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Investigating the impact of housing price increases on consumption: heterogeneity by age, tenure and housing quality

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Abstract

Purpose – The purpose of this paper is to understand the distributional impact of house price increases on consumption in the context of the energy transition.

Design/methodology/approach – This study draws from two micro cross-sectional datasets, the English Housing Survey (EHS) and the Living Costs and Food Survey (LCFS) to study the Marginal Propensity to Consume (MPC) out of changes in house prices. By employing pseudo-panel regressions, the paper examines the impact of house price changes on consumption among diverse household types.

Findings – This paper finds varying consumption responses to house price changes across age and tenure groups. Older homeowners tend to increase consumption when house prices rise. In contrast, middle-aged individuals, often renters or mortgage holders, reduce consumption in response to price increases. The youngest age group also experiences increased consumption but to a lesser degree than the oldest group. Energy-efficient homes are related to lower consumption across all tenure levels. However, when interacted with house prices and age, the estimates are positive, pointing to an unequal accrual of property premiums depending on housing market positions.

Research limitations/implications – The main limitations stem from data constraints. First, using a pseudo-panel approach hinders control for unobservable selection bias. Additionally, while robust under cross-validation and specifications tests, the energy efficiency variable imputation results in a low number of energy-efficient homes. Due to heterogeneous responses to rising house prices, this paper contends that an energy transition model that subsidises homeowners' renovation is likely to produce a negative impact on consumption among younger and middle-aged households.

Originality/value – This paper contributes to the MPC literature by incorporating energy efficiency as a key variable. It draws from recent data to obtain new estimates. By highlighting shifts in consumption patterns the paper contributes to a well-established body of literature with renewed policy relevance regarding housing retrofit.

Keywords MPC, Consumption, House prices, Age groups, Energy efficiency

Paper type Research paper

1. Introduction

In 2019, the UK committed to achieving net-zero CO_2 emissions by 2050, with housing decarbonisation, accounting for 19% of all emissions, playing a pivotal role in its strategy

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(BEIS, 2019a, b, 2020). A key policy proposal is the enhancement of Energy Performance Certificates (EPCs), a measure of energy consumption, from an average rating of D to C by 2035 (ONS, 2020). This improvement is projected to require an investment of £35–£65bn in housing retrofit, with at least £1bn per year expected to come from public grants (BEIS, 2019a, b). The financial feasibility of these renovations depends on two factors: the ability of energy savings to offset retrofit costs and the capitalisation of these savings in house prices, known as the energy efficiency premium.

The academic literature has increasingly focused on property premiums arising from energy efficiency improvements, using hedonic pricing models as proposed by Rosen (1974). These models view housing as a heterogeneous good with individual characteristics that can be priced separately. Over the past decade, Rosen's model has been extensively applied to EPCs, with studies in the UK, the Netherlands, Spain, and Sweden all reporting a positive impact of energy efficiency on house prices (Fuerst *et al.*, 2015; Brounen and Kok, 2011; Ayala *et al.*, 2016; Cerin *et al.*, 2014). A comprehensive meta-analysis by Wilkinson and Sayce (2020) confirms this trend, although the magnitude of the premiums varies by country and building type.

However, the literature also reveals a discrepancy between theoretical performance, as stated in the EPC, and actual energy consumption. Sunikka-Blank and Galvin (2012) propose the existence of pre and re-bound effects, where energy consumption in inefficient dwellings is lower than expected, and consumption in energy-efficient dwellings is higher. This disparity has also been observed in the Netherlands, with Brom *et al.* (2019) finding that post-renovation energy savings are dependent on household composition among other variables. Recent behavioural approaches have considered the risks of uncertain energy savings related to investment recoup from renovation in homeowner decision-making (Ebrahimigharehbaghi *et al.*, 2022). However, the distributional impacts of these type of built fabric interventions have only recently started to be explicitly explored. McCoy and Kotsch (2021) draw from a large dataset of energy consumption pre and post-renovation to study heterogeneity in energy savings in the UK They focus on household deprivation and the type of built-fabric intervention to show that investments targeting less well-off households may in fact be ineffective in reducing energy use.

The granularity and distributional impacts of micro-level studies contrast with macro-level research, which has underscored the positive impact of large-scale housing retrofit. National housing renovation strategies are anticipated to stimulate GDP growth by fostering increased public and private investment, thereby creating jobs with low-entry requirements in the construction sector, as exemplified by the Spanish case (Santiago-Rodriguez, 2021). At a macro level, Environmental-Energy-Economic models have proven instrumental in analysing the interplay between energy production and the economy (Cazcarro *et al.*, 2022). However, these models often lack micro-foundations. When such foundations are present, they tend to focus more on accounting for issues of built fabric and energy savings heterogeneity rather than household characteristics (Fotiou *et al.*, 2019, 2022).

The renovation of the housing stock is set to occur in a context of escalating property values, which have only been slightly offset by a minor reduction in prices over the past year. This paper draws from the economic literature on housing price shocks to contextualise energy efficiency improvements within the literature on household consumption. The capacity of house price increases to influence consumption has been a significant area of economic investigation. Micro studies utilising panel data (Suari-Andreu, 2021), pseudo panel (Campbell and Cocco, 2007), and macro time-series (Aoki *et al.*, 2004) have yielded widely varying estimates across tenure (Berger *et al.*, 2018) and age groups (Li and Yao, 2007). Building on this literature, this paper explores the question, "How do house prices affect household consumption across age, tenure, and energy efficiency standards?" The paper's primary focus is analysing the relationship between the Marginal Propensity to Consume (MPC) and fluctuations in house prices. To this end, this study delves into the interplay between household age, building quality, tenure, and MPC. The analysis is centred around two main aspects. Firstly, whether older cohorts, who are more likely to own their homes outright and have larger amounts of equity, exhibit a larger MPC out of house price shocks. Second, the role of building quality in mediating this relationship between household age, tenure and house prices. This analysis leverages a combination of two micro cross-sectional datasets: the English Housing Survey (EHS), which provides data on the housing stock and its inhabitants, and the Living Costs and Food Survey (LCFS), which offers detailed consumption and financial information.

The remainder of this paper is organised as follows: section two reviews the literature on MPC and housing price shocks, along with the main empirical and methodological divergences. Section three discusses the data background and the predictive modelling of energy efficiency ratings, combining EHS and LCFS datasets. Section four proposes a series of models to estimate MPC out of changes in house prices. Section five discusses the findings and shortcomings of the approach at hand. Section six addresses the policy implications of retrofit funding models, and section seven concludes.

2. Literature review

The link between house prices and consumption has been a focus of economic research particularly since the 1980s as cycles of housing booms and busts have become a prevalent phenomenon across Europe and the US. This section focuses first on the different channels through which house prices affect consumption and then discusses the wide range of estimates and methodological divergencies in the study of MPC.

On the one hand, the Permanent Income Hypothesis (PIH), predicts that consumption reactions to house price fluctuations should be small as these are offset by future implicit rental costs for a majority of households that are "short" in housing leaving budget constraints unchanged. Sinai and Souleles (2005) tested this assumption empirically with US micro-data and found that the probability of ownership increases with rent risk and the net risk of owning declines as the expected horizon of ownership rises. Following the PIH, in the UK, Campbell and Cocco (2007) find a larger consumption response to increases in house prices among households that are "long" in housing, that is older households with higher equity. On the contrary, for households that are not credit constrained these changes in value have no impact on consumption. Buiter (2008) explores the absence of a "pure-wealth" channel due to a fundamental change in house prices through a representative-agent model with overlapping generations. In this model, "speculative" changes do produce changes in consumption. As a result, the observed housing wealth effect must be a result of redistribution effects between long and short housing or the collateralisability of housing wealth.

Macro evidence points to the collateralisability of housing wealth as one of the financial channels of monetary policy transmission. Case *et al.* (2001) find a strong correlation between aggregated house prices and consumption using national data for 14 countries and regional data in the US. However, the multiple nature of housing as an asset, consumption good, collateral and heirloom complicates this correlation making it difficult to establish causality. Aoki *et al.* (2004) explore this correlation through an adaptation of the financial accelerator model of Bernanke *et al.* (1999) and propose that it arises from the interconnectedness of households balance sheets and housing markets resulting in lower borrowing constrains when house prices rise. Carroll *et al.* (2006) question the causal relationship between house prices and consumption and cast doubt over whether the relationship between aggregates may reflect omitted variables bias. Muellbauer *et al.* (1990)

also draw from macro data to relate the UK consumer boom in the late 1980s to rising house prices recommending a reduction in homeownership subsidies to curve the imbalances in the national balance of payments. Contrarily, King (1990), in a discussion of the previous article, argues that higher future income expectations were the common driver of both consumption and house prices.

