP for better EPC-rated properties is the investment channel. We suggest that the policy lead to homebuyers placing a higher weight on the EPC rating of the property due to the perceived valuation of a better EPC-rated property. This explanation is consistent with both (i) the battery of null findings that we document when evaluating the information channel, and (ii) our findings from the heterogeneity analysis. The findings from this analysis indicate that the consumption value of better EPC-rated properties was not a driver of the rise in EPC premiums, but point to the fact that homebuyers WTP for better EPC-rated properties was much higher post-policy in areas where homebuyers expect to stay in their property over a longer horizon. Such a finding speaks to the potential of market-facing regulatory policies such as the EPBR 2011 amendment for mitigating climate change – even if homebuyers do not explicitly internalize the carbon emission-based externalities of the properties they are considering, perceived valuation concerns of housing as an investment vehicle can lead individuals to increase their WTP for higher EPC-rated properties. Based on the evidence we present in Section 2.3, a policy that stimulates demand for better EPC-rated properties is a policy that indirectly stimulates demand for lower carbon emissions.

To complete the paper, we ask whether it is financially viable for homeowners to make EPC-rating enhancing retrofits on their properties. Given the externalities imposed by the housing stock in the UK (which we consider in our initial motivation for studying energy efficiency in the UK in Section 2.3), it is important to understand if it is reasonable to expect a homeowner response to the increase EPC-ratings premium. Such a response would set off a (short-run) virtuous cycle of energy efficiency upgrades, moving the housing stock to a new, more energy-efficient equilibrium. We present a temporally-specific cost-benefit vignette, where we document prohibitively large retrofit costs. In all but a single case, it does not make sense for homeowners to retrofit their properties in order to increase their EPC ratings, even when faced with elevated EPC premiums. This pessimistic conclusion is confirmed by making use of the panel element of the raw EPC data in order to investigate the incidence of energy efficiency-enhancing retrofitting. We find that very few homeowners make such changes, consistent with the prohibitively large costs of retrofitting that we document in our vignette.

Our study contributes to several other strands of the literature and has important policy implications. First, by providing both causal evidence on households' willingness to pay for a higher energy rated property, as well as providing evidence on the likely underlying channel, we make a core contribution to a growing literature documenting the impact of energy performance certificates on housing markets. Much of the earlier work in this area was correlational (Fuerst et al., 2015; Jensen et al., 2016; Fuerst et al., 2020). Three recent papers are exceptions. Two of these papers study the housing market responses to a localized mandatory energy efficiency disclosure policy in a single US city (Myers et al., 2022; Cassidy, 2023). Myers et al. (2022) finds that homebuyers and sellers are generally uninformed about quality of houses in terms of energy efficiency. The paper postulates that the market failure is led by lack of information provision, and documents the importance of providing certified energy audits to buyers. Cassidy (2023) studies the impact of observability of energy efficiency features on property sales prices in the context of the same policy in Austin, Texas. In an earlier paper, Aydin et al. (2020) follow an instrumental variable strategy to consider the extent to which energy efficiency is capitalized into house prices in the Netherlands.[6]

Second, by studying the housing market responses to an energy efficiency information shock, we also contribute to a wider literature which focuses on the how the salience of available information shapes choices in a variety of domains, for e.g., information shocks on crime risk can adversely affect housing market (Linden and Rockoff, 2008). In this respect, our work is closest to that of Hussain (2022) who studies the housing market response to school quality ratings disclosure in England. Other research has also explored how more information on schools affect parental decision making (Greaves et al., 2021; Hastings and Weinstein, 2008), hospital report cards affect health-care provider behavior (Dranove et al., 2003), information on hygiene of restaurants influence consumer behaviors (Jin and Leslie, 2003), or gas pipeline explosions affect house prices (Herrnstadt and Sweeney, 2022). Our focus on information salience links our work to recent papers that focus explicitly on the salience of available information as a mechanism explaining why consumers value certain information on energy efficiency differently,

[6]There are additional papers showing property owner responses to various energy efficiency policies, such as, Comerford et al. (2018); McAllister and Nase (2019). Finally, recent work by Fetzer et al. (2022) explores and quantifies the effects of energy price shocks in different parts of the UK.

e.g., works like He et al. (2022) and Fisman et al. (2023). Our work contributes to this debate and shows how salience plays an important role in information provision on energy efficiency in UK housing market.

Our third contribution is based on the policy implications of our work, which deepens our understanding of the role that regulation-initiated, market-driven policy instruments can play in shaping a more energy efficient housing stock. Our exploration of potential mechanisms that link the mandated energy efficiency disclosure we study to increased WTP for better EPC-rated properties, coupled with the theoretical framework we develop in this paper, allows us to document several key facts. First, homebuyers do not appear to pay more for higher EPC-rated properties due to the consumption value associated with more energy efficient housing. Second, in the post-policy period, homebuyers do not appear to make more use of the wider information contained in the full EPC to base their housing choice or valuation of housing on hard-to-observe features of the property, many of which will impact energy bill expenditure. Put differently over and above the EPC rating itself, homebuyers do not appear to adjust their pricing behavior along other energy efficiency-related margins. Having ruled out both consumption and information-based explanation, we propose that the policy impacted buyers' WTP for better EPC-rated properties to due market-valuation/investment concerns.

Our findings suggest that mandatory energy efficiency disclosure policies should be considered in company with other market-based regulatory approach to reducing carbon emissions. Examples of these other approaches include the cap and trade system of the EU Emissions Trading System (EUTS), and carbon taxation schemes (Hintermann and Zarkovic, 2020; Asen, 2021).[7]

The rest of the paper proceeds as follows. In Section we outline the institutional setting of our study, and motivate the topic of energy efficiency in housing 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 investigate the role of a key mechanism that may drive our results: the information channel. In Section 7.2 We investigate whether retrofitting is a financially viable option for homeowners. Section 8 concludes.

[7]Even though both policies have been somewhat successful in different contexts, their effectiveness are still under debate. Recent research suggest additional regulatory instruments are needed in addition to these market based solutions to address climate risk (Cullenward and Victor, 2020; Stavins, 2019). We see such regulatory-market interplay in the setting we study as well – the 2011 amendment to the original EPBR 2007 regulation was made due to the lack of initial market response.

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.[8] 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 to obtain the EPC within maximum 28 days by reasonable efforts.[9]

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). 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.[10,11] Key variables we

[8]This 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.

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

[10]Source: `https://www.gov.uk/government/statistical-data-sets/price-paid-data-downloads`, HM Land Registry.

[11]The 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`.

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".[12] 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 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.[13] We are able to match EPC data to the vast majority of house sales during our sample period (86.8%). 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
Building Age	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.

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.[14] 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%.

2.3 Motivating the Importance of Energy Efficiency in Housing

In order to provide initial motivation for studying energy efficiency in the housing market in England and Wales, we first take stock of the impact of housing on carbon emissions. The aim

[12]Source: `https://epc.opendatacommunities.org/`, Energy Performance of Buildings Register.

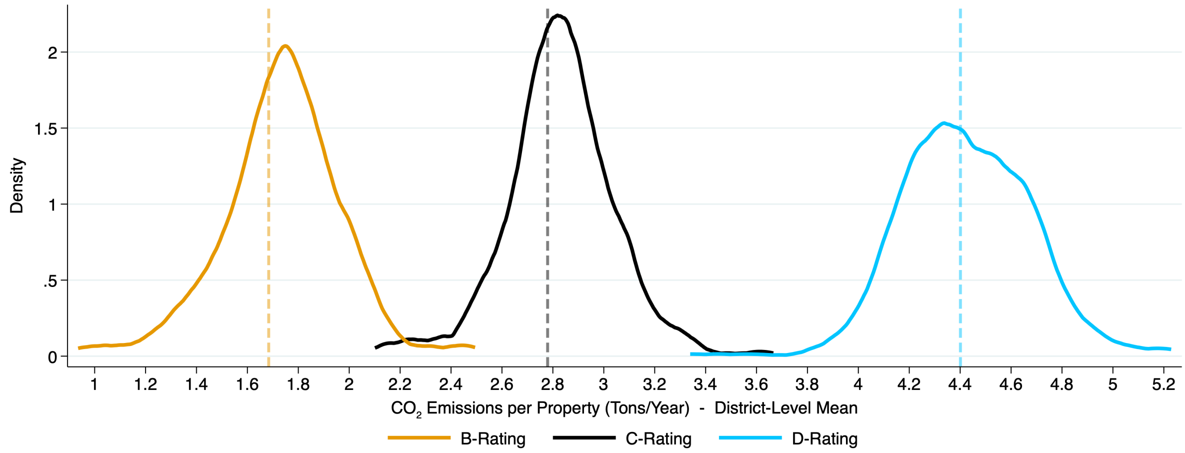
[13]Details on the data and merging process is included in appendix C.

[14]Figure 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.

of this exercise is twofold. First, we aim to quantify the both the extent of the carbon emissions of the housing stock in England and Wales. Additionally, we present one measure of the societal implications of these emissions. Second, we conduct a simple simulation experiment to gauge the impact of energy efficiency improvements.

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 CO_2, 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.

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 Bressler (2021) that considers the mortality cost of carbon, specifically the impact of carbon emissions on mortality between 2020 and 2100.[15]

[15] We note that this statistic takes 2020 as the starting point. Given that the consequences of an additional ton of carbon emission in 2020 are concentrated towards the end of the eighty year period, the 8-year asynchronicity between 2012 and 2020 – the anchoring year for the mortality cost of carbon calculation in Bressler (2021) – is likely to have a minimal effect on these calculations. By starting the clock for the costs of carbon 8 year later, it also means the figures we present here are a lower bound of

The calculations provided in 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 over 21,000 projected deaths over the period up to the year 2100, with the housing in the EPC rating range B-D that we consider in this work contributing over half of this number.

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 mortality 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 seven and a half thousand fewer deaths over the 2020-2100 period. Once again, the housing stock in the B-D range contributes the lion's share of this reduction.

