Department of Land Economy

Environment, Law & Economics

UNIVERSITY OF CAMBRIDGE

Real Estate Research Centre

Working Paper Series

No. 2019-02

Title: Housing Wealth and Residential Energy Consumption in the UK

Authors: Helen X H Bao[a] and Steven Li[b]

Affiliation: University of Cambridge[a&b]

Contact corresponding author: Helen X H Bao, hxb20@cam.ac.uk

Housing Wealth and Residential Energy Consumption in the UK

Helen X. H. Bao[1] and Steven H. Li

Department of Land Economy, University of Cambridge, CB3 9EP, UK

Abstract

Housing wealth effect often manifests as a positive relationship between consumption and perceived housing wealth (e.g., the perceived value of houses). When the perceived value of a property rises, homeowners may feel more comfortable and secure about their wealth, causing them to spend more. This study adopts a behavioural approach to verify if this relationship holds true for residential energy consumption in the UK. While controlling for property characteristics as well as a large number of demographic, socioeconomic and energy-use behaviour variables, we identified a significant relationship between housing wealth and energy consumption. Our models also considered psychological biases in energy consumption behaviours such as the framing effect. Our findings not only shed light on the behavioural aspects of housing wealth effect on residential energy consumption, but also demonstrates the possibility and potential to 'nudge' households towards energy conservation. Most importantly, we also provide empirical evidences on the intriguing relations among housing wealth, residential energy consumption, and fuel poverty. We argue that overlooking the presence of fuel poverty risks a superficial interpretation of any identified housing wealth effect on residential energy consumption. The fuel vulnerable group should be analysed separately from the rest of the population due to their different energy consumption patterns. This finding is particularly helpful to design and implement energy consumption policies that can strike a balance between social justice and economic efficiency.

Keywords: Prospect theory, mental accounting, behavioural economics, energy consumption, housing wealth, judgemental bias

JEL Classification: Q40, Q50, R20,

[1] Corresponding Author (hxb20@cam.ac.uk).

Housing Wealth and Energy Consumption in the UK

1. Introduction

Residential energy consumption represents more than a quarter of total energy consumption in most countries and plays a significant role in mitigating global climate change[2]. Therefore, considerable efforts have been made to study energy consumption of households. Unlike transport or industrial energy consumption, which is mostly affected by technological standards and regulations, residential energy consumption is determined by a wide range of factors. Physical characteristics of residential buildings, such as construction materials, property structure, and efficiency level of appliances are found to be important determinants of energy consumption (Druckman and Jackson, 2008; Valenzuela et al., 2014). A body of studies show that energy consumption can be largely influenced by household features (Tso and Guan, 2014; Valenzuela et al., 2014), because household characteristics can determine energy consumption via the direct channel of the energy use of home appliances and the indirect channel of their choices of housing units (Estiri, 2014). For example, household size has a positive impact on total energy consumption (Ndiaye and Gabriel, 2011), and a negative impact on per capita energy consumption (Brounen et al., 2012). Income level also significantly influence energy consumption levels (Druckman and Jackson, 2008; Gatersleben et al., 2002; Jackson et al., 2007). Energy consumption is higher for households with higher income level and remains stabilized for very high income levels families: a relationship holds at the national level as well (Nguyen-Van, 2010).

Although these building and household characteristics are crucial in determining basic requirement of energy consumption, they are not well suited to capture the effects of energy consumption behaviours or habits. There have been growing interests in the role of these human factors. When households receive feedbacks on their energy consumption levels, their electricity consumption is reduced by 20%, with older and energy conservative groups more likely to be affected by such feedbacks (Aydin et al., 2018). Real-time display of energy use can lead to households' energy conservative behaviour through the learning channel (Lynham et al., 2016). A sociopsychological perspective about residential energy consumption Nye et al. (2010) has been emerging.