Following Buiter (2008), the distributional impact of housing prices only arises under heterogeneous agents with different distributions of housing wealth and debt. The heterogeneity in consumption responses to house prices has also become a central topic in heterogeneous agent models (HAM) usually employed in macro analysis. For example, Kaplan *et al.* (2017) model movements in house prices to account for approximately half of volatility in non-durable expenditures. The construction of models with heterogeneous agents has opened up the possibility of accounting for varying asset distributions across household groups. For example, Cloyne *et al.* (2016) emphasised the differences in balance sheets that provoke differentiated responses to consumption across tenure groups, particularly outright owners and mortgagors. Bielecki *et al.* (2022) focus on the role of maturing assets, instead of balance sheets, in their study of the redistributive effects of monetary policy. However, their research does show that house price appreciation has in fact negative welfare effects over a majority of the population. Huo and Ríos-Rull (2016) contextualise the potential of balance sheets oscillation in consumption within the Great Recession and point to the limited capacity of households to acquire loans having been amplified by contractions in house prices.

These divergent views of the relationship between housing wealth and consumption are rooted not only in different theoretical views but also in different data sources and the use of different methodologies. While macroeconomists using time-series data find a strong correlation between house prices and consumption, the study of micro, household-level, datasets shows a more nuanced picture that challenges a straightforward causal relationship. Using UK micro data, Attanasio and Weber (1994) find that homeowners experiencing capital gains on their households do increase consumption with mortgagors increasing their consumption even further. Nevertheless, this is insufficient to explain the rise in consumption among younger households that they simulate as the result of an upward revision of permanent income that can result in a decline in aggregate saving rates.

Attanasio *et al.* (2011) confirm these findings in a further developed life-cycle model including uncertain processes for house prices and earnings. Li and Yao (2007) also use a life-cycle model with detailed mortgage market to investigate how, although aggregate levels of welfare and consumption show little variation to attributable to house prices, the effects on individual households are more diverse. Their conclusions are coherent with Attanasio *et al.* (2011) and point to older homeowners benefiting more from housing appreciation. However, Attanasio *et al.* (2009) contradict the wealth channel, in opposition to Campbell and Cocco (2007) and find that it is in fact consumption among younger households that is related to rising housing prices and the macro correlation is a result of common causality. The approaches of these two papers are similar and rely on constructing pseudo-panel data after a series of cross-sections from the Family and Expenditure Survey (FES) [1]. However, the treatment of the data is different as Campbell and Cocco (2007) deflate current household expenditures and control for income.

More recently, the use of alternative identification strategies and panel data that detail the channels of this wealth effect have offered different results. Guren *et al.* (2018) use systematic differences in city-level exposure to house price dynamics as an instrument and find more nuanced MPCs of about 3% during the 1980s for the US. Also, at a geographic scale, county-level, Mian *et al.* (2013) use credit card data to estimate one of the largest reductions in consumption resulting from declines in house prices, 0.6 to 0.8. While their model uncovers the distributional impact of the 2008 crisis, it does not isolate the role of house prices as it also includes non-tradeable labour income related to construction.

Browning *et al.* (2013), using a large panel dataset from Denmark, differ from prior papers in their exploration of unanticipated house price shocks. It follows from PIH that it is only those price shocks that alter lifetime wealth expectations that would have an impact on consumption. To assess this, Browning *et al.* (2013) test for a unit root in house price processes and find that persistent house prices are stationary precluding large wealth effects and the subsequent impact on consumption. Their findings highlight the expenditure growth among credit-constrained households but fail to find evidence that older homeowners' consumption reacts to house price changes. The authors of this paper point to the use of panel data instead of pseudo-panel in the consistency of their results. Also using panel data for the UK merged with financial data Disney *et al.* (2010), find a very low, 0.01, Marginal Propensity to Consume (MPC) out of unanticipated shocks in house prices. This literature points to three main reasons for a negligible wealth effect: few households liquidating housing wealth, perception of non-permanent shocks and bequests motives. Engelhardt (1996) observes a 0.03 MPC and highlights the asymmetry between households experiencing losses that offsets those experiencing gains. Suari-Andreu (2021) challenges this evidence, while his results also show indistinguishable from zero coefficients for a pure wealth effect using panel data, he does not find evidence of asymmetry among Dutch households for the period 2004 to 2018 characterised by both declines and rises in house prices.

However, drawing also from panel data, Berger *et al.* (2018) find a relevant counterpoint to this literature using a model of incomplete markets for the US case. After finding an elasticity of consumption of 0.33, they follow the sufficient statistics approach (Chetty, 2009) to derive a formula that approximates consumption responses to permanent house price shocks as the marginal propensity to consume out of temporary income times the value of housing. The formula breaks down when households are underwater. According to Berger *et al.* (2018), this points to a time-varying elasticity that is heterogeneous among households. Paiella and Pistaferri (2017) contend that the difference lies between anticipated and unanticipated shocks. To explore this issue they combine Italian data on subjective expectations on asset returns and return realisation to distinguish between anticipated and unanticipated changes in wealth and find evidence of a small 0.03 wealth effect. In a recent paper, Caloia and Mastrogiacomo (2022) draw from this approach to investigate whether disregarding home improvement biases the MPC out of housing wealth. While the bias is zero since the small home improvements found do not alter home values, their analysis shows a reduction in savings of 0.027 for the Netherlands and 0.03 for Italy after unexpected changes in housing wealth. This paper is particularly apposite as it points to a lack of improvements and maintenance being value preserving with little evidence of home investments out of housing wealth.

3. Approach and data

Building upon the previous section, this paper examines the relationship between MPC and house prices resulting from varying positions in the housing market. It explores the relation between household age and MPC in the context of rising house prices. According to the Permanent Income Hypothesis (PIH), this reaction can be attributed to younger generations, who are short in housing, reducing non-housing consumption in line with their future housing costs in response to price increases. In contrast, older households with larger equity proportions, long in housing, are expected to boost their consumption. Furthermore, this paper suggests examining energy efficiency in a similar light. Firstly, households in high energy-efficient dwellings would face increased housing costs to decrease energy expenses, either through retrofit or green premiums at purchase. A positive balance between these two expenditures would enable an increase in non-housing consumption, while a negative balance would lead to a reduction. Secondly, the interaction between energy efficiency and house prices could mutually reinforce each other. Households that are long in housing and live in energy-efficient homes would be expected to further increase their consumption when house prices rise, as they would not anticipate an increase in their future implicit housing costs. Conversely, younger households would counterbalance their energy efficiency premium against future housing costs.

In the UK, the lack of easily accessible longitudinal or administrative data at the household level complicates the study of the links between consumption and the built environment. To overcome this issue, this paper draws from a series of waves of two cross-sectional datasets collected through different surveys between 2009 and 2019. First, the English Housing Survey (EHS) gathers data on household characteristics and physical conditions, including energy efficiency. The EHS is a continuous national survey commissioned by the Department of Levelling Up, Housing and Communities. The survey has been running since 1967 and the latest available dataset, 2019, is accessible through the UK data service (MHCLG, 2021). Second, the Living Costs and Food Survey (LCFS), conducted across the UK, is the most relevant survey dealing with household spending and focussing on how the cost of living is reflected in household budgets. Although under different names, this survey has been running since 1957 and the latest available release at the time of writing, 2019, is accessible through the UK data service (ONS, 2022).

The main indicator of energy efficiency in the built environment are Energy Performance Certificates (EPCs). These were introduced in 2002 at EU level by the Energy Performance of Buildings Directive (EPBD). In the UK, EPCs were incorporated into national legislation in 2007 and progressively included as a mandatory requirement for the purchase and renting of real estate. To account for the gradual introduction of EPCs, this paper focuses on data from 2009 onwards, that is five waves of the EHS (77,798 observations), which is released biennially, and five waves of the LCFS (41,648 observations) [2], released annually. These two surveys share a number of fields referring to inhabitants' household size, housing typology, tenure, rent, mortgage, household income, educational attainment, gas heating, and reference person's age. These common variables allow the prediction of Energy Efficiency for LCFS observations using the EHS. For example, Bridgeman (2020) conducts for a merger of these two surveys through a random forest to create clusters of energy consumption profiles.

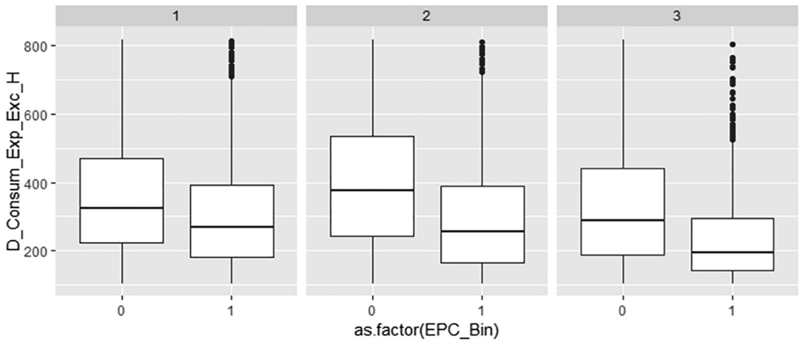
This paper uses a simplified version of this approach predicting Energy Efficiency in binary terms instead of a whole range of ordinal levels, see Table 1 for reference [3]. The prediction builds on a logistic binary model, see Appendix 1 for detail, using 80% of the EHS data for "training" and 20% for prediction testing, achieving an accuracy of 76%, see Appendix 1 for full regression and robustness checks. The cutting point on the binary prediction was 0.3, this threshold, lower than 0.5, did not compromise accuracy which points to an underprediction of Energy Efficiency. The final LCFS dataset included 38,753 non-energy-efficient households and 2,895 Energy-Efficient ones. The reduced numbers of energy-efficient homes points to issues of representativeness which could be related to the LCFS is not being designed to be representative of the overall housing stock. Ultimately, there seems to be a correlation between higher energy efficiency and lower overall consumption.