Table 2: Calculating the Associated Mortality Cost of Carbon Statistics for Housing 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)	Carbon-Based Mortality (Deaths per Year)	Mean CO_2 Emissions (Tons per Year)	Total CO_2 Emissions (Million Tons per Year)	Carbon-Based Mortality (Deaths per Year)	Mortality Difference (Deaths per Year)
B	1,409,869	1.7	2.38	538	.56	.79	179	359
C	4,559,558	2.8	12.7	2,868	1.7	7.79	1,762	1,107
D	7,802,150	4.4	34.2	7,740	2.8	21.8	4,925	2,816
E	4,495,556	6.6	29.6	6,681	4.4	19.8	4,473	2,208
F	1,369,880	9.7	13.2	2,983	6.6	9.07	2,050	932
G	327,364	11	3.61	817	9.7	3.14	709	108
Total: B-G			95.7	21,627		62.4	14,097	7,529
Total: B-D			49.3	11,147		30.4	6,865	4,282

Notes: The counterfactual calculations here simulate the reduction in carbon emissions from a one rating CO_2 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. The mortality cost of carbon estimate we use is 226 deaths per million Tons of carbon, based on Bressler (2021). 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.

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.

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 response to EPC ratings. Through the lens of a hedonic pricing model, individual i's valuation of a given property p is given by the

the true societal costs.

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 $\hat{\omega}^t_{EPC} = E[\omega_{ij}|j = EPC_k, t]$ as the estimated premium (weight) for the EPC category k in a given period t. We can then write our DD estimator as $\hat{\beta}_{EPC_k} = \hat{\omega}^1_{EPC_k} - \hat{\omega}^0_{EPC_k}$.

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:

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

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. Take for example, a property with a swimming pool ($a_{\text{pool}} = 1$).[16] $\alpha_{i,pool}$ 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 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 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.[17]

Based on this simple conceptual framework, we can express the 2011 EPBR amendment as two distinct shocks. First, given the increased salience of EPC rating information due to the

[16]Given 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.

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

policy, the amendment represents a positive shock to the salience of energy efficiency. In our framework, the result of this shock will be:

$$\frac{\partial \omega_{i,EPC}}{\partial s_{EPC}} = -(\alpha_{i,EPC} + \gamma_i \tilde{v}_{EPC}) \frac{\partial \theta_{i,EPC}}{\partial s_{EPC}} \geq 0 \tag{2}$$

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). Second, 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 houses with a better EPC rating:

$$\frac{\partial \omega_{i,EPC}}{\partial \tilde{v}_{EPC}} = \gamma_i (1 - \theta_i(s_{EPC})) \geq 0 \tag{3}$$

Without detailed information on the characteristics of homebuyers, we are not able to push any harder on the theoretical implications of our conceptual framework. Hence we conclude this section by highlighting what we gain from our approach. First, our framework elucidates the key channels that will drive any impact of the policy on the differential valuation of more energy efficient properties in the post period. Second, we note the unambiguous predictions from our framework – both Equation (2) and Equation (3) highlight that the effect of the policy should be to increase the weight individuals give to energy efficiency, which should translate into to a larger EPC premium.

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:

$$\begin{aligned} Price_{pt} = & \sum_{k \neq C}^{K} \alpha_k Category_k + \sum_{k \neq C}^{K} \beta_k (Post_t \times Category_k) + \sum_{t=0}^{1} \sum_{d=1}^{D} (District_d \times Post_t \times X_p^{'} \gamma_{dt}) \\ & + \sum_{w=1}^{W} \tau_w (Wider\, Neighborhood_w \times time_t) + \pi_{r \times t} + \theta_n + \epsilon_{pt} \ , \end{aligned} \tag{4}$$

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_i, 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.[18]

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 regression specifications in (4) is, in the nomenclature of Kuminoff et al. (2010), a generalized DD estimator.[19]

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 to 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 4. We do not estimate any significant placebo DD parameters for either England and Wales combined (Table A1), or for the London region (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. We cannot reject the null of equality of trends in any case. Finally we implement the honest difference-in-differences approach of Rambachan and Roth (2023), in order to create worst-case treatment effect bounds for potential violations of the parallel trends assumption, based on pre-trends. We discuss these results in Section A.1.3. 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

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

[19] As 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".

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 Table A4 for England and Wales, and Table A5 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 Table A4 and Table A5, where we present the p-values from a joint test of balance across all control variables.

5 The Value of Energy Efficiency Information

5.1 Housing Characteristics, Prices and Energy Efficiency Prior to the Amendment

Prior to presenting our baseline results, we first explore how key housing characteristics correlate with both sales price and energy efficiency. We do so for the two years prior to the policy. We estimate a regression specification of the form:

$$y_{pt} = X_p^{'}\beta + \sum_{w=1}^{W} \tau_w(Wider\,Neighborhood_w \times time_t) + \pi_{r\times t} + \theta_n + \epsilon_{pt} \ , \tag{5}$$

where, as before, 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 or (ii) the energy efficiency score of the property.

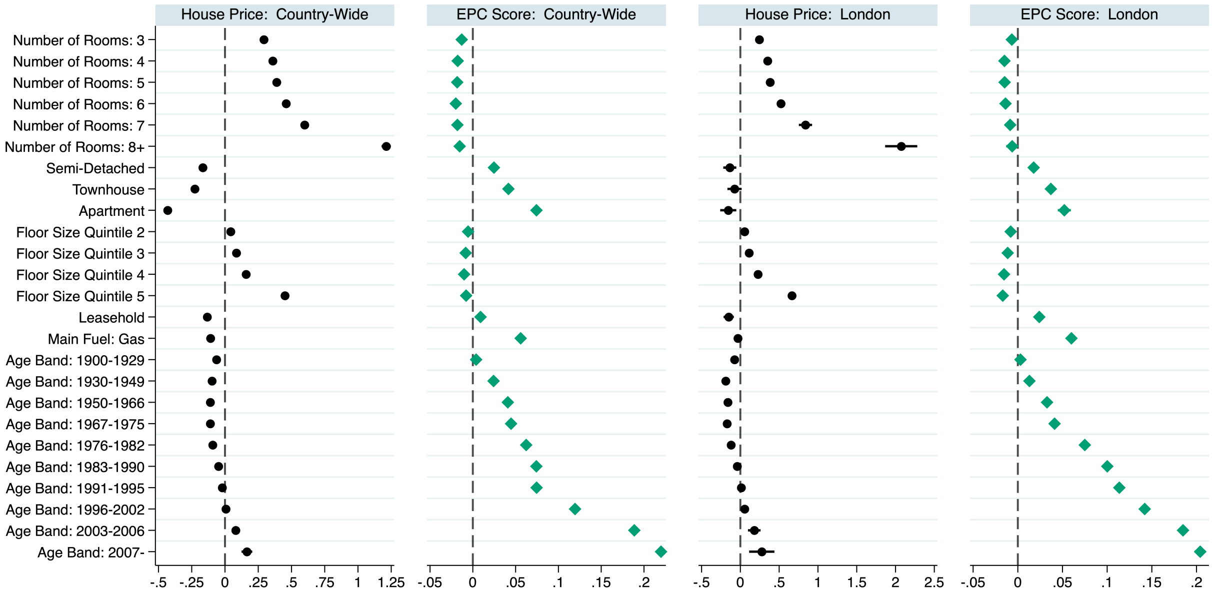
We present parameter estimates for key housing characteristics in Figure 2, for both outcomes based on the full set of properties in England and Wales, as well as for the London region.

The country-wide and London-specific estimates both tell the same story – housing characteristics that correlate with higher house prices are the same characteristics that correlate negatively with energy efficiency. This suggests that without energy efficiency-related policy, particularly policies that augment the energy efficiency-related information set of homebuyers such as the one we study in this paper, homebuyers are unlikely to choose more energy-efficient properties.

5.2 Country-Wide Results

We present the DD parameter estimates from Equation (4) in Column 7 of Table 3. The six preceding columns present DD estimates for less stringent variants of our baseline regression specification, in order to show parameter stability as we (i.) increase the resolution of the spatial fixed effects and (ii.) include local time trends at different levels of spatial resolution. In column 1 we take the housing market as the Travel To Work Area (TTWA) – analogous to Commuting Zones in the US, we account for time invariant at the TTWA level, and we do not include local time trends. With this specification, we document that the heightened salience of

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



Notes: Estimation sample: 6 April 2010 - 5 April 2012. Each point is the resulting coefficient from Equation (5) for each category. Lines represent 95% confidence interval for robust standard errors". We represent house price estimates with black, and EPC score estimates with green.

EPC rankings due to the EPBR 2011 amendment lead to B-rated properties selling for 5.4% higher prices ((B Rating × Post)/$\overline{Y}_{C,PRE}$ at the base of Table 3), and a 1.3% penalty ((D Rating × Post)/$\overline{Y}_{C,PRE}$) for D-rated properties, when compared to C-rated properties.

In Column (2) we include spatial effects at a lower spatial resolution, but keep fixed the rest of the specification. Moving from Column (2) to (3) we change our definition of the housing market from TTWA to district, which impacts the X interactions term. Both of these changes reduce the premium of a B rating, yet do little to change the D rating penalty, which suggests that high energy efficiency properties are non-uniformly located across housing markets. Moving from Column (3) to Column (7) does very little to change either of the two DD parameters estimates. Column (7) presents the DD estimates for our baseline specification, which features neighborhood fixed effects, wider neighborhood time trends, and district-by-period-by-X interactions for all controls. In this specification, we document that by making energy efficiency more salient to home-buyers, the EPBR 2011 amendment leads to a 3.1% premium for B rating properties, and a 1.3% penalty for D rating property, relative to the base category of C rated houses.

5.3 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 (4) on a region-by-region basis. We present the resulting DD coefficient estimates in Figure 3 below. London is a stand-out region 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.

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

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating × Post	11308**	8555**	6183*	6200*	6238*	6373**	6509**
	(4432)	(4147)	(3501)	(3216)	(3215)	(3085)	(3117)
D Rating × Post	–2778**	–2691***	–2987***	–2649***	–2653***	–2617***	–2603***
	(1092)	(1003)	(817)	(770)	(770)	(774)	(778)
$\overline{Y}_{C,PRE}$	207958	207958	207958	207958	207958	207958	207958
(B Rating × Post)/$\overline{Y}_{C,PRE}$	.0544**	.0411**	.0297*	.0298*	.03*	.0306**	.0313**
(D Rating × Post)/$\overline{Y}_{C,PRE}$	-.0134**	-.0129***	-.0144***	-.0127***	-.0128***	-.0126***	-.0125***
Spatial FEs	TTWA	District	District	Wider NH	Wider NH	NH	NH
Local Time Trends					District		Wider NH
X Interactions	TTWA× Post×X	TTWA× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×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%. The dependent variable in all regressions is the house price in £. The estimation sample is based on a +/-1 year window of sales dates around April 6, 2012. We restrict our attention to EPC ratings of B-D, which comprise the majority (.721) of the full sample.