We extend this line of research by studying the relationship between housing wealth and energy consumption. Housing wealth, defined as the total market value of the housing capital, is an important component of the total wealth of households. Housing wealth is about half of the total household wealth in the US (Iacoviello, 2011). In the UK, evidence shows that housing wealth gains increasing importance over time (Barrell et al., 2015). Since 2001 household housing wealth steadily outstripped financial wealth in the UK[3].

Housing wealth is different from financial wealth in many ways. Housing wealth is more important for households with their wealth within the median range. But

[2] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/573269/ECUK_November_2016.pdf

[3] 'Economic Statistics Transformation Programme: Historical estimates of financial accounts and balance sheets', Office for National Statistics, 2016.

financial wealth has a more unequal distribution, matters more for those in the top quantile. While financial wealth is more sensitive to short-term shocks, housing wealth is more responsive to long-term shocks. Although households can track financial wealth from the stock market on a daily basis, they do not receive frequent market feedback on their housing wealth. Finally, housing wealth is less liquid than financial wealth from the stock market. Financial wealth can be easily liquidated and used to fulfil other purchases. Housing wealth, on the other hand, does not give households an instant benefit to consume. Therefore, it influences consumption mainly by increasing borrowing power, or in most cases, by making homeowners feel wealthier psychologically. This psychological effect is not negligible. Housing wealth effect on general consumption has been increasing over the past thirty years (Kishor, 2007), and general consumption is much more responsive to changes in housing wealth than that in financial wealth [see, for example, Aladangady (2017) and Carroll et al. (2011)]. Significant housing wealth effect on consumption has been well documented by using evidence from many countries. (Bostic et al., 2009; Kishor, 2007; Paiella, 2007; Sonje et al., 2012).

Given the significant influence that housing wealth asserts on general consumption, this study sets off to investigate whether changes of housing wealth will affect energy consumption levels as well. An increase in housing wealth effect does not necessarily mean the owner will get more cash, particularly when the homeowner cannot sell her only house. However, it can increase life satisfaction (Chen, 2006), improve expectation (Ludwig and Sløk, 2002), reduce precautionary savings (Campbell and Cocco, 2007; Carroll, 1992), or improve one's financial situation through refinancing (Attanasio et al., 2009; Gan, 2010). All of these can potentially affect household energy consumption level as well. Given the size and the growing volatility of housing markets across the world, the role of housing wealth in energy consumption determination deserves scientific investigation.

There are studies linking household wealth to energy consumption already. Household energy consumption increases with household wealth (Huang, 2015; Rao and Reddy, 2007). Household wealth can also affect household's choice of energy sources (Khandker et al., 2012; Rahut et al., 2017). The increase of household wealth could lead to an increased propensity to pay for a better quality of energy source, which is shown by the acceleration of electricity use for light and cooking in such households (Rahut et al., 2017). Households tend to use modern efficient stoves and high quality fuels when their wealth level increases (Takama et al., 2012). The energy price shock, such as that of crude oil, can affect the macro economy through the wealth-consumption channel (Odusami, 2010). The price fluctuation of crude oil affects the household consumption to wealth response, partly because more than half of the energy spending is related to crude oil. Following the analytical frameworks identified in Swan and Ugursal (2009), we investigate housing wealth effect on domestic energy consumption at both the macro and micro levels. We use a large UK household survey dataset – Understanding Society Innovation Panel – to test our hypotheses. Overall, we find a significant positive relation between housing wealth and energy consumption. Age, financial situation, and energy conservative attitude all serve as moderator in the housing wealth effect on energy consumption. From the behavioural perspective, we identify a framing effect, with combined payment method linked to stronger housing wealth effect on energy consumption. Finally, housing wealth effect shows varying pattern in the upper half and lower half of the energy consumption distribution, reflecting greater housing wealth effects among households with high fuel poverty level.

The remainder of the paper is structured as follows. Section 2 analyses the long-run relationship between housing wealth and residential energy consumption by using macro-data. Section 3 presents the micro-level analysis using household survey data. Section 4 concludes the paper.