Table 1.
Energy efficiency rating explanation

EHS value	EPC	Efficiency	EPC binary
2	A/B	Most Efficient	1
3	C		1
4	D		0
5	E		0
6	F		0
7	G	Least Efficient	0

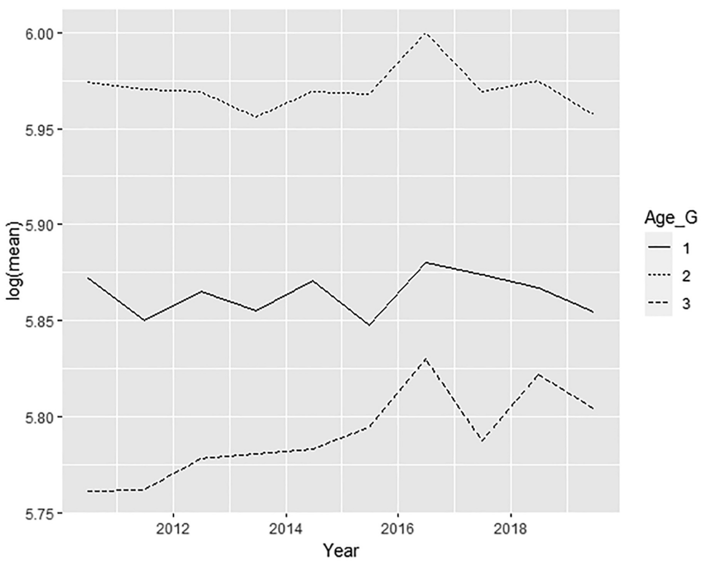
Boxplots in Figure 1 show average non-housing consumption by age group subdivided by habitation in an energy-efficient house. Those in energy-efficient homes display lower consumption than those in not energy-efficient ones across all tenures and age groups.

Following Attanasio *et al.* (2009) (from now on ABHL), non-housing consumption has been calculated by extracting housing costs, inclusive of energy, from total consumption and expressed in 2019 real prices using the Retail Price Index. LCFS microdata allows grouping consumption trends across three age groups, younger, under 35 years of age; middle–aged, 35–60 years; and older, above 60 years. Figure 2 shows that the upward trend in non-housing consumption seems to be only present in older households following the bouncing back of the real estate market post-2008. This contrasts with flat consumption in the two younger age groups, despite overall average consumption being lower for the oldest group. Older



Source(s): Prepared by the author

Figure 1. Real non-housing consumption in 2019 prices by age group (1, under 35; 2, 35–60; 3,65 or more) and EPC status (1, energy-efficient; 0 not energy-efficient)



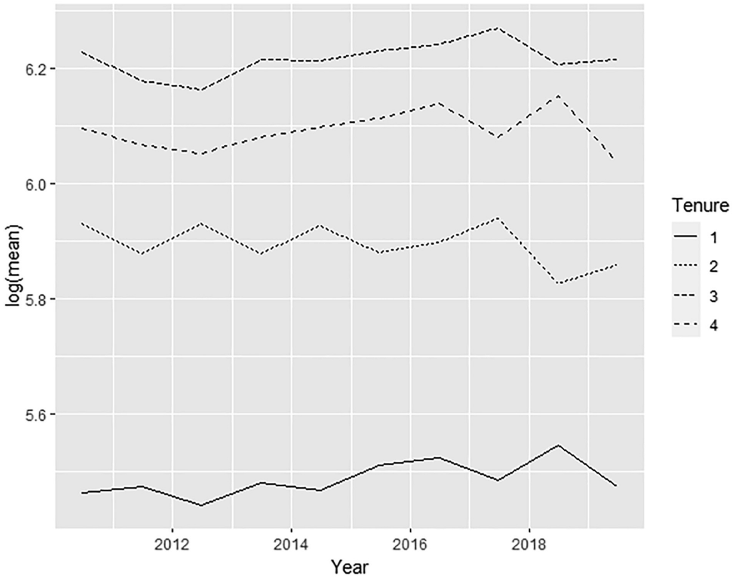
Note(s): 1, Under 35; 2, 35–60; 3,65 or more

Source(s): Prepare by the author

Figure 2. Time series log real non-housing consumption in 2019 prices by age group

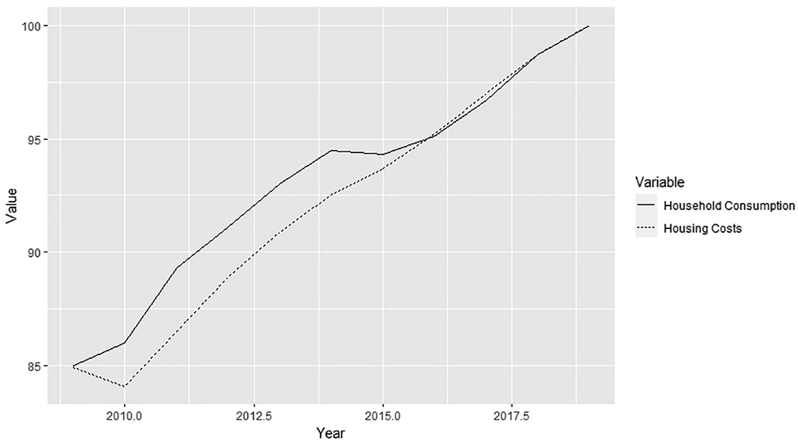
households' consumption also seems to correlate more strongly with stagnation in house prices in the last years of the 2010s. These trends seem to be replicated along tenure lines (see Figure 3), with owners outright and mortgagors displaying an apparent wealth effect, an increase in consumption in line with house prices; while private and social renters' non-housing consumption is not affected by house prices.

Figures 4 and 5, present the aggregate indicators of consumption, housing costs and house prices since 2009. In aggregate terms, consumption and house prices seem to move together,



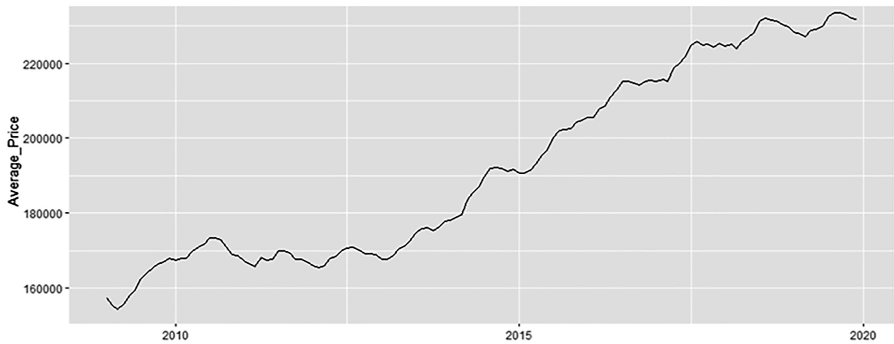
Note(s): 1, social renter; 2, private renter; 3, owner with a mortgage; 4 owner outright
Source(s): Prepared by the author

Figure 3.
Time series log deflated non-housing consumption by tenure



Note(s): 100 = 2019
Source(s): ONS National Accounts. Prepared by the author

Figure 4.
Time series consumption and housing consumption



Source(s): HM Land Registry. Prepared by the author

Figure 5.
Time series average house prices

however, household consumption seems to have stagnated in 2014 to recover its path in 2016 while housing costs have continued on the same path even above overall consumption from 2016 to 2018. The goal of this paper is to analyse where these increases in aggregate consumption have accrued at the micro level, particularly after the subtraction of housing costs and attending to differences by age group, tenure and energy efficiency.

Following ABHL, a number of variables have also been included as controls to account for household particularities, namely the number of children and adults, reference person's age and educational attainment level, see Table 2. Finally, house price data was drawn from HM Land Registry which periodically releases regional data on average house prices based on transactions in a time-series format (HMLR, 2022) which allows to account for the existence of regional dynamics in real estate markets, see Figure 6.

4. Estimation strategy

Prior research on the Marginal Propensity to Consume (MPC) has dealt with the lack of household-level longitudinal data through the use of pseudo-panels. Introduced by Deaton (1985), this technique relies on the use of cohort dummies to produce panel data out of repeated cross-sections. Cohort are groups with fixed membership, usually built according to the age of the respondent. In this paper, cohorts were built attending to the date of birth of the Household Responsible Person (HRP). The oldest, cohort 1, comprises households where the HRP was born before 1934, cohort 2 was born between 1935 and 1939 and so on with the last cohort including those born after 1995.