5.4 London-Specific Estimates

Based on the evidence we presented in the previous section, we now focus our attention on the London region, presenting estimates for a London-specific variant of Equation (4) in Table 4.

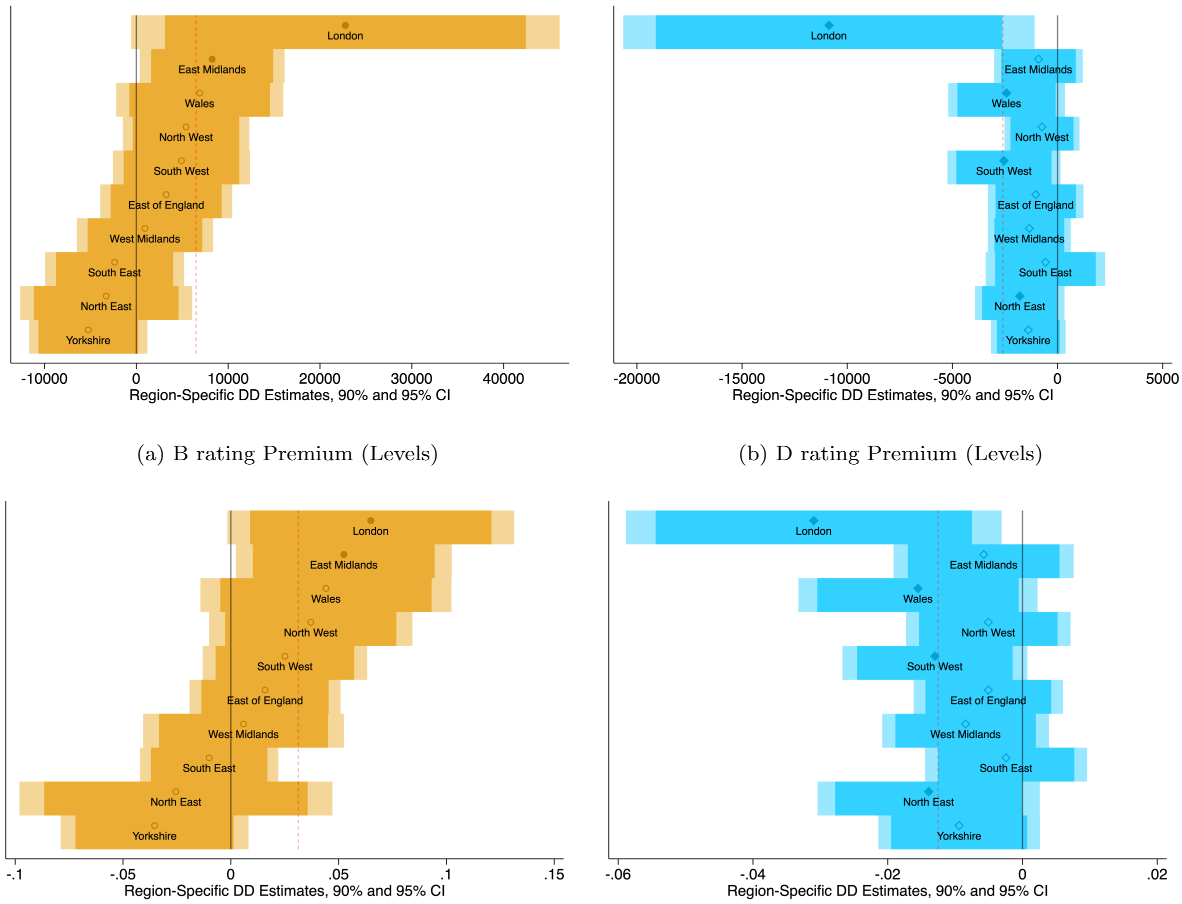
Table 4: DD Estimates from Introduction of EPC certificates – London Only

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating × Post	40450**	30005*	24993*	22314*	22244*	22854*	22769*
	(16966)	(15811)	(13499)	(12256)	(12250)	(11760)	(11909)
D Rating × Post	–16101**	–13437**	–11577**	–9763**	–9830**	–11140**	–10867**
	(7060)	(6401)	(5075)	(4800)	(4794)	(4947)	(4991)
$\overline{Y}_{C,PRE}$	350839	350839	350839	350839	350839	350839	350839
(B Rating × Post)/$\overline{Y}_{C,PRE}$	.115**	.0855*	.0712*	.0636*	.0634*	.0651*	.0649*
(D Rating × Post)/$\overline{Y}_{C,PRE}$	-.0459**	-.0383**	-.033**	-.0278**	-.028**	-.0318**	-.031**
Spatial FEs	TTWA	District	District	Wider NH	Wider NH	NH	NH
Local Time Trends					District		Wider NH
X Interactions	TTWA× Post×X	TTWA× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×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%. The dependent variable in all regressions is the house price in £. The estimation sample is based on a +/-1 year window of sales dates around April 6, 2012. We restrict our attention to EPC ratings of B-D, which comprise .718 of the full sample.

We note three key points in the London-specific results. First, house prices are considerably higher in London, thus it is instructive to consider the DD estimates in percentage terms relative to the base category in the pre-period – these are presented in the fourth and fifth rows of the table. Second, the patterns of coefficients as one moves rightwards across specifications mirrors what we saw in Table 3 – large parameters movements from Columns (1) to (3), followed by a stabilization of DD estimates. Third, in our main specification we find a premium for B rating

Figure 3: Region-specific DD estimates



(a) B rating Premium (Levels)

(b) D rating Premium (Levels)

(c) B rating Premium (Proportional)

(d) D rating (Proportional)

Notes: The figure presents point estimates from a region-specific variant of Equation (4) , 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.

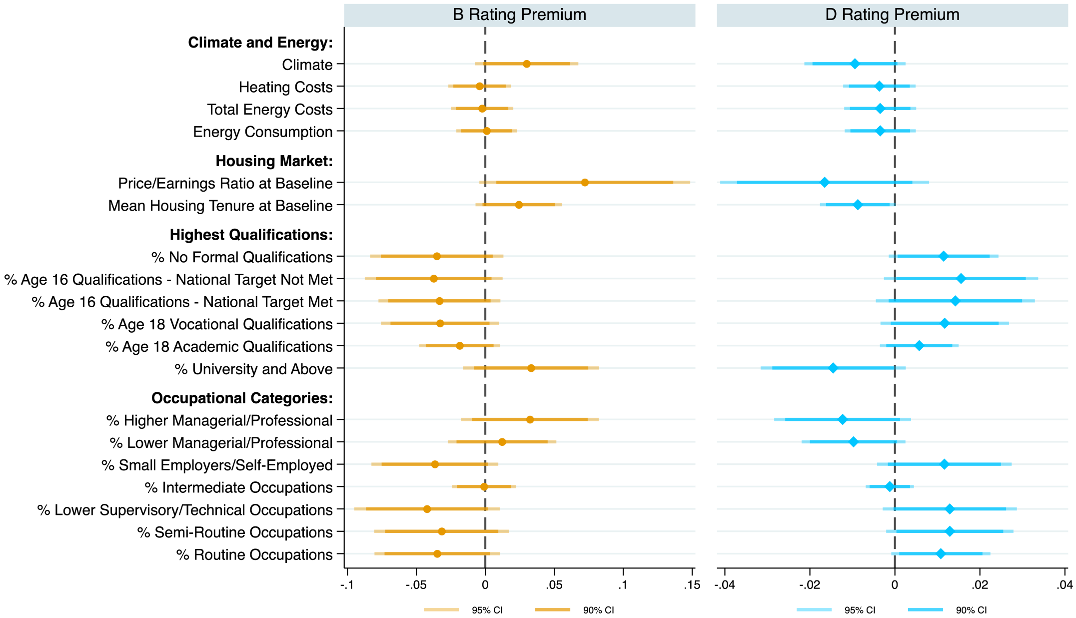
properties of 6.5%, and a D rating penalty of 3.0%. These premiums are double the magnitude of the DD estimates we document at the national level. We consider a range of candidates to explain for the spatial variation in energy efficiency information capitalization across areas in Section 6.

5.5 Heterogeneity Analysis

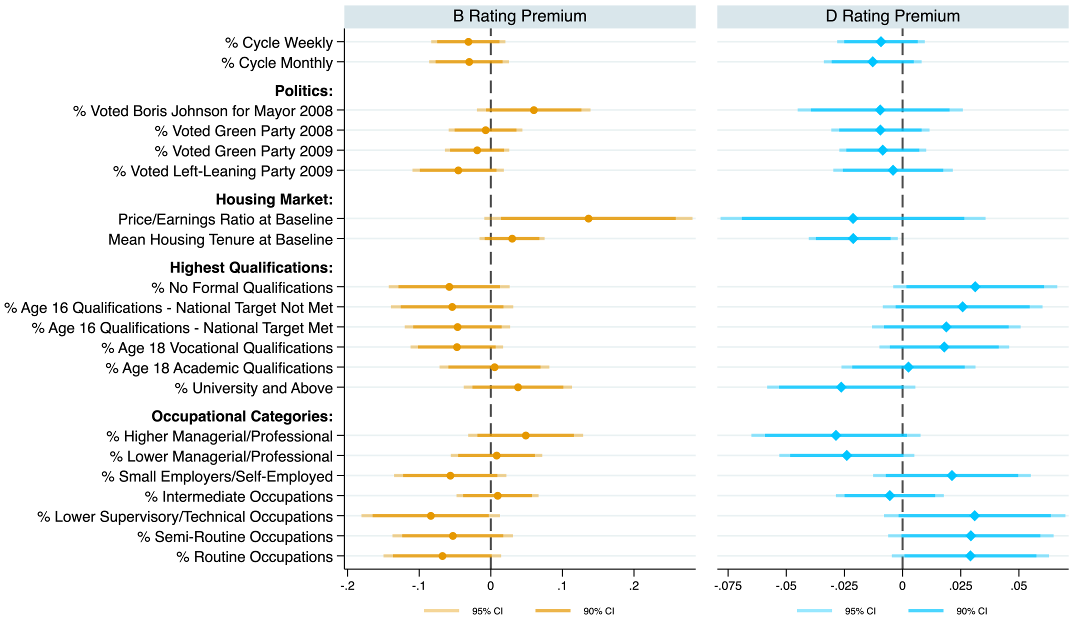
To complete our core results section, we explore the extent to which our DD estimates vary with area-specific attributes. The aim of this heterogeneity analysis is to better understand what drives the spatial heterogeneity in WTP for energy efficiency, both across the country, and within the London region. To the extent that this analysis can shed light on which local attributes matter, and do not matter, for the spatial heterogeneity of our key treatment effects, the evidence we present in this section can enable us to obtain a better sense of the underlying mechanisms that drive our main findings.

