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Does energy efficiency predict mortgage performance?

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Benjamin Guin[(1)] and Perttu Korhonen[(2)]

Abstract

We examine a unique micro-level data set on residential mortgages in the United Kingdom. Our analyses suggest that mortgages against energy-efficient properties are less frequently in payment arrears than mortgages against energy-inefficient properties. This result is robust when controlling for other relevant determinants of mortgage default including borrower income and the loan to value ratio of the mortgage. We conclude that energy efficiency is a relevant predictor of mortgage defaults.

Key words: Credit risk, energy efficiency, green mortgages.

JEL classification: G21, Q40.

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1 Introduction

While there is comprehensive evidence that energy efficiency of buildings is capitalized in rental rates and sales prices (Eichholtz et al., 2010, 2013; Fuerst et al., 2015), much less is known about its relevance for mortgage markets. In theory, effective house insulation can increase borrowers' savings on their energy bills. This can protect them from unexpected decreases in income (e.g. reduced overtime payments) or increases in expenses (e.g. health-care costs). Does this imply that mortgages against energy-efficient properties are less credit-risky?

We examine this question using a novel micro-level dataset on the performance of more than 1.8 million outstanding mortgages in the United Kingdom at end-2017. It includes information on whether mortgage payments are past due as well as a measure of the energy efficiency of the properties underlying the mortgage. In addition, it contains information on the income of the borrowers at the time of mortgage origination as well as further property and borrower characteristics.

Our descriptive analyses suggest that about 0.93% of residential mortgages against energy-efficient properties are in payment arrears.[1] This share is 0.21 percentage points lower than the share of mortgages against energy-inefficient properties. Estimating different specifications of a Logistic regression model, we then show that energy efficiency continues to be a relevant predictor of mortgage arrears even after controlling for a rich set of other relevant explanatory variables.

In our analyses, we first control for borrower income at origination to account for the possibility that low-income borrowers are more likely to take out mortgages against energy-inefficient properties. Such borrowers may fall into arrears more frequently. We show that the correlation between energy efficiency and mortgage payment arrears cannot be explained

[1] In the baseline analyses, we focus on any payments which are past due. In robustness tests, we then take into account the severity of these payment shortfalls in terms of time (90 days past due) as well as the outstanding amount

by higher income.

Second, we also control for the loan-to-value (LTV) as property values might reflect differences in energy efficiency and LTV is considered a strong predictor of mortgage arrears. Third, we control for the age of the borrower as well as an indicator for a joint income for the mortgage. In addition, we account for differences in property characteristics (whether the property is newly built as well as the size of the property measured by the number of rooms and the price of the property). Moreover, we control for the year of mortgage origination. This can account for differences in lending standards over time and it might serve as a proxy for the survivorship bias of our cross-section of mortgages still outstanding in 2017 (and not yet defaulted). We interact this year variable with regional fixed effects to ensure that we compare mortgages not only originated in the same year but also in the same region. This also serves as a proxy for different local economic conditions at the time of mortgage origination such as regional unemployment rates. In addition, we include the year of energy efficiency inspection to account for differences in EPC standards which might have changed over time.

In all specifications, the energy efficiency of the property is a statistically significant and an economically meaningful predictor of mortgage payment arrears. After controlling for the year of origination interacted with the region of the property, the difference in payment arrears between mortgages against energy-efficient properties compared to energy-inefficient properties decreases in magnitude by about 0.12 percentage points to 0.11 percentage points. However, it remains statistically significant at the 1 percent level.[2]

This paper contributes to the established literature on the determinants of mortgage arrears (Jones and Sirmans, 2015). This literature argues that both illiquidity and insolvency can trigger default (Elul et al., 2010; Elmer and Seelig, 1999). Consistent with this double trigger framework, it has identified drivers of mortgage distress which include borrower

[2]This suggests that these factors can explain some but not all of the correlation between energy efficiency and mortgages arrears.

income (Foote et al., 2008; Bhutta et al., 2010) as well as the loan to value ratio (LTV) (Lazarov and Hinterschweiger, 2018; McCann, 2014) and measures of negative equity (Aron and Muellbauer, 2016). In addition, the existing literature has identified a number of further predictors of mortgage defaults which include numerical ability (Gerardi et al., 2013) and genetic factors (Xu et al., 2017).