While the use of age cohorts in the estimation of consumption over the lifecycle is a standard practice, this type of OLS estimation does not allow to control for unobserved household effects (Aksoy *et al.*, 2021). As a result, OLS estimations are likely to be biased unlike those resulting from estimation with household-level fixed effects (Mundlak, 1978). To account for some of

Statistic	N	Mean	St. Dev	Min	Max
Non-housing consumption	41,648	357.111	180.400	103.003	817.921
Cohort	41,648	6.872	3.310	1	14
Age	41,648	53.119	16.293	3	80
N Children < 2	41,648	0.066	0.259	0	3
N Children $2 \leq t < 5$	41,648	0.099	0.330	0	3
N Children $5 \leq t < 18$	41,648	0.383	0.785	0	7
N Adults	41,648	1.790	1.192	0	8

Table 2.
Descriptive statistics

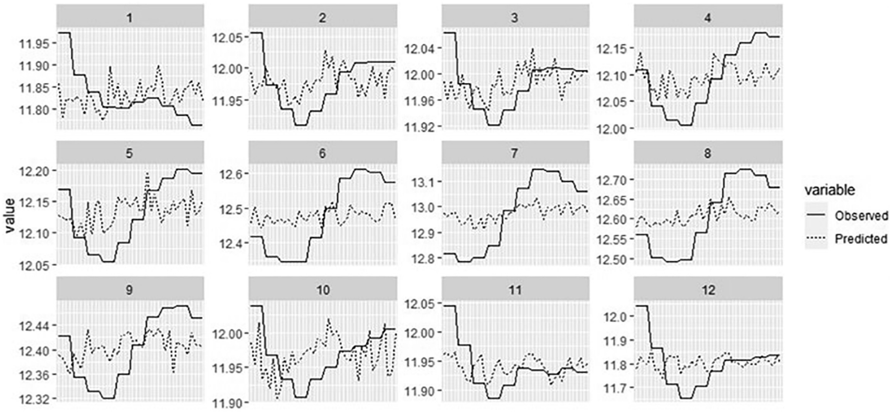


Figure 6.
Quarterly predicted and observed house prices by region (2009–2019)

Note(s): 1, North East; 2 North West & Merseyside; 3, Yorkshire and the Humber; 4, East Midlands; 5, West Midlands; 6, Eastern; 7, London; 8, South East; 9, South West; 10, Wales; 11, Scotland; 12, Northern Ireland

Source(s): Prepared by the author

these biases, this paper includes a number of controls presented in the data section. For instance, household composition, number of children and adults, are likely to change over the lifecycle and have a direct impact over consumption. A polynomial for age and various measures of educational attainment have been introduced as proxies for lifetime income, following ABHL. It is in fact the intersection of age and cohort features that allows accounting for any deterministic trends (Attanasio and Weber, 1994), like the macroeconomic environment. There is also no direct inclusion of income since in a life-cycle framework, permanent income is captured by the constants and unexpected income is included in the errors.

Over the ABHL baseline specification including the aforementioned controls, this paper adds a binary energy efficiency variable (Equation (1)) (Table 1). The addition of energy efficiency as a control is a means of accounting for the premium of living in a home with enhanced fabric standards. Since the variable of housing costs excluded from consumption includes energy costs, this variable serves to account for the difference between energy savings and extra costs resulting from retrofitting or purchasing an energy-efficient home. As introduced in the data section, lower consumption among households in energy-efficient homes points to increased costs not being compensated by energy savings. This paper's main objective is to assess if the increases in house prices experienced in the 2010s have accrued in consumption across particular household types, namely age tenure and energy efficiency. The academic literature presents various hypotheses regarding the heterogeneous impact house prices can have on household consumption. From the tenure side, house prices accrue on homeowners' capital gains producing a wealth effect. This should be particularly noticeable in older homeowners long in housing. On the contrary, the absence of distinguishable coefficients across tenures and age groups would preclude the establishment of a causal relationship and point to the common causation between consumption and house prices.

Baseline:

$$\begin{aligned}\log(\text{NHConsumption}) = \text{Constant} + \text{cohort}^{C} + f\left(\text{age}^{5}\right) + N_{\text{children}} + N_{\text{Adults}} \\ + D_{2\text{Adult}} + \text{Degree} + \text{Alevels} + \text{EPC} + \cdot\,\text{Age Groups} + \epsilon\end{aligned} \tag{1}$$

From now on:

$$\text{Controls} = \text{cohort}^C + f\left(\text{age}^5\right) + N_{\text{children}} + N_{\text{Adults}} + D_{2\text{Adult}} + M_{\text{Soc}} \tag{2}$$

Following ABHL, two strategies, both drawing from the time-series dataset on regional house prices presented above, are used to account for the effect of house prices on consumption. The first house price specification uses the log level of house prices by region over time interacted with age groups (Equation 3). The second house price specification (Equation 4) repeats equation 3 and adds EPC. To assess the role of differences in housing tenure, this same equation is also estimated with an interaction term including tenure instead of age groups (Equation 5).

Average House Price and Age Group:

$$\begin{aligned}\log(\text{NHConsumption}) = {} & \text{Constant} + \text{Controls} + \text{Age Groups} + \log(\text{House Price}) \\ & + \log(\text{House Price}) \cdot \text{Age Groups} + \epsilon\end{aligned} \tag{3}$$

Average House Price, EPC and Age Group:

$$\begin{aligned}\log(\text{NHConsumption}) = {} & \text{Constant} + \text{Controls} + \text{EPC} + \text{Age Groups} + \log(\text{House Price}) \\ & + \log(\text{House Price}) \cdot \text{Age Groups} + \epsilon\end{aligned} \tag{4}$$

Average House Price, EPC and Tenure:

$$\begin{aligned}\log(\text{NHConsumption}) = {} & \text{Constant} + \text{Controls} + \text{EPC} + \text{Tenure} + \log(\text{House Price}) \\ & + \log(\text{House Price}) \cdot \text{Tenure} + \epsilon\end{aligned} \tag{5}$$

The second house price specification accounts for expected and unexpected changes in property prices. Since the LCFS does not include household-level expectations of house price increases, a model estimating house price variations was used to predict house prices (Equation 5). This model regresses Real Interest Rates, Regional Average Income, and regional dummies (Table 3), proxies expectations of house price changes understood as an ex-ante belief about the long-term trend of house prices. Similarly to ABHL, this simple model has a relatively high R2. Interestingly, the coefficient for household income is much lower in our specification than the one found by ABHL and Real Interest Rate seems to have a much larger impact. These differences point to an increased role of credit in determining house prices which seems coherent with current explanations of worsening housing affordability in the last decade (Meen and Whitehead, 2020). As Figure 6 shows, this model seems to be able to track house price changes in most regions with a degree of accuracy. The largest differences between predicted and observed prices are in London, Eastern and the South-East, where observed house prices are much above the level predicted by the model.

$$\begin{aligned}\log(\text{House Prices}) = {} & \text{Constant} + \text{Real Interest} + \log(\text{Average Regional Household Income}) \\ & + \text{Regional Dummies} + \epsilon\end{aligned} \tag{6}$$

The last equation estimated, 6, draws from predictions from this first-stage model. These are subtracted from actual observations and the difference together with the predicted level are

Table 3.
First order regression on house prices

	Dependent variable log(HP)
log(HI)	0.245***
	(0.040)
Real.Interest	0.011***
	(0.003)
Region 2	0.126***
	(0.017)
Region 3	0.137***
	(0.017)
Region 4	0.239***
	(0.017)
Region 5	0.278***
	(0.017)
Region 6	0.600***
	(0.018)
Region 7	1.067***
	(0.021)
Region 8	0.714***
	(0.020)
Region 9	0.543***
	(0.017)
Region 10	0.119***
	(0.017)
Region 11	0.089***
	(0.017)
Region 12	−0.027
	(0.016)
Constant	10.243***
	(0.264)
Observations	480
R^2	0.957
Adjusted R^2	0.956
Residual Std. Error	0.073 (df = 466)
F-statistic	807.023*** (df = 13; 466)

Note(s): *p<0.1; **p<0.05; ***p<0.01

included in a three-way interaction with age groups and EPC (Equation 6). This specification aims at identifying any differences between expected and unexpected house price shocks across age groups and EPC. The objective of differentiating between energy-efficient and not energy-efficient housing aims to analyse whether house price appreciation impacts consumption differently albeit belonging to the same age group.

$$\begin{aligned}\log(\text{NHConsumption}) = {} & \text{Constant} + \text{Controls} + \text{EPC} + \text{Age Groups} \\ & + \log(\text{Predicted}) + \log(\text{Diff}) + \text{Age Groups} \cdot \log(\text{Predicted}) \\ & + \text{Age Groups} \cdot \log(\text{Diff}) + \text{EPC} \cdot \log(\text{Predicted}) \\ & + \text{EPC} \cdot \log(\text{Diff}) + \text{EPC} \cdot \text{Age Groups} \\ & + \text{Age Groups} \cdot \log(\text{Predicted}) \cdot \text{EPC} \\ & + \text{Age Groups} \cdot \log(\text{Diff}) \cdot \text{EPC} + \epsilon \end{aligned} \tag{7}$$

5. Findings and limitations

The baseline model presented in Equation (1) (Table 4), (see Appendix 2 for full detail) offers an overview of the level of consumption explained by lifecycle patterns. The intersection of age variables and cohorts together with controls for household size and education are capable of tracing consumption across a majority of age groups (Figure 7). In contrast to ABHL, the use of a shorter time span, does increase volatility in consumption resulting from inconsistent membership. The results from the estimation of the baseline model also confirm the descriptive statistics and do find an overall negative effect of a positive EPC on consumption. This is coherent with what the literature on energy savings calls the pre and rebound effects (Sunikka-Blank and Galvin, 2012) where actual and expected consumption differ since households in low energy-efficient homes consume less energy than those in energy-efficient ones. Limitations of this particular finding are discussed more in-depth above, as drawbacks from the EPC imputation model, and below in the findings contextualisation.