To operationalize this approach, we estimate a modified, triple-difference (DDD) version of Equation 4, whereby we interact our DD terms with a third, district-level variable. Each row of the coefficient plots presented in Figure 4 relate to a separate DDD regression. To ease comparison across specifications, we standardize all attributes for this analysis. We first

Figure 4: 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 standardize 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 4a 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 4b, additional data include information on transport and politics (source: London Datastore).

make use of the climatic variation across England and Wales – we document a $3.2°C$ or $5.7°F$ range in climate across districts – to explore the relationship between climate and the policy-induced change in EPC premiums.[20] The logic behind this starting point is simple – all else equal, a colder climate should mean a higher WTP for energy efficiency in order to offset higher energy spending. And yet the evidence we present in Figure 4a are is not consistent with this hypotheses. We find estimates to be opposite-signed to this what this logic would suggest – warmer climates are associated with a larger B-rating premium and a large D-rating penalty. Approaching this idea from a different angle, we find no significant DDD estimates across areas with higher energy consumption. Viewed through the lens of our conceptual framework, these findings suggest that the policy-induced EPC premium is not being driven by the consumption value (the α term in our model) of better rated EPC properties.

For the London region we have additional data on district-level cycling propensity, and voting patterns, both of which could shed light on the extent to which EPC premiums are driven by "green" or liberal tendencies of the local populations. We find no support for the hypothesis that more liberally-minded areas respond more to the policy in terms of how local inhabitants value EPC ratings.

For both the country-wide and London-specific DDD specifications, we examine both (i) highest levels of education and (ii) occupation-based socioeconomic status categories. Here we document a consistent, albeit statistically insignificant pattern, for both measures of socioeconomic status of the area – the higher the proportion of higher educated or those in professional occupations, the higher is the EPC rating premium (more positive for B-ratings, more negative for D-ratings, both relative to C-rated properties).

It is for the two housing market-related variables where we document the only meaningfully consistent and statistically significant patterns, both for the country-wide and London-specific DDD regression estimates. EPC premiums are larger in areas where either (i) the average house price to earnings ratio is larger or (ii) the mean housing tenure at baseline is higher. The DDD evidence we document from these specifications is that when homebuyers are faced with either less affordable housing (and are thus less likely to repeat-move within a given time-frame) or are looking to buy in areas where tenure is on average longer, they have a higher policy-induced WTP for higher EPC-rated properties. The inference we draw from these findings relates to perceived valuation component ($\gamma_i \tilde{v}_j$) of the valuation term from our conceptual framework. In areas where homebuyers are making their housing investment over a longer expected time-horizon, they respond to the policy by placing larger hedonic weights on the EPC rating of the property. We return to the ramifications of this finding in the conclusion.

6 Hard-to-Observe Property Attributes and the Information Channel

As we note above, 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

[20]The district encompassing the English Lake District has the lowest 30-year temperature of $8.5°C$, and the City of London has the highest, with $11.7°C$.

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 of 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. This includes both the cost and potential benefits of retrofit upgrades, 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.[21] In absence of an EPC, this information would be extremely difficult to ascertain.

In this section, we explore the possibility that it is this more detailed information that drives our core empirical findings of a policy-induced rise in the premium for EPC ratings. Put differently we ask if homebuyers are responding to this information-rich environment by paying more for properties with more energy efficient features. Such a finding would provide support for an *information channel* (Jin and Leslie, 2003), whereby the policy reduced the cost of acquiring hard-to-observe information on the property. To be clear, this information was available in both the pre- and post-policy periods. What is different post-policy is that (i) the EPC ratings and the EPC itself are now far more salient, and (ii) the EPC front page is made available at the start of the home buying, which could catalyze homebuyers to review the entire EPC at this stage of the process.

To test this information channel hypothesis, we estimate a variant of Equation (4), where we replace the EPC ratings with one of three sets of features of the property, indexed by f. This leads to a series of equations of the form:

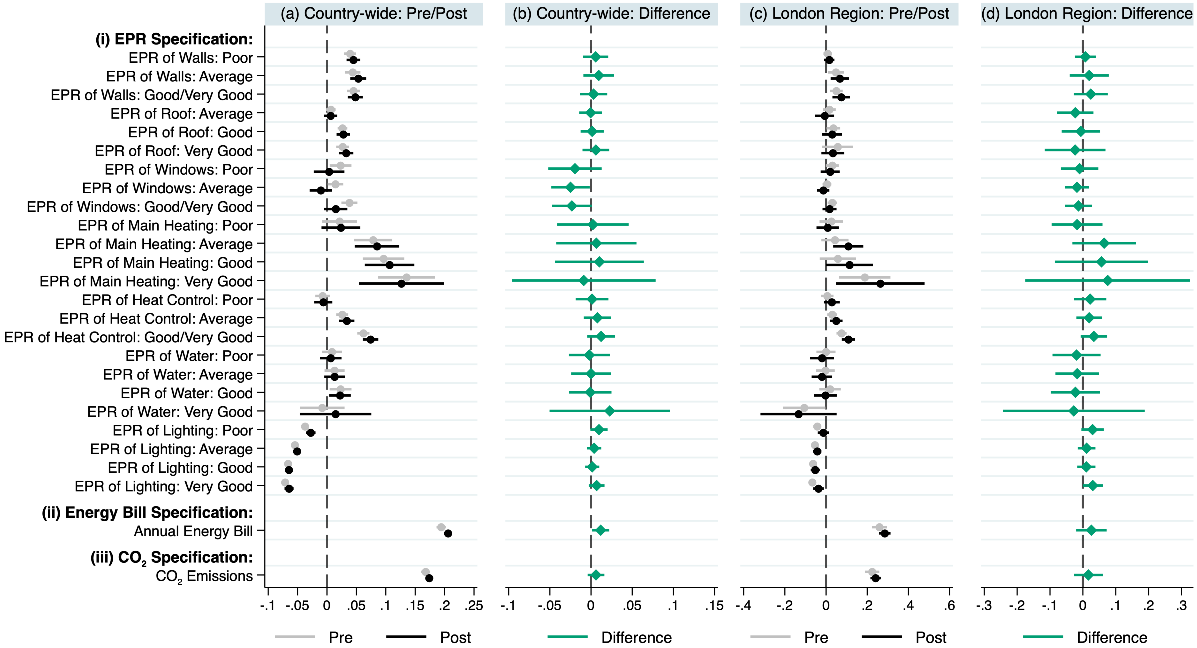
$$\begin{aligned} Price_{pt} =& F'_{fp}\alpha_f + Post_t \times F'_{fp}\beta + \sum_{t=0}^{1}\sum_{d=1}^{D}(District_d \times Post_t \times X'_p\gamma_{dt}) \\ &+ \sum_{w=1}^{W} \tau_w(Wider\,Neighborhood_w \times time_t) + \pi_{r\times t} + \theta_n + \epsilon_{pt} \text{ for } f = (1,2,3). \end{aligned} \quad (6)$$

For the first set of features, $F_{1p} = EPR_p$, a vector of all the key feature-specific energy performance ratings presented in the full EPC.[22] In the second specification, $F_{2p} = EB_p$, the annual energy bill estimate, calculated by the energy assessor based on the energy performance of the property. In the final specification $F_{3p} = C02_p$, 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 5 below. In panels (a) and (c) we present the corresponding point estimates 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

[21] See Figure B4 for an example from an EPC.

[22] The 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.

Figure 5: 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.

how homebuyers value these hard-to-observe attributes of the property. 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 message we take away from these results is that even though the policy plausibly made the provision of hard-to-observe information more salient, homebuyers do not differentially respond to this information. The results of specification 2 highlights that the policy does not lead homeowners to meaningfully change how they factor in energy costs of the property. The results of specification 3 shows that homebuyers are not differentially internalizing the carbon emission of the property in the post-policy period.

These null finding 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. Hence, we see no change in how homebuyers value these feature-specific energy performance ratings. The findings of this section underscore the importance of information salience in such policies.

From these analyses, we conclude that the mechanism that leads homebuyers to pay a higher premium for better EPC-rated properties is not based on an informational channel. The policy does not lead to homebuyers increasing their WTP for properties with better feature-specific energy performance ratings. The policy does not lead to homebuyers increasing their WTP for properties with lower energy bills. The policy does not lead to homebuyers increasing their WTP for properties with carbon emissions. So why *do* we find such pronounce EPC-rating premiums?

One possibility, outlined in our conceptual framework in Section 3, is the investment channel. Housing is the largest asset investment that most individuals make, thus the policy may lead to homebuyers placing a higher weight on the EPC rating of the property due to the perceived valuation of a better EPC-rated property. This explanation is consistent with both (i) the battery of null findings that we provide in this section, and (ii) the DDD estimates we present in Figure 4: DD estimates are considerably higher in areas where homebuyers expect to stay in their property over a longer horizon. Such a finding speaks to the potential of market-facing regulatory policies such as the EPBR 2011 amendment for mitigating climate change – even if homebuyers do not internalize the carbon emission-based externalities of the properties they are considering, perceived valuation concerns of housing as an investment asset can lead individuals to increase their WTP for higher EPC-rated properties. Based on the evidence we present in Section 2.3, a policy that stimulates demand for better EPC-rated properties is a policy that indirectly stimulates demand for lower carbon emissions.

7 Is Retrofitting a Financially Viable Option?

Given the evidence we document in Section 5 of a policy-induced rise in the WTP for better EPC-rated properties, it is instructive to consider the extent to which there is scope for a subsequent supply-side response. The response we have in mind is for homeowners to retrofit their properties to achieve a higher EPC rating.

Constructing a cost-benefit analysis for our setting in a temporally consistent manner is somewhat complicated, given that the key benefit we measure (the house-price based DD estimate for the amendment) is for a specific time-period. To address this, in Section 7.1 we construct a temporally-specific cost-benefit analysis. It is for this reason that we frame this approach as a cost-benefit vignette.