The paper closest to ours comes from Kaza et al. (2015) who find that default and prepayment risks are significantly lower in mortgages against energy-efficient properties in the United States. However, some borrower characteristics which can determine mortgage arrears, such as borrower income, are not available in their dataset. Controlling for these factors is relevant, as higher EPC levels have been shown to be associated with higher income levels (Adalilara et al., 2015). And they have been shown to be reflected in property prices in the United States (Eichholtz et al., 2010, 2013; Kahn and Kok, 2014) as well as in the United Kingdom (Fuerst et al., 2015; Fuerst and McAllister, 2011) and in Australia (Fuerst and Warren-Myers, 2018). We complement Kaza et al. (2015) by showing that the relationship between energy efficiency and mortgage arrears holds in the UK when controlling for a large set of borrower characteristics.[3]

2 Background

In the United Kingdom, Energy Performance Certificates (EPC) provide potential buyers and tenants with an indication of the energy efficiency of a property. In particular, they contain information about the property's typical energy energy costs for heating, lighting, and ventilation less any energy generated from energy generation technology installed in the building (such as solar water heating) (DCLG, 2017). Whenever properties are built, sold, or rented, the owners need to ensure that their properties have EPCs. These EPCs can be obtained by an accredited energy assessor who visits the property to collect the necessary

[3]Besides, the present paper overcomes some further limitations in the paper by Kaza et al. (2015). They mention that the ENERGY STAR certification they examine covers just new homes as well as industrial and commercial buildings. Besides, different states and local governments have different building standards that make this certification more or less accessible.

information. This process of obtaining an EPC costs between GBP 60 and GBP 120 and EPCs are valid on a property for 10 years.[4]

EPCs classify properties into seven categories which range from A (being the most energy efficient) to G (being the least energy efficient). For simplicity, we group these seven categories into three buckets[5]:

- *High energy efficiency* (EPC ratings of A, B or C),
- *Medium energy efficiency* (EPC rating of D),
- *Low energy efficiency* (EPC ratings of E, F or G).

Table 1 displays average annual energy expenses (in GBP) by property type and energy efficiency as measured by EPC buckets. It can be seen that difference in energy costs can be sizeable. For example, the annual energy bill of a highly energy-efficient 2-bedroom flat (GBP 417) is on average GBP 606, or about 59%, lower than for a 2-bedroom flat with low energy efficiency (GBP 1,023). Similarly, the annual energy bill of a highly energy-efficient 4-bedroom house (GBP 695) is on average GBP 1,080, or about 61%, lower than for a 4-bedroom house with low energy efficiency (GBP 1,775).

Table 1: Annual energy costs by type and energy efficiency of the property

	High energy efficiency	Medium energy efficiency	Low energy efficiency
2-bedroom flat	£417	£676	£1,023
3-bedroom house	£578	£891	£1,340
4-bedroom house	£695	£1,130	£1,775

Note: This table shows annual energy costs (in GBP) by type of the property and energy efficiency ratings (EPC). Source: authors' calculations using EPC data.

[4]Source: https://www.gov.uk/buy-sell-your-home/energy-performance-certificates, accessed on 09 July 2019.

[5]We choose this grouping to ensure that the number of properties in each bucket is sufficient for a robust analysis.