2. The long-run relationship between housing wealth and energy consumption

We first examine the long-run relationship between housing wealth and energy consumption at the national level. A total of three energy consumption variables are considered, namely, total energy consumption, gas consumption, and electricity consumption. For comparison purposes, we also considered three general consumption measurements: total consumption, goods consumption, and services consumptions. For each of the six types of consumption, we use the following equation to capture the impacts from housing wealth.

$$\frac{C}{Y} = f\left(\frac{HW}{Y}, \frac{FW}{Y}, S\right) + \varepsilon \qquad (1)$$

where C is consumption, HW is housing wealth, FW is financial wealth, Y is household disposable income, S is market sentiment. Note that both consumption and wealth variables are income-adjusted to remove the size effect of the income (Deaton, 1992; Paiella, 2007). By expressing consumption and wealth as ratios of household disposable income, Equation (1) can reliably separate the net effect of housing wealth. Market sentiment is considered in Equation (1) due to its well-established relationship with consumption (Ludvigson, 2004).

We obtain data on consumption and wealth from the National Office of Statistics UK. We use the GfK consumer confidence index[4] as the measurement of market sentiment. Variable definitions and descriptive statistics can be found in Table 1. All variables are quarterly time series from 1995Q4 to 2016Q4. In Figure 1, we contrast the consumption and wealth variables before and after the income adjustment. The relationship between consumption and market sentiment is more obvious after the income adjustment. This pattern shows the benefits of the income-adjustment strategy as shown in Equation (1).

Augmented Dickey-Fuller (ADF) unit root tests confirm that all variables are integrated of order one, or I(1). According to the Johansen's trace test there is only one cointegration relationship between consumption and other variables. We proceed to estimate Equation (1) by using the Vector Error Correction Model (VECM), which is routinely used to estimate long-term relationships in the energy economics literature (See, for example, Iyke, 2015; Miller and Ratti, 2009; Shahbaz et al., 2017). AIC and

[4] GfK consumer confidence index is the longest running and one of the most watched indicators in the UK. On behalf of the European Commission, GfK conducts the UK consumer confidence survey on a representative sample, focusing on their opinions on household finances, purchasing climate, and the general economy.

BIC statistics suggest that no lagged terms should be included in the VECM models. The coefficient estimates and model fitting statistics are reported in Table 2.

Housing wealth has a long-run positive, albeit statistically insignificant, effect on total consumption and goods consumption. For example, the estimated housing wealth effect on total consumption is 2.1840, meaning that when housing wealth to income ratio increases by one percent, total consumption to income ratio goes up by 0.002184% as well[5]. However, the relationship is not significant at any conventional levels. Housing wealth affects the consumption of services primarily, which is indicated by the only statistically significant housing wealth effects in model 3. The results of the first three models generally support the life-cycle model prediction (Ando and Modigliani (1963), and Gourinchas and Parker (2002)): after adjusting for income level, changes in housing wealth and financial wealth do not affect consumption level in the long term.

We then proceed to investigate the effects of financial and housing wealth changes on energy consumptions. Note that energy consumption is classified as goods consumption by the ONS, and is included in the goods consumption statistics. Although goods consumption as a whole do not response to wealth changes in the long-run, a positive housing wealth effect is identified for all three energy consumption models (i.e., models 4 – 6 in Table 2). After controlling for income effects and market sentiment, energy consumption (i.e., total, gas, and electricity) as a ratio of income will increase in the long term when housing wealth-income ratio increases. The effect is smaller in magnitude than that on general consumptions (i.e., total, goods, and serves consumption), but with high statistical significance. The coefficient estimates of housing wealth variables are 1.0295, 0,8829, and 0.3002 in the total energy, gas, and electricity consumption models, all of which are less than one-third of that in the services consumption model (i.e., the model 3 in Table 2). This lasting effect of housing wealth on energy consumption is at odds with the life-cycle model prediction. It does not, however, suggest a failure of a long-established, classic model, but rather suggests that some sector specific characteristics should be considered to make sense of the observed anomaly. This conclusion leads to our decision to examine the housing wealth effects on energy consumption by using household and individual levels data. Such an approach allows the consideration of household and individual traits, which proved to be influential on energy consumption behaviours (e.g. Aydin et al., 2018; Sapci and Considine, 2014; Willis et al., 2011).