7.1 A Cost-Benefit Vignette

The vignette proceeds as follows.[23] We consider a homeowner who decides to retrofit their property in 2010 to improve its energy efficiency. They do so in a strategic manner – they make the minimum required changes in order to move up one EPC rating band. We assume these changes are completed and paid for in September 2010. The homeowner then sells the property in September 2012, within the post-period in our DD analysis framework. They thus benefit from a price premium equal to the relevant DD estimate. In the intervening two years and as a consequence of their energy efficiency improvements on their property, the homeowner benefits (privately) from reduced energy costs, and also reduced CO_2 emissions – a social benefit for which they may receive a private, warm-glow benefit. We present the details from this vignette in Table 5.

[23]See Appendix B.4 for details on the components of the cost-benefit analysis.

Table 5: Would it Have Paid Off to Make an EPC-Rating-Enhancing Retrofit in September 2010?

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
				Amount (£s)		**N.P.V. Amount (£s)**	
	Type	Accrual Period	Timing	D-Rating to C-Rating	C-Rating to B-Rating	D-Rating to C-Rating	C-Rating to B-Rating
a.) Nation-wide							
Costs							
C1: Retrofitting	Private	One-off	09–2010	21,930.00	16,953.00	21,930.00	16,953.00
Benefits							
B1: Reduced Energy Costs	Private	Continual		184.05	64.21	367.18	128.11
B2: Price Premium on Sale	Private	One-off	09–2012	2,603.00	6,509.00	2,577.16	6,444.40
B3: Reduced CO_2 Emissions	Social	Continual		13.89	3.80	27.70	7.58
Total Private Benefit						2,944.34	6,572.50
Total Benefit						2,972.05	6,580.09
b.) London Region							
Costs							
C1: Retrofitting	Private	One-off	09–2010	21,485.00	12,407.00	21,485.00	12,407.00
Benefits							
B1: Reduced Energy Costs	Private	Continual		189.79	96.33	378.64	192.18
B2: Price Premium on Sale	Private	One-off	09–2012	10,867.00	22,769.00	10,759.14	22,543.01
B3: Reduced CO_2 Emissions	Social	Continual		14.33	5.99	28.59	11.96
Total Private Benefit						11,137.78	22,735.19
Total Benefit						11,166.37	22,747.15

Notes: The N.P.V calculations discount all amounts to the time period when the retrofit cost is incurred – September 2010. The discount rate of 1/(1+r) uses the prevailing interest rate at the time: 0.5%, and the prevailing cost of carbon used by the UK government at the time – £13.50 per ton CO_2 emitted. In this manner, we approximate the information set of the homebuyer at the time of retrofit.

The message we take from this cost-benefit analysis is stark – in all but one specific case (homeowners of C-rated properties in the London region), it does *not* make financial sense for homeowners to invest in energy efficiency-enhancing retrofitting of one's property. For the majority of the cases, on average, retrofit investment costs far exceed the benefits of such improvements. Put differently, investment inefficiencies, in the nomenclature of Allcott and Greenstone (2012), do not appear to be the primary impediment to improving energy efficiency for the housing stock in England and Wales. Rather it is the result of energy efficiency-enhancing improvements not being privately profitable for homeowners to undertake. The caveat to this statement is that while this is true *on average*, there will be a subset of homeowners who could make such improvements that would pass a private cost-benefit test.

7.2 The Incidence of Retrofitting

We next make use of the panel element of the underlying energy performance certificate data, where we can link EPC inspections for the same property over time. With this data, we are able to create measures of retrofitting based on changes in the EPC score of the property across inspections. We consider all properties observed with EPC inspections in the year prior to and after the policy, and create a variable to indicate whether or not this property had a previous inspection in the two years prior to the current inspection date. For those that do have a previous inspection within the preceding two years, we construct a series of indicator variables quantifying whether or not the property improved upon the prior EPC score by a given margin, e.g. an improvement of 5+ EPC score points. Such properties are allocated an indicator value of 1. Properties that do not have previous inspections within the time-frame, or that do but do not see the requisite improvements are coded as 0. In the Table 6 below, we report the proportion of properties with retrofit improvements across a series of thresholds based on this procedure.

Table 6: Energy Efficiency-Enhancing Retrofit Incidence

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Size of Improvement (Based on ΔEPC Score Points)							
	Small (2+)		**Medium (5+)**		**Large (8+)**		**ΔRating**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
a.) Country-Wide								
B-Rating	.00408	.0036	.000478	.000774	.0000367	.000298	.0000367	.000298
C-Rating	.00874	.0104	.00326	.00399	.00122	.00192	.00183	.00234
D-Rating	.0215	.0227	.0141	.015	.0083	.0094	.0104	.0122
b.) London								
B-Rating	.00387	.0044	.00043	.000352	0	.000176	0	.000176
C-Rating	.0144	.0145	.00626	.00497	.00254	.00168	.00334	.00227
D-Rating	.0293	.0295	.0201	.0198	.012	.0116	.0151	.0157

Notes: Data used: EPC inspection data: 6 April 2010 - 5 April 2013. The Small/Medium/Large retrofit improvement indicators are respectively defined as 1 for properties that have two inspections within a 24 month period, and a 2+/5+/8+ EPC score improvement in the later inspection, and 0 otherwise. The ΔRating retrofit improvement indicator is defined as 1 for properties that have two inspections within a 24 month period, and improve by 1+ EPC rating indicators (e.g., D to C) in the later inspection.

The evidence we present in Table 6 suggests that very few homeowners are making retrofit improvements to their properties. To anchor our choice of EPC score improvements, a medium-level retrofit of 5 points can be achieved by replacing an old boiler with a newer, condensing boiler. A large improvement of 8 points could be achieved by fitting solar roof panels. Considering D-rated properties, under 2% of homeowners engage in medium retrofit improvements over a two year period, and approximately 1% conduct large improvements. Such low retrofit incidence is consistent with the costs of such retrofits that we document in our cost-benefit vignette in Section 7.1.

8 Conclusion

In this paper we study a country-wide policy that mandated the provision of energy efficiency information of a property at listing. We develop a conceptual framework to make clear the key channels through which the policy can affect house prices. Using a generalized difference-in-differences specification, we provide causal evidence of the WTP of households for higher energy efficiency ratings. We document that homebuyers value energy efficiency, paying a premium of 1-3% more for a higher EPC rating country-wide, and 3-6% more in London.

Our DDD-based heterogeneity analysis, and our exploration of homebuyer response to the hard-to-observe features of the property contained in the full EPC, suggest that the key channels that drive our findings are not consumption- or information-based. Rather, we suggest that it is the market valuation channel that we present in our conceptual framework. We provide indirect support for this conclusion by documenting the large, statistically significant DDD estimates in areas where homeowners expect to stay at the property over a longer time horizon. This conclusion has important ramifications for public policy design in the area of energy efficiency.

Our study highlights the importance of regulatory adjustment with market-oriented policies such as the regulation underpinning Energy Performance Certificates. When the regulation was first introduced, the design was insufficient for the market to adequately respond to EPCs. The 2011 EPBR amendment made the energy rating information more visible, more salient and made it available at the right time – when properties are first listed. Accordingly, the market could better respond to the regulations. In this manner Energy Performance Certificates share commonalities with other market-based regulatory instruments that aim to lower emissions, such as carbon taxes and cap and trade schemes. The more we can collectively understand about the strengths and weaknesses of such approaches, the better we can implement market-facing regulatory instruments in the fight to stave off a climate emergency.

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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 (4) – 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 × Post	5550	5174	4415	3249	3102	2267	2583
	(3458)	(3246)	(2729)	(2530)	(2530)	(2362)	(2328)
D Rating × Post	–650	–934	–719	–633	–588	–770	–629
	(888)	(805)	(664)	(616)	(615)	(622)	(630)
$\overline{Y}_{C,PRE}$	208824	208824	208824	208824	208824	208824	208824
(B Rating × Post)/$\overline{Y}_{C,PRE}$	.0266	.0248	.0211	.0156	.0149	.0109	.0124
(D Rating × Post)/$\overline{Y}_{C,PRE}$	-.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× Post×X	TTWA× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×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%. The dependent variable in all regressions is the house price in £. The estimation sample is based on a +/-1 year window of sales dates around April 6, 2011. We restrict our attention to EPC ratings of B-D, which comprise the majority (.693) of the full sample.

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 extract the residuals.

$$Price_{pt} = \sum_{d=1}^{D}(District_d \times X_p^{'}\gamma) + \sum_{w=1}^{W}\tau_w(Wider\,Neighborhood_w \times time_t) + \theta_n + \epsilon_{pt}\ , \quad (7)$$

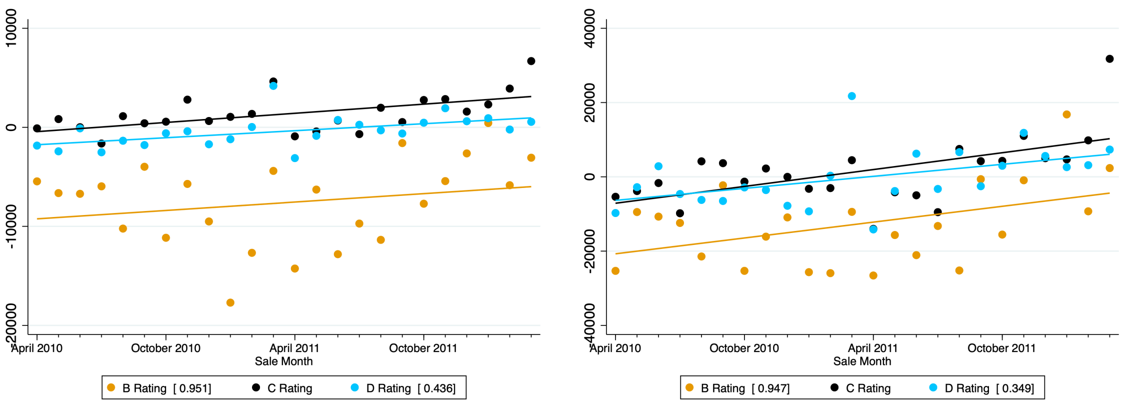
Table A2: DD Estimates from Introduction of EPC certificates – London Only – Placebo

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
B Rating × Post	12870	9541	2941	2079	1435	621	1873
	(13231)	(12307)	(10156)	(9303)	(9297)	(8664)	(8441)
D Rating × Post	623	–1762	–1173	–1578	–1400	–2027	–1203
	(5384)	(4789)	(3704)	(3426)	(3415)	(3565)	(3629)
$\overline{Y}_{C,PRE}$	349173	349173	349173	349173	349173	349173	349173
(B Rating × Post)/$\overline{Y}_{C,PRE}$	.0369	.0273	.00842	.00595	.00411	.00178	.00536
(D Rating × Post)/$\overline{Y}_{C,PRE}$	.00178	-.00505	-.00336	-.00452	-.00401	-.0058	-.00344
Spatial FEs	TTWA	District	District	Wider NH	Wider NH	NH	NH
Local Time Trends					District		Wider NH
X Interactions	TTWA× Post×X	TTWA× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×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%. The dependent variable in all regressions is the house price in £. The estimation sample is based on a +/-1 year window of sales dates around April 6, 2011. We restrict our attention to EPC ratings of B-D, which comprise .688 of the full sample.