3 Data

We obtain data on all EPCs issued since August 2008 from the Ministry of Housing, Communities & Local Government. This dataset covers all domestic properties in England and Wales. And it has been used in the existing literature (Fuerst et al., 2015). In addition to EPC ratings, this dataset also includes other relevant information, such as the year of the EPC inspection and the number of heated rooms. From Table 2, it can be seen that about 23% of all properties are of high energy efficiency (EPC ratings of A, B or C), 49% are of medium energy efficiency (EPC rating of D) and about 29% are of low energy efficiency (EPC ratings of D, E or F). In addition, EPCs provide a continuous measure of energy efficiency underlying the discrete EPC ratings ranging from A to G. It ranges from 0 to 100. To interpret our regression results more easily, we rescaled this original range by 100 such that our variable, *Energy efficiency (cont.)*, ranges from 0 to 1. Table 2 shows that the average value is 0.59 (or 59 in original values).[6]

We complement this dataset with information on mortgages which we obtain from the FCA's Product Sales Database (PSD). This database has been used in the existing academic literature (Cloyne et al., 2019; Benetton et al., 2018). It contains all owner-occupied mortgages originated by regulated firms since 2005 in the United Kingdom. It includes specific information on whether a mortgage is in payment arrears. Table 2 suggests that about 1.0% of all mortgages are in arrears in 2017. In addition to the arrears status, the dataset covers a wide array of mortgage characteristics (such as loan amount and lender name) and property characteristics (such as the property price). Most importantly, it includes information on borrower characteristics such as income at origination and borrower age. Table 2 shows that average gross income is about 55k GBP. The main borrower was on average 37 years old at the time of the mortgage application.

Lastly, we match both datasets with detailed property transaction prices that are sourced from the HM Land Registry website. This dataset contains information on residential prop-

[6] A table displaying the definitions of all variables can be found in Table A1 in the Appendix.

erty sales in England and Wales from 1995. And it also has been widely used for research purposes (Fuerst et al., 2015; Bracke, 2015). Our final sample consists of over 1.8 million mortgages originated in the time period 2008 to end-2017.

Table 2: Summary statistics

	Mean	St.Dev.	Min	Max	Observations
Mortgage performance					
Arrears	0.0103	0.1008	0	1	1,833,653
Property characteristics					
High energy efficiency	0.2251	0.4176	0	1	1,833,653
Medium energy efficiency	0.4875	0.4998	0	1	1,833,653
Low energy efficiency	0.2874	0.4526	0	1	1,833,653
Energy efficiency (cont.)	0.5923	0.1236	0	1	1,833,638
Main control variables					
Gross income	0.5480	0.3681	0	2	1,826,399
LTV	0.8136	0.3650	0	7	1,833,653
Age of borrower	36.6788	9.4655	17	95	1,833,653

Note: This table shows the summary statistics of the variables displayed in the regression tables. The summary statistics of property control variables, contract control variables, origination year control variables and EPC inspection year control variables are available upon request.

4 Methodology

In order to examine the the relationship between the energy efficiency of a property and payment arrears of a mortgage borrower, we estimate the following Logistic model using a maximum likelihood estimation method.

$$Arrears_i = f(\alpha + \beta_1 High\ energy\ efficiency_i + \beta_2 Medium\ energy\ efficiency_i + X_i' \beta_3) + \epsilon_i$$

where:

- $Arrears_i$ is a dummy variable indicating whether mortgage i in payment arrears at year-end 2017.
- $High\ energy\ efficiency_i$ is a dummy variable indicating whether the property underlying mortgage i has an EPC rating of A, B or C.
- $Medium\ energy\ efficiency_i$ is a dummy variable indicating whether the property underlying mortgage i has an EPC rating of D.
- X_i indicates a vector of loan-to-value (LTV), gross household income (in 100,000 GBP)[7], the age of borrower in 100 years and an indicator of whether there are two, joint income sources. In refined specifications, we also include property characteristics (whether the property is newly built, the size of the property measured by the number of rooms as well as the property price). Moreover, we control for the year of mortgage origination which we interact this with regional fixed effects. Last, we include the year of EPC inspection.

Our regression tables present the point estimates of *High energy efficiency* and *Medium energy efficiency* which one can interpret as marginal effects relative to the baseline category *Low energy efficiency* which is omitted. And we calculate heteroscedasticity robust standard errors by clustering on the regional level.