The first house price specification, Equation (3), summarised in Table 4, builds on regional house prices (log average house price) included in interactions with each group (Age G).

	Dependent variable log(Non-housing consumption) EPC (1)	Age groups (2)	EPC + Age groups (3)	EPC + Tenure (4)
EPC_Bin1	−0.180*** (0.010)		−0.180*** (0.010)	−0.049*** (0.010)
log(Average_Price)		0.002 (0.013)	0.028** (0.013)	0.026 (0.016)
Age_G2		0.556*** (0.207)	0.695*** (0.206)	
Age_G3		−1.011*** (0.210)	−0.722*** (0.210)	
log(Average_ Price):(Age_G)2		−0.043** (0.017)	−0.054*** (0.017)	
log(Average_ Price):(Age_G)3		0.078*** (0.017)	0.055*** (0.017)	
(Tenure)2				0.263 (0.269)
(Tenure)3				0.702*** (0.241)
(Tenure)4				−0.132 (0.238)
log(Average_ Price):(Tenure)2				−0.010 (0.022)
log(Average_ Price):(Tenure)3				−0.036* (0.020)
log(Average_ Price):(Tenure)4				0.039** (0.020)
Constant	6.544*** (0.410)	5.270*** (0.503)	4.967*** (0.502)	6.417*** (0.444)
57404.64	57644.77	57297.41	55336.3	
Observations	41,646	41,646	41,646	41,646
R^2	0.178	0.174	0.181	0.218
Adjusted R^2	0.178	0.173	0.180	0.218
Residual Std. Error	0.482 (df = 41,623)	0.483 (df = 41,619)	0.481 (df = 41,618)	0.470 (df = 41,616)
F-statistic	410.240*** (df = 22; 41,623)	336.266*** (df = 26; 41,619)	339.517*** (df = 27; 41,618)	400.696*** (df = 29; 41,616)

Note(s): *p<0.1; **p<0.05; ***p<0.01

Table 4. Regression results

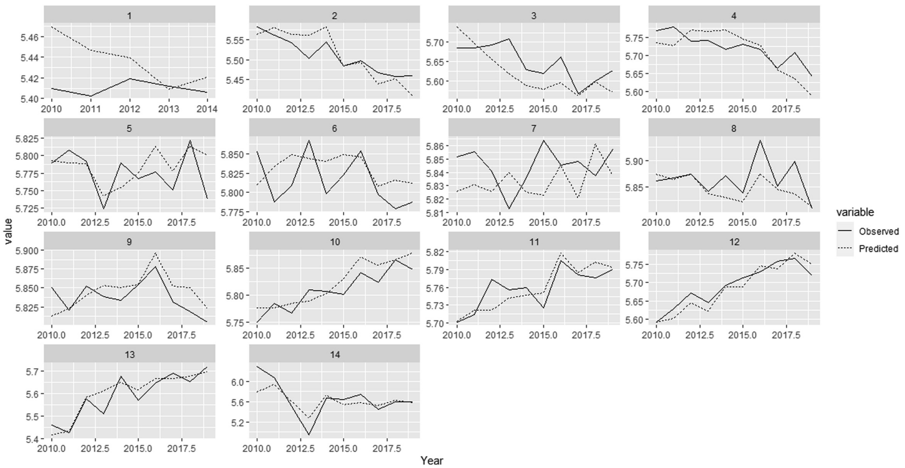


Figure 7.
Log yearly predicted and observed deflated consumption baseline model excluding housing costs in logs by age cohort

Note(s): 1 oldest – 14 youngest
Source(s): Prepared by the author

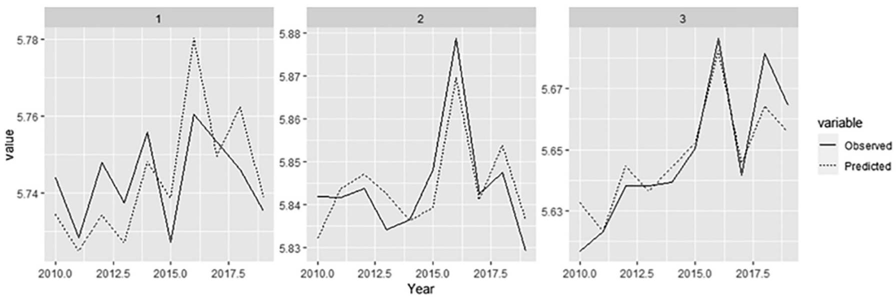
The estimates point to a positive effect of house prices on consumption when interacted with age groups. Older households present a 0.078 estimate with a small error (0.017) while there is a negative effect for middle-aged ones (−0.043), the estimate for younger households is included in the constant. Once we incorporate EPC as a control, Equation 4, these differences are mitigated, showing a (0.055) estimate for older households with a small error (0.017) while there is a negative effect for middle-aged ones (−0.054). Albeit these effects are small, they are in contrast with those found by ABHL. In their case, the coefficients across age groups are similar and point to the co-movement of house prices and consumption. On the contrary, these estimates differ by age group pointing to a positive wealth effect of rising house prices on consumption for older households, "long" in housing, more likely to own and have larger amounts of equity in their homes. Meanwhile, middle-aged households experienced a negative impact of house price increases in consumption. These households are more often "short" in housing, that is, just entered a mortgage or are likely to need to move into larger properties as their household size expands. When it comes to younger households, their estimate seems to be in between the two groups which points to co-movement with housing prices. These findings are more in line with those of Campbell and Cocco (2007) despite not including income as a control. The dissimilarities in the coefficients also seem to support the findings of Engelhardt (1996) of a small MPC that is in fact compensated by different reactions across groups (see Figure 8).

The specification resulting from equation (5) substitutes Age Groups with Tenure (1, social renter; 2, private renter; 3, owner with a mortgage; 4 owner outright) also interacted with log Average House Prices. The estimates between owner with a mortgage (−0.036) and owner outright (0.039) have the same signs as those of age groups and reinforce the hypothesis of a moderate wealth effect whereby households owning outright do consume more as house prices increase, while mortgagors are in fact negatively affected by house prices, as entry costs in mortgages go up and the perspective of upsizing becomes presumably more costly. The AIC is substantially lower in the Tenure specification pointing to differences in asset positions related to tenure being more relevant than age in explaining consumption patterns. These findings are consistent with those in the model presented by

Berger *et al.* (2018) for the US, which shows low consumption response for renters and mortgagors and larger responses for outright owners.

Interpreting these results in the manner of ABHL, the existence of different coefficients for age groups and tenures points to the breaking down of co-movement between house prices and consumption. In the last ten years, this relationship seems to only hold strongly for older households pointing to a moderate wealth effect for older households. Despite the inclusion of controls for life-cycle variables through age, this correlation between older households' consumption and house price appreciation could also be a result of common trajectories between house prices and other types of capital gains related to the appreciation of other more liquid financial assets. While larger coefficients for older groups point to wealth effects, larger coefficients for younger groups could be associated with an increase in economic activity resulting in higher expected future income for those relying on the labour market. In the estimates, this only seems to be the case for younger cohorts. These could reinforce a nuanced co-movement argument for younger households. Encountering such different estimates to those in ABHL may point to the establishment of different consumption patterns and expected incomes after the GFC. This is reinforced by a lower R2 (0.178–0.218) than in similar specification by ABHL (0.51–0.52).

In the second price specification, outlined in Equation (7), house prices are divided into two variables. The first variable represents predicted prices, as forecasted by the house price model specified in the methodology section (Figure 6). The second variable entails the discrepancy between the predicted and observed house prices (as per Equation (6)). These variables are then interacted with age groups and the Energy Performance Certificate (EPC) binary indicator (see Table 5 and Appendix 3 for detailed estimates). Unexpected house price increases appear to negatively impact consumption among households in energy-efficient homes. However, an interaction with age suggests a positive effect for households within the older age bracket. In other words, unanticipated house price increases seem to positively influence consumption among older households residing in energy-efficient homes. While the error in this coefficient is substantial, the magnitude appears to be significantly larger than those previously encountered in the other regressions (0.7). This sizable positive estimate could indicate a larger wealth effect associated with house price appreciation in energy-efficient homes, particularly among older households. This suggests a heterogeneous accrual of property premiums dependent on household age. Older households, being long in housing, would also be better poised to benefit from superior quality homes since they do not need to account for upsizing or future investments. Hence, they increase their consumption in line with house