Two other interesting findings in this analysis are also used in the design of our household-level analysis. Firstly, in all six models, financial wealth does not have any long-term relationship with consumptions, nor does it response to deviations from the long-term equilibrium. This is true with or without the consumer confidence measurement in the models, which rules out the concerns over the high-correlation between the two variables. Our empirical evidences suggest that financial wealth effects are not significant in the long-run. One might be tempted to omit financial wealth in the household-level analysis. This is particularly true when reliable measurement of financial wealth on household level is hard to come by, which is true for the UK. However, the insignificant financial wealth effect might be misleading due to the

[5] Note that housing wealth and financial wealth are measured in £billions, whilst consumptions are in £millions. Therefore, we made adjustments to the coefficient estimates accordingly.

limitations of macro data. In response to the concern associated with estimating wealth effects with macro data (Dolmas, 2003), we will further investigate the robustness of this finding by using alternative measurements and reliable proxies of financial wealth in our micro-level analysis to follow.

Secondly, the consistently positive effect of market sentiment also shows the importance of considering behavioural factors (e.g., market sentiment) in housing wealth effect studies. Based on these macro-level analysis results, we proceed to investigate housing wealth effects on energy consumption at the household and individual levels, taking into account of behavioural factors such as confidence and framing effects. The research design of the micro-level analysis is given in the next section.