[7] Household income is winsorized at the 99 percentile to account for outliers.

5 Results

Table 3 shows simple univariate comparisons. It suggests that about 0.93% of residential mortgages against highly energy-efficient properties are in payment arrears (column (1)). This share is 0.07 percentage points, or 7%, lower than the share of mortgages in payment arrears against properties whose energy efficiency falls into the medium bucket, which is 1.00% (column (2)). This share is 0.21 percentage points, or about 18%, lower than the share of mortgages in payment arrears against low energy-efficient properties, which is 1.14% (column (3)). Both differences are statistically significant at the 1 percent level.

Table 3: Share of mortgages in payment arrears by energy efficiency of the property

Energy efficiency	High (1)	Medium (2)	Low (3)	Difference (1)-(2)	Difference (1)-(3)
Arrears	0.0093	0.0100	0.0114	-0.0007***	-0.0021***
	(N=412,704)	(N=893,913)	(N=527,026)	(N=1,306,627)	(N=939,730)

Note: This table shows the share of mortgages in payment arrears in end-2017, Arrears, by energy efficiency ratings (EPC) of the underlying property (in columns (1)-(3)). Arrears is a discrete variable that equals 1 if the mortgage is in payment arrears; 0 otherwise. Columns (4)-(5) test the mean differences. N indicates the number of mortgages. ***, **, * denote statistical significance at the 0.01, 0.05 and 0.10 level respectively.

Two mechanisms could be driving this difference. On the one hand, energy bills are lower for energy-efficient properties. Savings on energy bills could lead to lower arrears rates ("energy savings effect"). Alternatively, high-income borrowers could be more likely to take out mortgages against energy-efficient properties. Such borrowers may fall into arrears less frequently ("income selection effect"). To examine the relevance of the "income selection effect", we compare mortgage arrears of borrowers with similar income. Practically, we control for borrower income at origination in our Logistic regression model.

Table 4 presents these results. Column (1) replicates the univariate results not controlling for further characteristics in a multivariate Logit model outlined above.[8] In column (2),

[8]Slight differences in point estimates come from the non-linear nature of this model. We present marginal

we control for borrower income (measured in 100,000 GBP), the age of the main borrower (in 100 years) and the loan-to-value ratio, LTV, of the mortgage. In addition, we control for an indicator of whether the there are two joint income sources. The difference in payment arrears of mortgages against energy-efficient properties compared to mortgages against energy-inefficient properties remains qualitatively similar. We conclude that the "income selection effect" does not explain lower mortgage arrears for mortgages against energy-efficient properties.

In additional specifications, we then control for further relevant explanatory variables. In column (3), we include the loan amount and the property price as separate variables in the Logistic regression model. We also control for property characteristics (whether the property is newly built and the number of rooms) as well as regional fixed effects interacted with the year of the loan origination. The latter ensure that we compare mortgage borrowers in the same region at a specific point in time. The estimated effect of *High energy efficiency* on payment arrears decreases in magnitude to 0.11 percentage points (column (3)). It remains statistically significant at the 1 percent level. This suggests that these factors can explain some but not all of the correlation between energy efficiency and mortgages arrears.

In column (4), we control for the year of the EPC inspection to account for differences in EPC standards over time. The difference in payment arrears between mortgages against energy-efficient properties compared to energy-inefficient properties decreases in magnitude to 0.10 percentage points (column (4)). It remains statistically significant at the 1 percent level. This suggests that also differences in EPC standards over time do not explain the correlation between energy efficiency and mortgages arrears.

To verify these results, we run a battery of robustness tests. In particular, we examine the effects of a continuous EPC variable, *Energy efficiency (cont.)*, underlying the discrete EPC ratings ranging from A to G. The values of this continuous variable range from 0 to

effects.