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



(a) England and Wales

(b) London

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.1.3 Honest Difference-in-Differences – Rambachan and Roth (2023)

Finally, we implement the honest difference-in-differences approach of Rambachan and Roth (2023), in order to create worst-case treatment effect bounds for potential violations of the parallel trends assumption, based on pre-trends. In order to operationalize this approach, we use data for sales that occur in the three years between 6 April 2010 and 5 April 2013, and create

3 periods: 1.) An initial period of 6 April 2010 - 5 April 2011 that is prior to the pre-period used in the main analysis, 2.) the pre-period of 6 April 2011 - 5 April 2012 and 3.) the post-period of 6 April 2012 - 5 April 2013. We then implement our core DD model, but based on the extended data and a 3 period approach, as follows:

$$Price_{pt} = \sum_{j=1,\neq 2}^{3} \sum_{k\neq C}^{K} \beta_{jk}(Period_j \times Category_k) + \sum_{j=1,\neq 2}^{3} \sum_{d=1}^{D}(District_d \times Period_j \times X_p^{'}\gamma) + \pi_{r\times t}$$
$$+ \sum_{j=1,\neq 2}^{3} \sum_{w=1}^{W} \tau_{wj}(Period_j \times Wider\,Neighborhood_w \times time_t) + \theta_{n\times j} + \epsilon_{pt} \ , \quad (8)$$

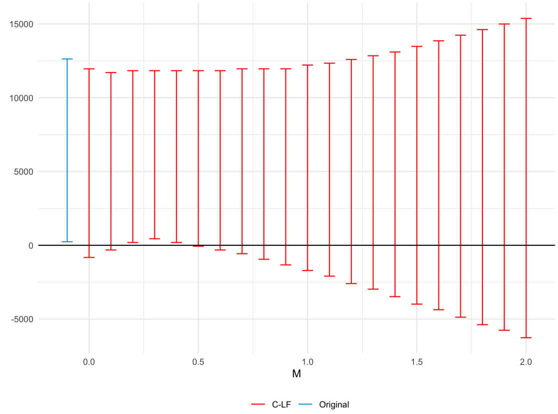
The coefficients presented in Table A3 below, and accompanying variance-covariance matrices are the required inputs into the R package (HonestDiD) that implements the Rambachan and Roth (2023) approach.

Table A3: The Inputs For the Honest DD Approach Highlight The Large Ratio Between Placebo and Actual Treatment Effects From a Pooled Estimation

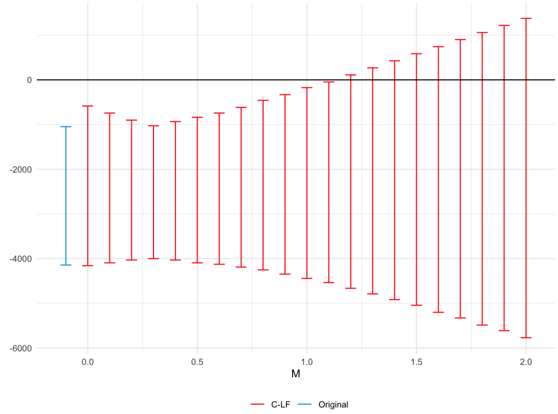
	(1)	(2)
	England and Wales	London
B Rating $\times$Period$_1$	–1638	461
	(2477)	(9256)
B Rating $\times$Period$_3$	6433**	21775*
	(3161)	(12104)
D Rating $\times$Period$_1$	800	10.7
	(649)	(3782)
D Rating $\times$Period$_3$	–2596***	–11071**
	(790)	(5072)
$\overline{Y}_{C,PRE}$	207958	350839
Adjusted R^2	.766	.726
Observations	997,799	134,079

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. We restrict our attention to EPC ratings of B-D. The variables Period$_1$ and Period$_3$ are dummies corresponding resepctively to the earlist pre-period of 6 April 2010-5 April 2011, and the post-policy period of 6 April 2012-5 April 2013. The pre-policy period of 6 April 2011-5 April 2012 is the omitted period.

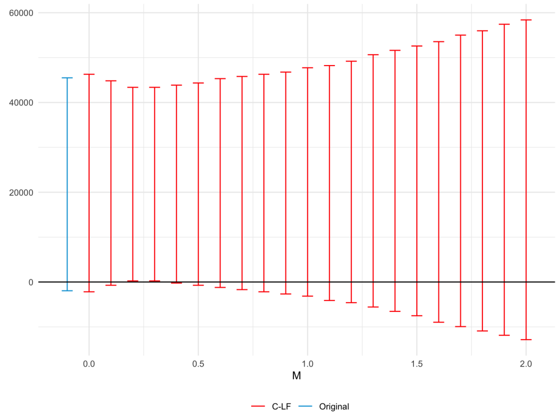
Figure A2: Pre-trends



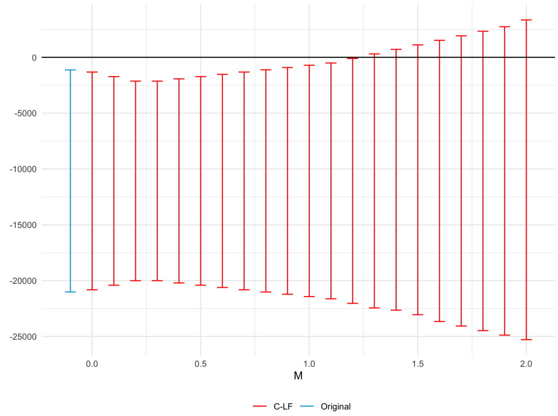
(a) B Rating - England and Wales



(b) D Rating - England and Wales



(c) B Rating - London Only



(d) D Rating - London Only

Notes: The blue bands ("Original") are the respective 90% confidence interval of the DD treatment effect estimates ($Period_3 \times Category_k$ in Table A3). The red bands ("C-LF") are the robust confidence intervals for the Rambachan and Roth (2023) Relative Magnitude-based bounds. These vary with the x-axis – $\overline{M}$ – which designates factors of the maximum pre-treatment violation of parallel trends. Thus a confidence interval that does not intersect 0 when $\overline{M} = 1$ informs us that when we allow any parallel trend violations in the post-period to be as large as the maximum pre-treatment violation, the 90% confidence intervals for the bounded treatment effect do not include zero. Period: 6 April 2010 and 5 April 2013.

The graphical outputs from the Rambachan and Roth (2023) approach, where we use the Relative Magnitude approach for bounding, are presented in Figure A2. Although the ratio of the period 3 to period 1 rating coefficients in Table A3 are large, the "breakdown values" of $\overline{M}$ – the factor of the pre-trends at which the bounds on the estimated treatment effect overlap with zero – are surprisingly low in some cases. This appears to be more a factor of the imprecisely estimated period 1 ratings premiums, rather than the point estimates being excessively large of these premiums.

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 A4 for England and Wales, and Table A5 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 54 balance tests we present, 3 are significant at the 5% level. Given that 3/54=.056, we ascribe this to sampling error, and conclude that the group composition is stable for both England and Wales, and London.

Table A4: 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	p-value: Difference	Pre Period	Post Period	p-value: Difference	Pre Period	Post Period	p-value: Difference
Sample Size	109402	106689		9554	7829		227077	242611	
Property Type:									
Detached	.191	.168	[.029]	.0139	.0112	[.720]	.255	.261	[.402]
	(.00531)	(.00544)		(.00344)	(.00411)		(.00379)	(.00355)	
Semi-Detached	.235	.238	[.811]	.0335	.0207	[.282]	.322	.322	[.964]
	(.00564)	(.00579)		(.0056)	(.00652)		(.00427)	(.004)	
Terraced	.293	.309	[.219]	.0841	.106	[.408]	.305	.311	[.419]
	(.00627)	(.00644)		(.0121)	(.0143)		(.00399)	(.00374)	
Apartment	.281	.286	[.611]	.868	.862	[.820]	.118	.106	[.016]
	(.00506)	(.00519)		(.0124)	(.0147)		(.00257)	(.00241)	
Leasehold	.326	.328	[.800]	.881	.879	[.956]	.162	.153	[.096]
	(.00539)	(.00553)		(.0127)	(.015)		(.00294)	(.00275)	
Building Age	1976	1975	[.140]	1999	2000	[.774]	1950	1950	[.249]
	(.42)	(.432)		(.749)	(.876)		(.334)	(.313)	
Floor Size:									
Quintile 1	.272	.273	[.966]	.543	.448	[.133]	.157	.157	[.994]
	(.00636)	(.00653)		(.0293)	(.0346)		(.0035)	(.00328)	
Quintile 2	.199	.223	[.049]	.23	.272	[.491]	.194	.192	[.750]
	(.00603)	(.00619)		(.0275)	(.0325)		(.00393)	(.00368)	
Quintile 3	.169	.183	[.211]	.111	.112	[.991]	.216	.212	[.591]
	(.00556)	(.00572)		(.0211)	(.0248)		(.00407)	(.00382)	
Quintile 4	.163	.153	[.373]	.0795	.076	[.935]	.224	.223	[.900]
	(.00557)	(.0057)		(.0199)	(.0235)		(.00419)	(.00392)	
Quintile 5	.197	.168	[.012]	.0355	.0928	[.086]	.209	.216	[.314]
	(.00561)	(.00575)		(.0153)	(.0182)		(.00391)	(.00366)	
Number of Rooms	4.35	4.28	[.098]	2.96	3.02	[.611]	4.69	4.72	[.297]
	(.0234)	(.024)		(.0504)	(.0597)		(.0142)	(.0133)	
Main Fuel is Gas	.886	.89	[.661]	.664	.696	[.543]	.917	.919	[.571]
	(.00428)	(.00438)		(.0247)	(.0291)		(.00223)	(.00209)	
Joint Test			[.337]			[.855]			[.866]