Note(s): 1, under 35; 2, 35–60; 3,65 or more

Source(s): Prepared by the author

Figure 8.
Log yearly predicted and observed deflated consumption average house price model in logs by age group

	log(Non-housing consumption)
EPC_Bin	−0.098***
	(0.015)
Predicted	0.007
	(0.014)
(Age_G)2	0.072
	(0.219)
(Age_G)3	−0.140
	(0.218)
Diff_Pred_Obvs	0.058
	(0.071)
Predicted:(Age_G)2	−0.003
	(0.018)
Predicted:(Age_G)3	0.009
	(0.018)
(Age_G)2:Diff_Pred_Obvs	0.004
	(0.091)
(Age_G)3:Diff_Pred_Obvs	−0.128
	(0.090)
EPC_Bin1:Diff_Pred_Obvs	−0.464**
	(0.218)
EPC_Bin1:(Age_G)2	−0.109***
	(0.022)
EPC_Bin1:(Age_G)3	−0.159***
	(0.024)
EPC_Bin1:(Age_G)2:Diff_Pred_Obvs	0.592*
	(0.327)
EPC_Bin1:(Age_G)3:Diff_Pred_Obvs	0.764**
	(0.353)
Constant	5.180***
	(0.575)
AIC	57306.52
Observations	41,646
R^2	0.181
Adjusted R^2	0.180
Residual Std. Error	0.481 (df = 41,606)
F-statistic	235.448*** (df = 39; 41,606)

Note(s): $^*p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

Table 5.
Regression results predicted vs observed house prices

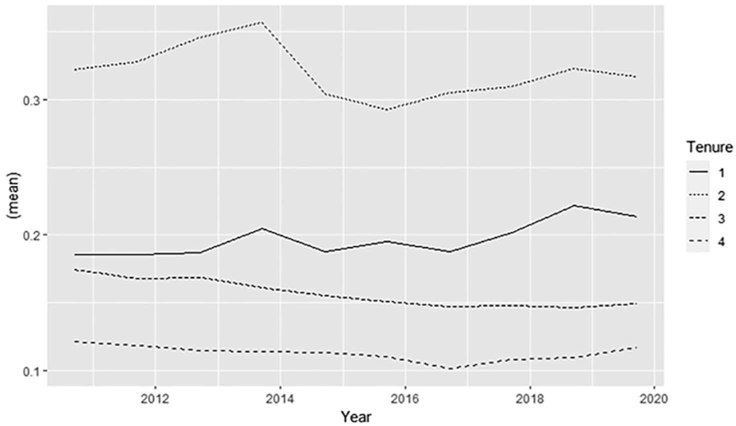
prices. This also seems to be the case for middle-aged households in energy-efficient homes, albeit to a lesser extent. A complementary specification included in Appendix 3 further explores this possibility by interacting tenure and EPC. However, the estimates are not statistically significant. Consequently, these regression results should be interpreted cautiously as evidence of a heterogeneous accrual of property premiums across different age groups but not tenures.

The lack of any significant coefficients between predicted house prices and consumption points to the de-coupling of earnings and house prices since predicted house prices are a function of regional average household income and interest rates. There are two relevant limitations of these findings. First, there is a lack of actual estimates of house price value collected via surveys such as the ones used by Caloia and Mastrogiacomo (2022) for Italy and the Netherlands. The second limitation relates to the prediction of EPC certificates and how LCFS may not be representative when it comes to built-environment dimensions, as a result, the negative estimate for consumption in energy-efficient properties should be interpreted with caution. Furthermore, one of the main limitations of the current approach is the lack of panel data which allows to compare pooled OLS results, biased due to unobservables; and estimates from a fixed effects model that would overcome these biases, as presented in the methodology section. The divergence between the estimates obtained and those encountered in the literature relates to the use of actual panel data and specifications using fixed effects, i.e. (Disney *et al.*, 2010; Suari-Andreu, 2021). Finally, more granular data, capturing location, could allow the use of an IV building on differential exposure to house price and retail employment shocks as in Guren *et al.* (2018).

6. Discussion and policy relevance

This paper has analysed heterogeneous consumption reactions to house price increases across households with varying positions in the housing market, tenure and energy efficiency levels. Incorporating heterogeneous consumption reactions allows for a more comprehensive understanding of the distributional implications of changes in the housing market. These findings provide insight into how different households are affected by large-scale changes in the housing market and can inform targeted policy interventions to address both energy efficiency and wealth disparities.

Noticeably, from a tenure perspective, the regression presented above only offers statistically significant results for homeowners with a contrast between outright and owners with a mortgage. As shown in Figure 9, these two groups are the ones whose housing costs to income ratio is the lowest and has remained the most stable or even decreased in the last decade. On the contrary, the proportion of income taken up by housing has increased for renters. The finding of a wealth effect among older homeowners is coherent with these observations since older households are more likely to own outright or have larger amounts of equity and are hedged against increases in house prices. Although the increase in housing costs for the youngest group is more nuanced than among private renters, differences in housing costs translate to age groups. This stems from the average age of renters having slowly increased over the last 10 years, Figure 10. While age profiles have remained fairly constant in the other age groups, the average age of renters has increased which points to a different life-cycle consumption pattern for younger generations. This raises questions about



Note(s): 1, social renter; 2, private renter; 3, owner with a mortgage; 4 owner outright

Source(s): Prepared by the author

Figure 9. Time-series average ratio of housing costs to income by tenure

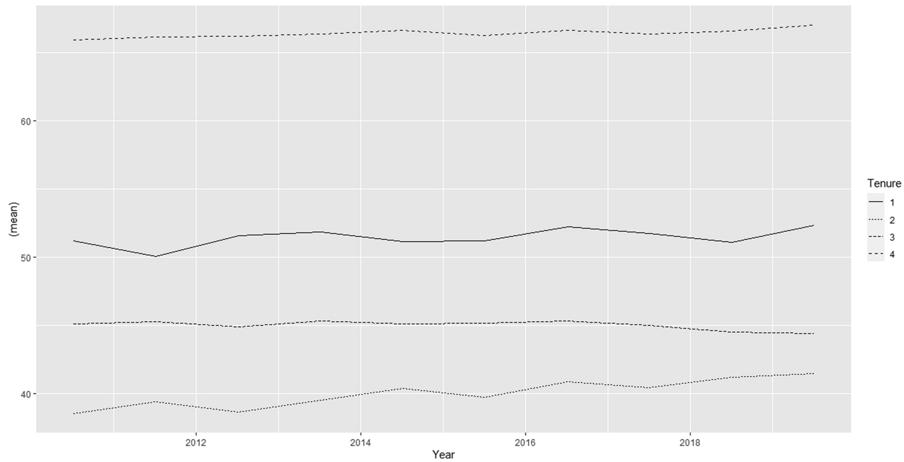


Figure 10.
Time-series average age by tenure

Note(s): 1, social renter; 2, private renter; 3, owner with a mortgage; 4 owner outright
Source(s): Prepared by the author

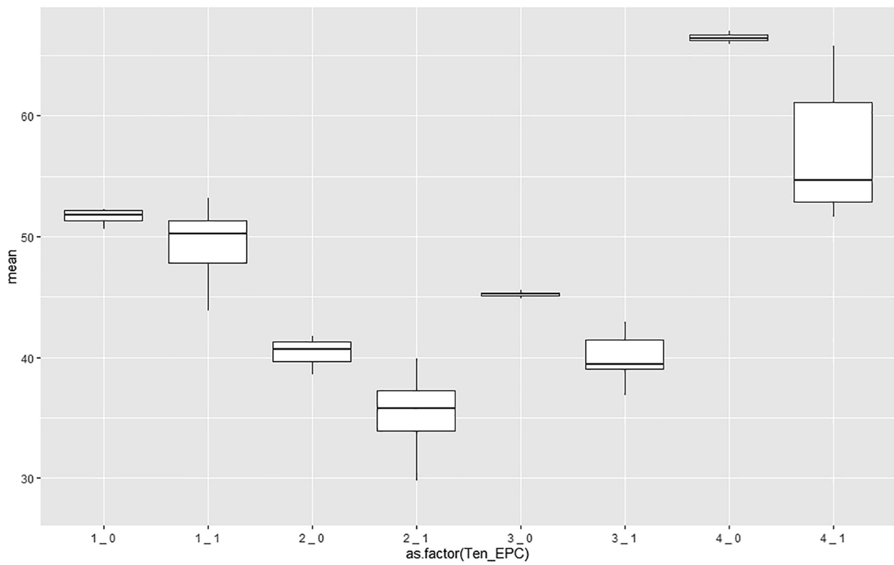
how further property appreciation resulting from energy improvements may affect younger households without assets.

Establishing a dialogue between the literature on consumption and house prices, together with the hedonic pricing literature on energy efficiency is particularly pertinent for the design of policies incentivising retrofit. Although there are disputes regarding the size of the premium, it has been well-established that higher energy efficiency increases property values both in rental and owner-occupation markets, see Fuerst *et al.* (2015, 2020). According to this paper's findings, property value increases are likely to accrue in the consumption of older households, while they may further reduce the chances of acquiring property for first-time buyers or upscaling for households with low equity. While this paper does not find a relationship between the consumption of renters and house prices, the existence of a negative relationship between owners with a mortgage and house prices may point to increased leveraging and the foregoing of consumption for deposit savings. Further research on the consumption patterns of households constrained by large housing costs may help elucidate the distributional impact of EPC improvements.