Table 4: Mortgage payment arrears and energy efficiency (multivariate analyses)

	Arrears (1)	Arrears (2)	Arrears (3)	Arrears (4)
Energy efficiency				
High energy efficiency	-0.0023***	-0.0027***	-0.0011***	-0.0010***
	(0.0005)	(0.0003)	(0.0003)	(0.0003)
Medium energy efficiency	-0.0015***	-0.0018***	-0.0005***	-0.0005**
	(0.0003)	(0.0002)	(0.0002)	(0.0002)
Main control variables				
Gross income		0.0003	-0.0005	-0.0006
		(0.0011)	(0.0006)	(0.0005)
LTV		-0.0024***	0.0032***	0.0032***
		(0.0006)	(0.0003)	(0.0003)
Age of borrower		0.0017	0.0036*	0.0036*
		(0.0034)	(0.0022)	(0.0022)
Borrower control variables	No	Yes	Yes	Yes
Property control variables	No	No	Yes	Yes
Regional x origination year FE	No	No	Yes	Yes
Inspection year FE	No	No	No	Yes
Observations	1,833,653	1,826,399	1,826,162	1,826,117
Pseudo R2	0.0005	0.0086	0.0445	0.0446
Mean of dep. variable	0.0103	0.0103	0.0103	0.0103

Note: This table shows marginal effects of logistic regression model estimated using maximum likelihood (ML) with the propensity of payment arrears, Arrears, as the dependent variable. Arrears is a discrete variable that equals 1 if the mortgage is in payment arrears; 0 otherwise. The main explanatory variables are indicators of the energy efficiency of the properties, High energy efficiency and Medium energy efficiency. Columns (2)-(4) include variables for the gross income, loan-to-value, age of the borrower and an indicator for joint income. Columns (3)-(4) include property control variables (new building, number of rooms, price). Besides, they include regional fixed effects interacted with mortgage origination year fixed effects. Column (4) include EPC inspection year control variables. The sample includes mortgages in 2017 H2. Observations are at the mortgage level. Standard errors are clustered on the postcode region level. ***, **, * denote statistical significance at the 0.01, 0.05 and 0.10 level respectively.

1.[9] Table A2 in the Appendix shows the corresponding results. The estimated coefficient for *Energy efficiency (cont.)* is negative and highly statistically significant at the 1 percent level. In terms of economic magnitudes, increasing energy efficiency from the minimum (0) to the maximum (1) is associated with a 0.8 percentage point, or about 80%, decrease in payment arrears (column (1)). Controlling for our set of variables, the point estimates slighly decreases to about 0.5 percentage point (columns (3)-(4)).

We run a set of unreported robustness checks. First, we use this continuous EPC variable to create alternative binary EPC buckets. Second, we run a robustness test in which we control for the natural logarithm of gross income instead of the level of gross income. We also examine the robustness of these baseline results by taking into account two measures of severity of mortgage arrears.[10] In unreported robustness tests, we first change the threshold to payments being at least one month, two months and three months past due. We then change the threshold to payments to at least 1.5% of the outstanding balance, 5% of the outstanding balance and 7.5% of the outstanding balance. Both set of results suggest that the point estimates of *High energy efficiency* becomes smaller in magnitude and statistical significance with a non-result using the most material definitions. This suggests that payment arrears associated with energy-efficiency are of temporary and less material nature.

6 Conclusion

Overall, these results suggest that mortgages against energy-efficient properties are less frequently in payment arrears. Mortgage borrowers' income at origination cannot explain this difference. However, the dates of mortgage origination and EPC inspection do explain some but not all of this correlation. We conclude that the energy efficiency of a property is a relevant predictor of mortgage payment arrears.

[9]To interpret our regression results more easily, we rescaled the original range from 0 to 100 by 100 such that this variable ranges from 0 to 1.

[10]In our sample, only 0.05% of outstanding mortgages are repossessed. The low number of repossessed mortgages does not allow us to conduct a meaningful analysis on repossessions.