Notes: Means and standard erors (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 A5: 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	*p*-value: Difference	Pre Period	Post Period	*p*-value: Difference	Pre Period	Post Period	*p*-value: Difference
Sample Size	15210	14928		2290	2008		28831	30470	
Property Type:									
Detached	.0136	.0273	[.092]	.00137	.00147	[.847]	.0427	.0394	[.744]
	(.00406)	(.00421)		(.000546)	(.000626)		(.00526)	(.00498)	
Semi-Detached	.0455	.0556	[.444]	.00362	.00316	[.610]	.181	.167	[.462]
	(.00662)	(.00678)		(.000778)	(.000784)		(.0101)	(.0095)	
Terraced	.188	.224	[.179]	.00566	.0217	[.600]	.363	.401	[.119]
	(.0134)	(.0137)		(.0146)	(.0162)		(.0126)	(.012)	
Apartment	.753	.693	[.035]	.989	.974	[.610]	.413	.393	[.386]
	(.0142)	(.0145)		(.0146)	(.0163)		(.0122)	(.0116)	
Leasehold	.76	.711	[.080]	.982	.986	[.847]	.419	.414	[.846]
	(.0139)	(.0142)		(.0116)	(.013)		(.0123)	(.0116)	
Building Age	1960	1959	[.859]	1995	1993	[.398]	1926	1929	[.205]
	(1.55)	(1.58)		(1.39)	(1.49)		(1.09)	(1.03)	
Floor Size:									
Quintile 1	.28	.289	[.789]	.349	.355	[.946]	.132	.159	[.154]
	(.018)	(.0183)		(.046)	(.0502)		(.00985)	(.00938)	
Quintile 2	.243	.244	[.961]	.225	.28	[.597]	.175	.181	[.775]
	(.017)	(.0173)		(.0501)	(.0547)		(.0116)	(.011)	
Quintile 3	.172	.215	[.159]	.227	.186	[.692]	.208	.191	[.452]
	(.0154)	(.0157)		(.0505)	(.055)		(.0121)	(.0114)	
Quintile 4	.155	.135	[.502]	.155	.0997	[.582]	.253	.218	[.149]
	(.015)	(.0152)		(.0485)	(.053)		(.0127)	(.012)	
Quintile 5	.151	.116	[.241]	.0434	.0789	[.611]	.232	.251	[.424]
	(.0147)	(.0149)		(.0334)	(.0367)		(.0125)	(.0118)	
Number of Rooms	3.37	3.37	[.987]	2.7	2.68	[.900]	4.18	4.2	[.847]
	(.0498)	(.0508)		(.09)	(.0993)		(.0437)	(.0415)	
Main Fuel is Gas	.82	.84	[.473]	.705	.605	[.261]	.94	.931	[.459]
	(.0141)	(.0143)		(.0428)	(.0466)		(.00572)	(.00545)	
Joint Test			[.237]			[.984]			[.318]

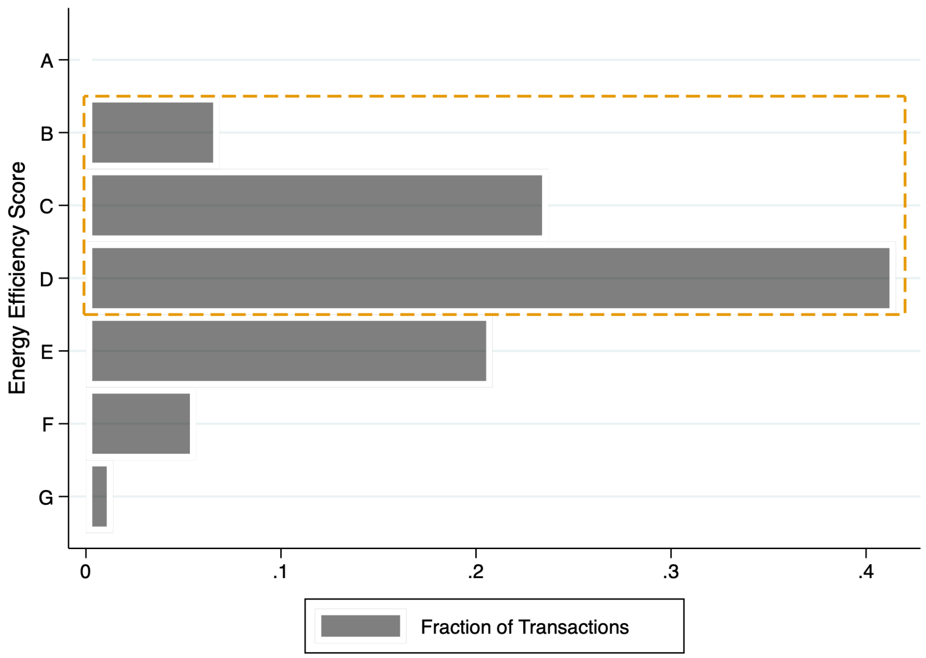
Notes: Means and standard erors (in parentheses) are shown. *p*-values are based on OLS regressions with Eicker-Huber-White standard errors. We do not control for any household-level characteristics in the balance test regressions, but we do account for the following spatiotemporal variables: Neighborhood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

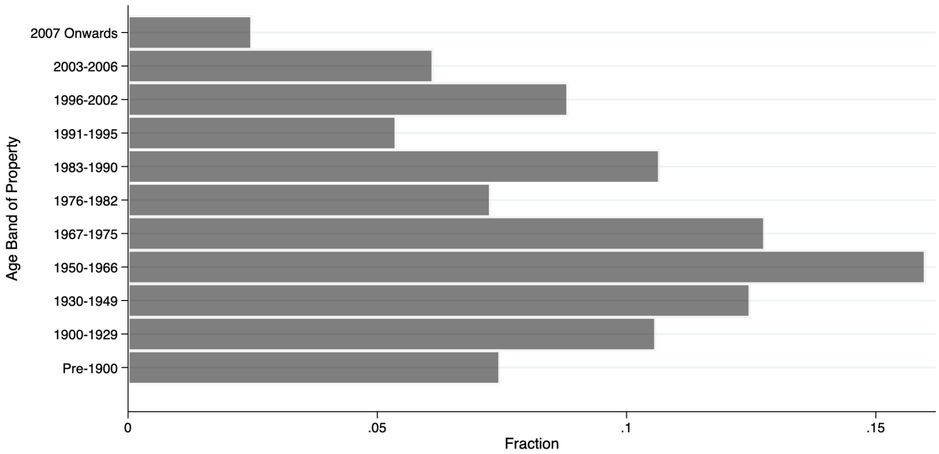
Figure B1 presents the distribution of EPC scores during our sample period.

Figure B1: EPC Rating Distribution



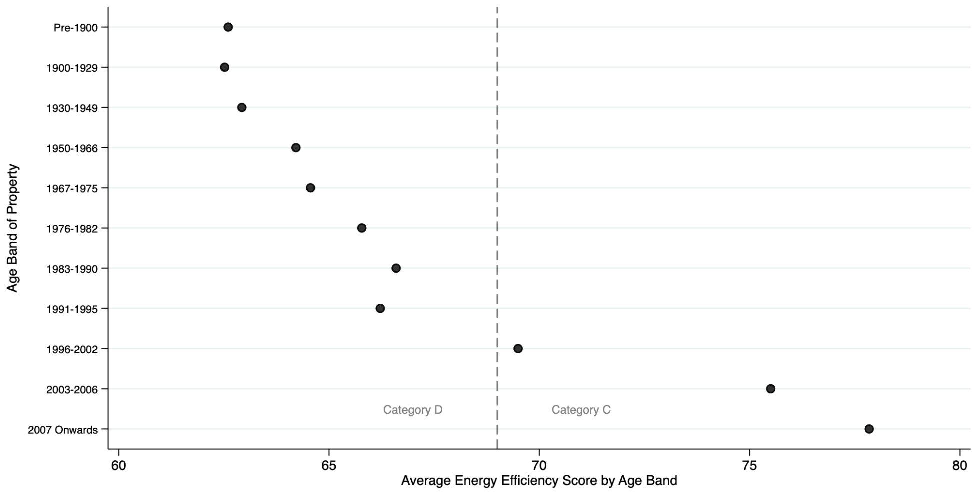
The UK has an older housing stock than many other European countries. Figure presents the distribution of property age during our sample period. Figure B3 documents the consequence

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 Sensitivity Analysis

B.2.1 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.[24] 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 × Post	11681***	8888**	6482*	6430**	6462**	6450**	6600**
	(4443)	(4158)	(3476)	(3194)	(3193)	(3071)	(3103)
D Rating × Post	–2715**	–2618***	–3005***	–2685***	–2690***	–2629***	–2641***
	(1099)	(1010)	(826)	(779)	(779)	(787)	(793)
$\overline{Y}_{C,PRE}$	208176	208176	208176	208176	208176	208176	208176
(B Rating × Post)/$\overline{Y}_{C,PRE}$	.0561***	.0427**	.0311*	.0309**	.031**	.031**	.0317**
(D Rating × Post)/$\overline{Y}_{C,PRE}$	-.013**	-.0126***	-.0144***	-.0129***	-.0129***	-.0126***	-.0127***
Spatial FEs	TTWA	District	District	Wider NH	Wider NH	NH	NH
Local Time Trends					District		Wider NH
X Interactions	TTWA× Post×X	TTWA× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×X
Adjusted R^2	.458	.558	.69	.737	.737	.759	.759
Observations	694,795	694,795	694,795	694,795	694,795	694,795	694,795

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. The dependent variable in all regressions is the house price in £. The estimation sample is based on a +/-s year window of sales dates around April 6, 2012. We restrict our attention to EPC ratings of B-D, which comprise the majority (.718) of the full sample.