Current policies incentivising housing retrofits rely on the one hand, on the subsidisation of a proportion of retrofit costs. First, the Green Homes Local Authority Delivery Scheme offered £0.5 billion in 2020–21 for which local authorities could bid to fund improvements in energy efficiency. Funding could go up to £10,000 in the case of homeowners and £5,000 per property in the case of private rental with landlords contributing at least a 1/3 of the costs (BEIS, 2020). Also, the Green Homes Grant Voucher Scheme specifically targeted the retrofit of owner-occupied homes. However, according to the National Audit Office (NAO, 2021), payment delays and time constraints in fund allocation prevented it from reaching its goals both on carbon reduction and job creation. On the other hand, the government has also introduced Minimum Energy Performance standards (MEPS) which precluded the granting and continuation of tenancies of properties with an EPC below F and G. According to Ferentinos *et al.* (2021), this policy decreased values in affected properties by about £5,000 to £9,000 relative to unaffected ones.

Heterogenous reactions to house price increases, resulting from the unequal capitalisation of energy efficiency, become relevant when evaluating retrofit policy options. As a result of these heterogenous estimates, older households seem better poised to benefit from the value uplift resulting from retrofit than younger ones. This observation is backed by recent OECD data pointing out that housing wealth is increasingly concentrated in high-income and high-wealth households (Causa *et al.*, 2019). It follows that subsidies targeting the worst-performing stock regardless of its occupants' socioeconomic characteristics can reinforce the concentration of wealth since older households tend to live in the least energy-efficient section of the stock, see Figure 11. This type of housing quality-centred transition subsidies would be regressive, lowering housing costs for the already wealthy outright homeowners. Conversely, the introduction of MEPS, instead of subsidies, could serve as a redistributive mechanism triggering investment from these same older households without over-subsidisation.

Taxation is another possible path towards a redistributive incentivisation of housing retrofit. Muellbauer (2018) has introduced the idea of a Green Land Tax composed of two elements, one based on built-up surface and another one on unoccupied land. Energy-efficient buildings would pay the same tax as unoccupied land while energy-inefficient ones would pay a proportional increase by energy use. Such tax would create incentives to retrofit and improve the financial viability of increasing densities as the tax burden on built-up surface could be shared by different households in multiple occupation buildings but concentrated in one in the case of single-family dwellings. In this regard, the study of policies such as mortgage interest deduction has pointed out how the lack of adequate taxation leads to the overconsumption of owner-occupied housing and increases in house prices (Fatica and Prammer, 2018; Poterba, 1984). On the one hand, targeting grants to households could incentivise retrofit among low-income homeowners for whom the impact of increased costs could pose affordability problems. On the other hand, increased taxation of energy-inefficient homes could help redistribute housing wealth toward younger homeowners in the most



Note(s): 1, social renter; 2, private renter; 3, owner with a mortgage; 4 owner outright
Source(s): Prepared by the author

Figure 11. Average age by EPC binary (1 = Efficient) tenure

energy-efficient proportions of the stock and incentivise retrofit through increasing housing costs for house-wealthy households. However, the political feasibility of these drastic policy changes remains questionable.

In short, the overall conceptualisation of the energy transition in housing as a technological issue related to energy savings and upgrading costs does not capture the impact that widespread property appreciation can have over consumption and asset distribution. Incorporating a distributional analysis of house price appreciation in policy design has the potential to mitigate the further eschewing of housing wealth toward older asset–wealthy households at the expense of younger ones.

7. Conclusion

Drawing from the economic literature on house prices and consumption, this paper aimed to critically discuss the existence of a wealth effect relating property appreciation and consumption in the UK. The regression findings show that older households and outright owners have increased their consumption in line with property prices. Conversely, middle-aged households and owners with a mortgage have in fact experienced a negative effect of house price increases on consumption. Younger households seem to increase their consumption less than older ones but are still partially in line with house prices. This points to the existence of a certain wealth effect for older households and outright owners, while younger households' consumption seems to co-move with house price increases, probably due to common causation. The negative coefficient for energy efficiency over consumption once excluding housing and energy costs, also suggests that households in energy-efficient homes do experience higher housing costs not compensated by energy savings. When interacted with house price and age, energy efficiency seems to have a more positive effect on older households' consumption. Ultimately, this points to differentiated distributional impacts of house price appreciation over age groups. This consideration is usually absent from the design of housing retrofit incentives. While grants directly increase the viability of retrofit, this may result in regressive impacts. Alternatively, forms of green land value tax as proposed by Muellbauer (2018) and MEPS have the potential to place incentives on property owners with large assets capable of mobilising private investment to improve energy efficiency.

Notes

1. FES is the predecessor of LCFS, one of the two surveys used in this paper.
2. The LCFS survey uses weights to deal with outliers, since these weights are wave-based this paper has excluded the lowest and highest 10% in consumption deemed outliers.
3. The bundling of A, B and C ratings as energy efficient follows the objective of attaining a national average of C set out in 2020, see introduction.

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Appendix 1
Predict EPC – Binary logit model and robustness checks

	Dependent variable (EPC_Bin)
(M_Year)2012–2013	0.639***
	(0.031)
(M_Year)2014–2015	0.971***
	(0.030)
(M_Year)2016–2017	0.987***
	(0.069)
(M_Year)2018–2019	1.426***
	(0.069)
(M_HS)2	−0.009
	(0.027)
(M_HS)3	0.037
	(0.034)
(M_HS)4	0.025
	(0.038)
(M_HS)5	0.129**
	(0.051)
(M_HS)6	0.157**
	(0.080)
(M_HS)7+	0.180
	(0.110)
(M_HT)2	−0.319***
	(0.039)
(M_HT)3	−0.009
	(0.037)
(M_HT)4	1.624***
	(0.043)
(M_HT)5	−0.589***
	(0.075)
(M_Ten)2	−0.237***
	(0.046)
(M_Ten)3	−0.317***
	(0.056)
(M_Ten)4	0.267***
	(0.048)
(M_Ten)5	0.787***
	(0.047)
M_Rent	0.001***
	(0.0002)
M_Mort	0.0003
	(0.0002)

Table A1.
EPC prediction

(continued)

	Dependent variable (EPC_Bin)
M_Inc	0.0001***
	(0.00004)
(M_Age)2	0.005
	(0.056)
(M_Age)3	−0.121**
	(0.056)
(M_Age)4	−0.291***
	(0.057)
(M_Age)5	−0.315***
	(0.058)
(M_Age)6	−0.301***
	(0.058)
(M_Soc)1	0.216***
	(0.080)
(M_Soc)2	0.141*
	(0.073)
(M_Soc)3	0.164**
	(0.082)
(M_Soc)4	0.024
	(0.085)
(M_Soc)5	0.113
	(0.086)
(M_Soc)6	0.148**
	(0.076)
(M_Soc)7	0.033
	(0.077)
(M_Gas)1	1.021***
	(0.032)
Constant	−2.877***
	(0.084)
Observations	62,238
Log Likelihood	−30,844.260
Akaike Inf. Crit	61,758.530

Note(s): *$p<0.1$; **$p<0.05$; ***$p<0.01$

Table A1.

df	Mean	n
35	61758.57	1
34	62037.53	4
33	62316.66	6
32	62595.50	4
31	63931.74	4
30	64311.15	13
29	64163.73	23
28	63662.23	23
27	63519.64	20
26	65012.99	26
25	65810.34	38
24	65486.36	47
23	65020.57	51
22	65199.62	51
21	65990.02	50
20	66770.50	54
19	67008.88	63
18	66833.55	68
17	66633.96	63
16	66883.73	54
15	67796.60	50
14	68711.83	51
13	68902.64	51
12	68328.99	47
11	67928.18	38
10	69041.04	26
9	71258.23	20
8	71091.18	23
7	70236.83	23
6	69882.61	13
5	70593.26	4
4	73215.22	4
3	73530.94	6
2	73859.98	4
1	74206.15	1

Table A2.
Stepwise regression analysis summary results, AIC by degrees of freedom

Robustness checks: K-fold Test and Stepwise logistic regression.

Generalised Linear Model.

62,238 samples 10 predictor 2 classes: '0', '1'

No pre-processing Resampling: Cross-Validated (10 fold) Summary of sample sizes: 56,015, 56,014, 56,015, 56,014, 56,014, 56,014, . . .Resampling results:

Average Accuracy: 0.7485298 Kappa: 0.2176083.

Using a 10-fold cross-validation procedure to determine the ability of the model to generalise to unseen data, we demonstrate that the accuracy remains stable across folds. This indicates that taking different subsets of the data does not lead to different model estimates. In addition, a stepwise logistic regression was performed to estimate the adequacy of the predictor variables for imputing EPC bin in the consumption dataset. The procedure shows the lowest AIC value for the model including all predictor variables. This can be seen as the logistic regression with all variables being a valid way to impute the dependent variable. In sum, the two checks performed support the reliability and validity of the regression results across subsamples and regression specifications.