Does this imply that there is a causal relationship between higher energy efficiency and lower mortgage payment arrears? Not necessarily. In fact, there is a set of factors which we do not control for. For example, mortgage borrowers with different levels of financial literacy, risk aversion or time preferences might be more or less inclined to buy energy-efficient properties. At the same time, these individuals might display different arrears rates - for example as they might choose riskier mortgage contracts. Further research is needed to examine the exact channel of the relationship.

However, our result might become relevant for credit risk modeling done by lenders. The financial regulator in the UK, the Prudential Regulation Authority, does not prescribe the input variables to firms' probability of default (PD) models (PRA, 2016, 2017). Industry practice differs widely across firms which result in various risk weights of mortgage exposures (BCBS, 2016). In our analyses, we control for many of the typical input factors, such as LTV and income. However, energy efficiency is typically not considered in most PD models for residential mortgage exposures. Hence, our results suggest that the energy efficiency of a property could be factor in PD models. In addition, it might become a relevant factor for risk-adjusted pricing of mortgages.

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Table A1: Variable definitions

Variable name	Definition	Source
Mortgage performance		
Arrears	Indicator of whether the mortgage is in payment arrears (0 or 1).	PSD
Property characteristics		
High energy efficiency	Indicator of whether the property has an energy efficiency rating of A, B or C.	EPC
Medium energy efficiency	Indicator of whether the property has an energy efficiency rating of D.	EPC
Low energy efficiency	Indicator of whether the property has an energy efficiency rating of E, F or G.	EPC
Energy efficiency (cont.)	Continuous energy efficiency measure between 0 and 1.	EPC
Borrower characteristics		
Gross income	Gross household income at mortgage origination (in 100,000 GBP).	PSD
LTV	Loan-to-value ratio at mortgage origination (between 0 and 1).	PSD
Age of borrower	Age of the borrower (in 100 years).	PSD

Note: This table shows the definition of variables displayed in the regression tables. The definition of property control variables, contract control variables, origination year control variables and EPC inspection year control variables are available upon request.

Table A2: Mortgage payment arrears and energy efficiency (continuous EPC)

	Arrears (1)	Arrears (2)	Arrears (3)	Arrears (4)
Energy efficiency				
Energy efficiency (cont.)	-0.0076***	-0.0087***	-0.0046***	-0.0046***
	(0.0011)	(0.0006)	(0.0009)	(0.0009)
Main control variables				
Gross income		0.0003	-0.0007	-0.0007
		(0.0010)	(0.0007)	(0.0007)
LTV		-0.0022***	0.0039***	0.0039***
		(0.0006)	(0.0003)	(0.0004)
Age of borrower		0.0014	0.0043	0.0043
		(0.0032)	(0.0027)	(0.0027)
Borrower control variables	No	Yes	Yes	Yes
Property control variables	No	No	Yes	Yes
Regional x origination year FE	No	No	Yes	Yes
Inspection year FE	No	No	No	Yes
Observations	1,833,638	1,826,384	1,826,147	1,826,102
Pseudo R2	0.0008	0.0090	0.0446	0.0447
Mean of dep. variable	0.0103	0.0103	0.0103	0.0103

Note: This table shows marginal effects of logistic regression model estimated using maximum likelihood (ML) with the propensity of payment arrears, Arrears, as the dependent variable. Arrears is a discrete variable that equals 1 if the mortgage is in payment arrears; 0 otherwise. The main explanatory variables is a continuous measure of energy efficiency, Energy efficiency (cont.). Columns (2)-(4) include variables for the gross income, loan-to-value, age of the borrower and an indicator for joint income. Columns (3)-(4) include property control variables (new building, number of rooms, price). Besides, they include regional fixed effects interacted with mortgage origination year fixed effects. Column (4) include EPC inspection year control variables. The sample includes mortgages in 2017 H2. Observations are at the mortgage level. Standard errors are clustered on the postcode region level. ***, **, * denote statistical significance at the 0.01, 0.05 and 0.10 level respectively.