[24] Source: https://www.legislation.gov.uk/uksi/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 × Post	41734**	30848*	25788*	22568*	22428*	22611*	22357*
	(16985)	(15827)	(13356)	(12125)	(12120)	(11663)	(11808)
D Rating × Post	–14662**	–12260*	–10773**	–9395*	–9454*	–10992**	–10872**
	(7079)	(6427)	(5116)	(4852)	(4846)	(5022)	(5085)
$\overline{Y}_{C,PRE}$	351,492	351,492	351,492	351,492	351,492	351,492	351,492
(B Rating × Post)/$\overline{Y}_{C,PRE}$	.119**	.0878*	.0734*	.0642*	.0638*	.0643*	.0636*
(D Rating × Post)/$\overline{Y}_{C,PRE}$	-.0417**	-.0349*	-.0307**	-.0267*	-.0269*	-.0313**	-.0309**
Spatial FEs	TTWA	District	District	Wider NH	Wider NH	NH	NH
Local Time Trends					District		Wider NH
X Interactions	TTWA× Post×X	TTWA× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×X	District× Post×X
Adjusted R^2	.298	.446	.641	.696	.696	.717	.718
Observations	92,710	92,710	92,710	92,710	92,710	92,710	92,710

Notes: *** denotes significance at 1%, ** at 5%, and * at 10%. The dependent variable in all regressions is the house price in £. The estimation sample is based on a +/-s year window of sales dates around April 6, 2012. We restrict our attention to EPC ratings of B-D, which comprise .715 of the full sample.

B.3 Energy Performance Ratings Example

Figure B4: Suggested Energy Efficiency Improvements 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.

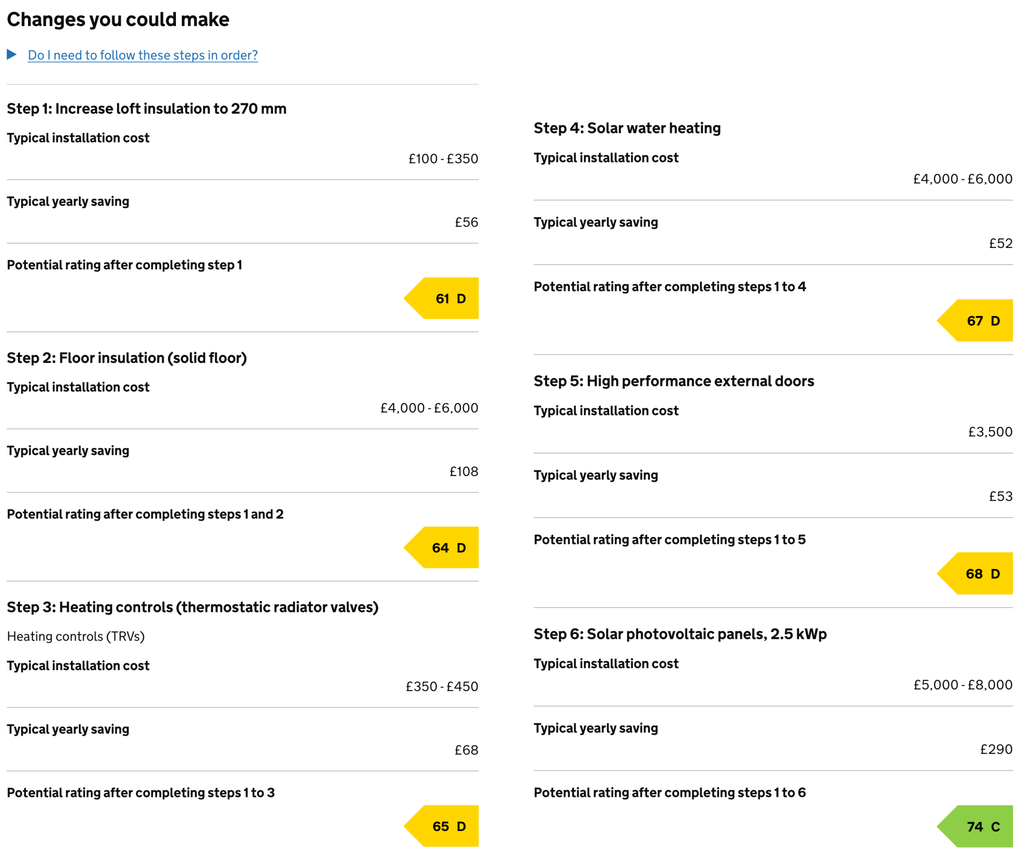
Feature	Description	Rating
Wall	Timber frame, as built, insulated (assumed)	Good
Roof	Pitched, 100 mm loft insulation	Average
Window	Fully double glazed	Average
Main heating	Boiler and radiators, mains gas	Good
Main heating control	Programmer and room thermostat	Average
Hot water	From main system	Good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

B.4 Cost-Benefit Analysis Details

Retrofit Costs In this section, we detail the calculation of the key inputs for our cost-benefit vignette analysis, presented in Table 5. We calculate the retrofit costs as follows. Using data on all EPC inspections for the two years prior to the policy, we sum the cost estimates for all assessor recommendations – if all of these recommendations were implemented, the property would move from the current to the potential energy efficiency score. We then calculate the distance between the property's potential and current energy efficiency score. Dividing the sum of the cost estimates by the energy score gap yields a property-specific estimated cost per additional energy efficiency score. We consider all D-rated and C-rated properties respectively, and calculate a measure for improving the rating of these properties – moving from the current score to the lowest score in the next category.

To elucidate these steps, take the EPC excerpt from a property in South London suburbia, listed in Figure B5 below. The property has an EPC score of 60 – a low scoring D-rated property – and a potential EPC score of 74 – a mid-range score for category C. The energy score gap in this case is 14, and the mid-range cost estimate required to achieve the potential EPC score for the property (which entails making all of the improvements as suggested below) totals £20,625 (minimum estimate:£16,950, maximum estimate: £24,300). This means estimated cost per score improvement for this property is (£20,625 / 14 = £1,473.21). We now calculate the cost of moving to the lowest score of the next rating up – in this case the score is 69, as the example property is currently D-rated. We are now able to calculate our target retrofit measure – moving from the current score to the lowest score in the next category: £1,473.21 × 69-60 = £13,258.93. Finally, we average over all properties within a category to arrive at our final retrofit costs, presented in rows entitled C1 in Table 5.

Figure B5: Suggested Energy Efficiency Improvements from the EPC



Changes you could make

Do I need to follow these steps in order?

Step 1: Increase loft insulation to 270 mm

Typical installation cost: £100 - £350

Typical yearly saving: £56

Potential rating after completing step 1: 61 D

Step 2: Floor insulation (solid floor)

Typical installation cost: £4,000 - £6,000

Typical yearly saving: £108

Potential rating after completing steps 1 and 2: 64 D

Step 3: Heating controls (thermostatic radiator valves)

Heating controls (TRVs)

Typical installation cost: £350 - £450

Typical yearly saving: £68

Potential rating after completing steps 1 to 3: 65 D

Step 4: Solar water heating

Typical installation cost: £4,000 - £6,000

Typical yearly saving: £52

Potential rating after completing steps 1 to 4: 67 D

Step 5: High performance external doors

Typical installation cost: £3,500

Typical yearly saving: £53

Potential rating after completing steps 1 to 5: 68 D

Step 6: Solar photovoltaic panels, 2.5 kWp

Typical installation cost: £5,000 - £8,000

Typical yearly saving: £290

Potential rating after completing steps 1 to 6: 74 C

Reduced Energy Costs and CO_2 Emissions To estimate the impact of increasing an EPC rating on energy costs and carbon emissions, we estimate an equation of the form:

$$y_{pt} = \sum_{k \neq C}^{K} \alpha_k Category_k + X_p^{'} \beta + \sum_{w=1}^{W} \tau_w (Wider\ Neighborhood_w \times time_t) + \pi_{r \times t} + \theta_n + \epsilon_{pt} \ , \quad (9)$$

where y_{pt} is either the total annual energy cost of the building or the annual carbon emission of the property. α_B and α_D are the parameters of interest here, and are used to create the average energy cost reduction or carbon emission reduction of improving an EPC rating by one category. We use these parameters as inputs for rows entitled B1 and B3 in Table 5.

Price Premium on Sale For the premiums on sale for a higher EPC-rated property, we use our baseline DD parameter estimates (β_B and β_D from Equation 4.

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).[25] 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.[26] 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 response to the EPBD 2010.[27]

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,

[25]There 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.

[26]It 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).

[27]Explanatory Note: `https://www.legislation.gov.uk/uksi/2011/2452/made`

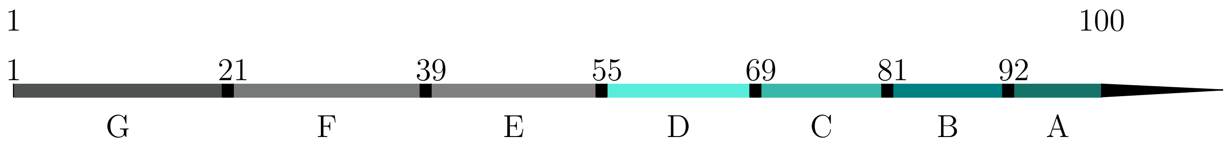


Figure C1: EPC Rating Categories and Underlying Scores

date of inspection, certificate date and serial number, total floor area, as well as recommendations 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.
2008	06 April: All new-built homes require EPC upon completion. 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.
2013	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.
2018	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. 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.[28] 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 find 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.

[28] It 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.

For the entire exercise, we use extremely conservative tolerance levels of 0.98 or more. We 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%.[29]

[29] Chi 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)

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

Dwelling type:	Detached house	**Reference number:**	0919-9628-8430-2785-5996
Date of assessment:	15 August 2011	**Type of assessment:**	RdSAP, existing dwelling
Date of certificate:	13 March 2012	**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

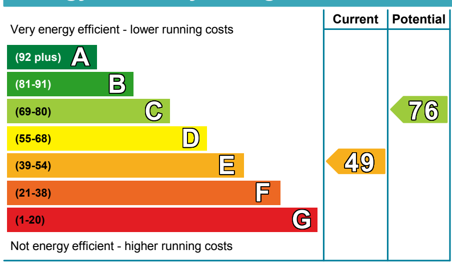
Estimated energy costs of dwelling for 3 years	**£5,367**
Over 3 years you could save	**£2,865**

Estimated energy costs of this home

	Current costs	Potential costs	Potential future savings
Lighting	£375 over 3 years	£207 over 3 years	You could save £2,865 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



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.

Page 1 of 4