Appendix 2
Full regression results 1–4

	Dependent variable log(Non-housing consumption)			
	EPC (1)	Age groups (2)	EPC + Age groups (3)	EPC + Tenure (4)
(Year)2011	−0.003	−0.005	−0.004	−0.002
	(0.010)	(0.010)	(0.010)	(0.010)
(Year)2012	0.002	−0.006	0.002	−0.005
	(0.010)	(0.010)	(0.010)	(0.010)
(Year)2013	0.001	−0.009	0.001	−0.002
	(0.011)	(0.011)	(0.011)	(0.010)
(Year)2014	0.008	−0.004	0.006	−0.0004
	(0.011)	(0.011)	(0.011)	(0.010)
(Year)2015	0.009	−0.006	0.005	0.001
	(0.011)	(0.011)	(0.011)	(0.011)
(Year)2016	0.032***	0.017	0.027**	0.020*
	(0.011)	(0.011)	(0.011)	(0.011)
(Year)2017	0.006	−0.011	−0.0002	−0.008
	(0.011)	(0.011)	(0.011)	(0.010)
(Year)2018	0.033***	0.010	0.026**	0.014
	(0.011)	(0.011)	(0.011)	(0.010)
(Year)2019	0.015	−0.011	0.008	−0.004
	(0.011)	(0.011)	(0.011)	(0.010)
Age	−1.170***	−0.464	−0.433	−1.273***
	(0.248)	(0.289)	(0.288)	(0.242)
I(Age^2)	0.343***	0.195***	0.184***	0.347***
	(0.057)	(0.065)	(0.065)	(0.055)
I(Age^3)	−0.044***	−0.030***	−0.029***	−0.043***
	(0.006)	(0.007)	(0.007)	(0.006)
I(Age^4)	0.003***	0.002***	0.002***	0.002***
	(0.0003)	(0.0004)	(0.0004)	(0.0003)
I(Age^5)	−0.0001***	−0.00005***	−0.00005***	−0.0001***
	(0.00001)	(0.00001)	(0.00001)	(0.00001)
N_Children_U_2	−0.005	−0.00004	−0.004	0.004
	(0.010)	(0.010)	(0.010)	(0.010)
N_Children_2_t_5	0.020***	0.026***	0.023***	0.031***
	(0.008)	(0.008)	(0.008)	(0.008)
N_Children_5_t_18	−0.063***	−0.061***	−0.061***	−0.045***
	(0.004)	(0.004)	(0.004)	(0.004)
N_Adults	0.220***	0.230***	0.224***	0.209***
	(0.005)	(0.005)	(0.005)	(0.004)
Dummy_More_2_	−0.086***	−0.098***	−0.094***	−0.065***
A1	(0.010)	(0.010)	(0.010)	(0.010)
Alevel	0.089***	0.091***	0.088***	0.071***
	(0.006)	(0.006)	(0.006)	(0.006)
Degree	0.136***	0.136***	0.134***	0.104***
	(0.005)	(0.005)	(0.005)	(0.005)
EPC_Bin1	−0.180***		−0.180***	−0.049***
	(0.010)		(0.010)	(0.010)
log(Average_Price)		0.002	0.028**	0.026
		(0.013)	(0.013)	(0.016)

(*continued*)

Table A3.
Regression results

	Dependent variable log(Non-housing consumption)			
	EPC (1)	Age groups (2)	EPC + Age groups (3)	EPC + Tenure (4)
Age_G2		0.556***	0.695***	
		(0.207)	(0.206)	
Age_G3		−1.011***	−0.722***	
		(0.210)	(0.210)	
log(Average_ Price):Age_G2		−0.043**	−0.054***	
		(0.017)	(0.017)	
log(Average_ Price):Age_G3		0.078***	0.055***	
		(0.017)	(0.017)	
Tenure2				0.263
				(0.269)
Tenure3				0.702***
				(0.241)
Tenure4				−0.132
				(0.238)
log(Average_ Price):Tenure2				−0.010
				(0.022)
log(Average_ Price):Tenure3				−0.036*
				(0.020)
log(Average_ Price):Tenure4				0.039**
				(0.020)
Constant	6.544***	5.270***	4.967***	6.417***
	(0.410)	(0.503)	(0.502)	(0.444)
57404.64	57644.77	57297.41	55336.3	
Observations	41,646	41,646	41,646	41,646
R^2	0.178	0.174	0.181	0.218
Adjusted R^2	0.178	0.173	0.180	0.218
Residual Std. Error	0.482 (df = 41,623)	0.483 (df = 41,619)	0.481 (df = 41,618)	0.470 (df = 41,616)
F-statistic	410.240*** (df = 22; 41,623)	336.266*** (df = 26; 41,619)	339.517*** (df = 27; 41,618)	400.696*** (df = 29; 41,616)

Note(s): *p<0.1; **p<0.05; ***p<0.01

Table A3.

Appendix 3
Full regression results 5

	Dependent variable log(Non-housing consumption) (1)	(2)
(Cohort)2	0.056***	0.051***
	(0.015)	(0.015)
(Cohort)3	0.104***	0.090***
	(0.020)	(0.020)
(Cohort)4	0.086***	0.057***
	(0.023)	(0.022)
(Cohort)5	0.098***	0.065***
	(0.026)	(0.025)
(Cohort)6	0.129***	0.109***
	(0.029)	(0.028)
(Cohort)7	0.132***	0.127***
	(0.031)	(0.030)
(Cohort)8	0.121***	0.108***
	(0.033)	(0.032)
(Cohort)9	0.091***	0.068**
	(0.035)	(0.034)
(Cohort)10	0.073**	0.045
	(0.037)	(0.036)
(Cohort)11	0.076*	0.053
	(0.039)	(0.038)
(Cohort)12	0.084**	0.067*
	(0.041)	(0.040)
(Cohort)13	0.077*	0.055
	(0.044)	(0.043)
(Cohort)14	0.074	0.032
	(0.058)	(0.056)
Age	−0.501	−0.989***
	(0.336)	(0.305)
I(Age^2)	0.209***	0.295***
	(0.077)	(0.071)
I(Age^3)	−0.032***	−0.039***
	(0.008)	(0.008)
I(Age^4)	0.002***	0.002***
	(0.0004)	(0.0004)
I(Age^5)	−0.0001***	−0.0001***
	(0.00001)	(0.00001)
N_Children_U_2	−0.002	0.005
	(0.010)	(0.010)
N_Children_2_t_5	0.026***	0.035***
	(0.008)	(0.008)
N_Children_5_t_18	−0.061***	−0.044***
	(0.004)	(0.004)
N_Adults	0.225***	0.213***
	(0.005)	(0.004)
Dummy_More_2_A1	−0.096***	−0.073***
	(0.010)	(0.010)

(*continued*)

Table A4. Regression results predicted vs observed house prices

	Dependent variable log(Non-housing consumption)	
	(1)	(2)
Alevel	0.089***	0.071***
	(0.006)	(0.006)
Degree	0.136***	0.106***
	(0.005)	(0.005)
EPC_Bin1	−0.098***	−0.045***
	(0.015)	(0.014)
Predicted	0.007	0.011
	(0.014)	(0.017)
Age_G2	0.072	
	(0.219)	
Age_G3	−0.140	
	(0.218)	
Tenure2		0.234
		(0.296)
Tenure3		0.303
		(0.253)
Tenure4		0.285
		(0.248)
Diff_Pred_Obvs	0.058	−0.051
	(0.071)	(0.090)
Predicted:Age_G2	−0.003	
	(0.018)	
Predicted:Age_G3	0.009	
	(0.018)	
Age_G2:Diff_Pred_Obvs	0.004	
	(0.091)	
Age_G3:Diff_Pred_Obvs	−0.128	
	(0.090)	
Predicted:Tenure2		−0.008
		(0.024)
Predicted:Tenure3		−0.003
		(0.021)
Predicted:Tenure4		0.005
		(0.020)
Tenure2:Diff_Pred_Obvs		0.174
		(0.124)
Tenure3:Diff_Pred_Obvs		0.097
		(0.106)
Tenure4:Diff_Pred_Obvs		0.001
		(0.104)
EPC_Bin1:Diff_Pred_Obvs	−0.464**	−0.011
	(0.218)	(0.196)
EPC_Bin1:Age_G2	−0.109***	
	(0.022)	
EPC_Bin1:Age_G3	−0.159***	
	(0.024)	
EPC_Bin1:Age_G2:Diff_Pred_Obvs	0.592*	
	(0.327)	
EPC_Bin1:Age_G3:Diff_Pred_Obvs	0.764**	
	(0.353)	
EPC_Bin1:Tenure2		0.041*
		(0.024)

Table A4.

(continued)

	Dependent variable log(Non-housing consumption) (1)	(2)
EPC_Bin1:Tenure3		−0.047*
		(0.026)
EPC_Bin1:Tenure4		0.037
		(0.041)
EPC_Bin1:Tenure2:Diff_Pred_Obvs		−0.622*
		(0.365)
EPC_Bin1:Tenure3:Diff_Pred_Obvs		−0.243
		(0.387)
EPC_Bin1:Tenure4:Diff_Pred_Obvs		−0.385
		(0.622)
Constant	5.180***	5.999***
	(0.575)	(0.541)
57306.52		
Observations	41,646	41,646
R^2	0.181	0.219
Adjusted R^2	0.180	0.218
Residual Std. Error	0.481 (df = 41,606)	0.470 (df = 41,601)
F-statistic	235.448*** (df = 39; 41,606)	265.450*** (df = 44; 41,601)

Note(s): *p<0.1; **p<0.05; ***p<0.01

Table A4.

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