Figure 1. Consumption, Wealth, and Market Sentiment

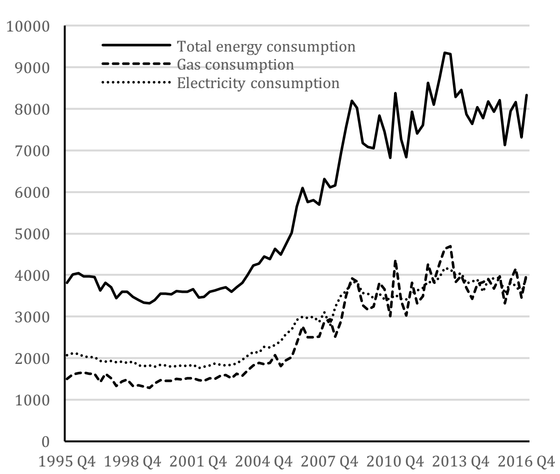


Figure 1a: Energy Consumptions

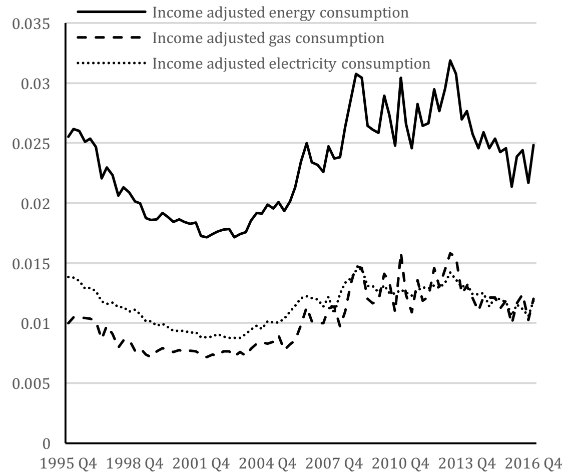


Figure 1b: Income-adjusted Energy Consumptions

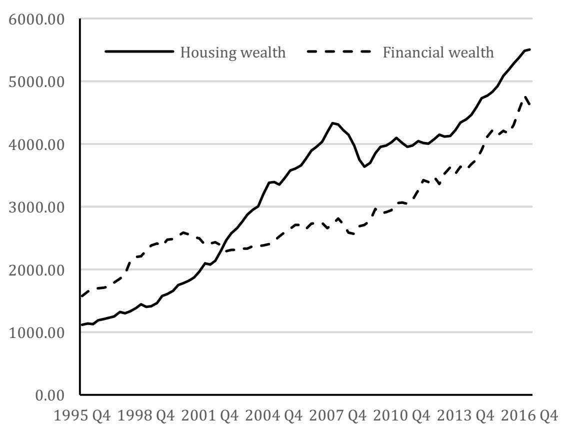


Figure 1c: Wealth

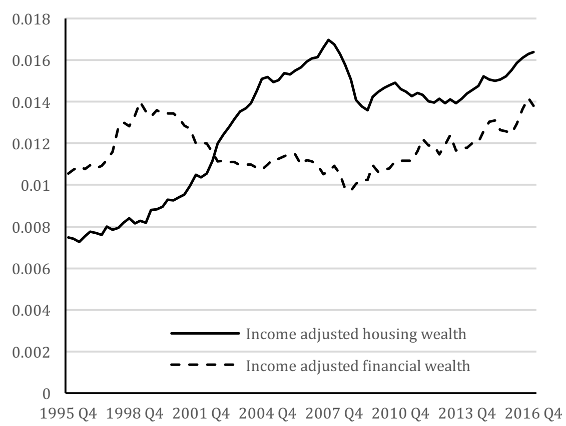


Figure 1d: Income-adjusted Wealth

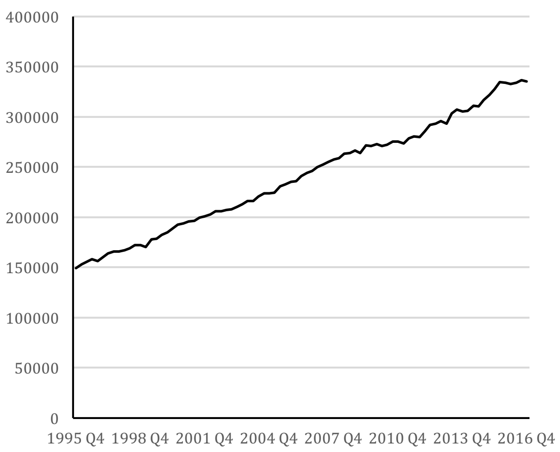


Figure 1e: Household disposable Income

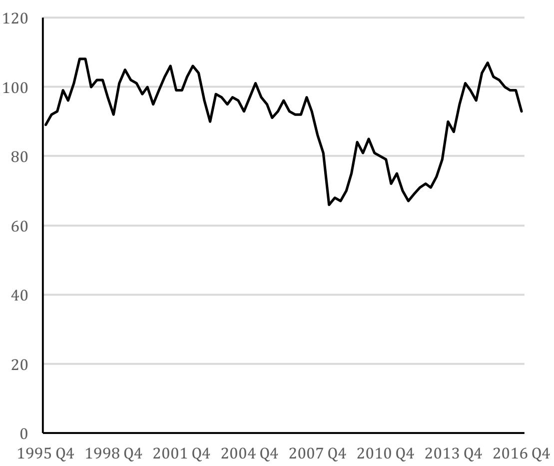


Figure 1f: Consumer Confidence Index

Table 1. Data source and transformation

Variable Name	Definition	Source	Mean	S.D.	Min	Max
TCON	Total consumption (£million, SA)	ONS UK consumer trends UK domestic total: Sum of durable, semi-durable and non-durable goods plus services.	219160.20	48508.84	134577	310643
GCON	Goods consumption (£million, SA)	ONS UK consumer trends Total for goods: Sum of durable, semi-durable and non-durable goods.	94065.60	19270.74	59504	128249
SCON	Services consumption (£million, SA)	ONS UK consumer trends Services: Clothing and footwear, housing, water, electricity, gas and other fuels, furnishing, household equipment and routine maintenance of the house, financial services, transport and communication, restaurants and hotels, package holiday, education, social protection, recreation and cultural services.	125094.60	29294.73	75073	182394
ECON	Total energy consumption	ONS UK consumer trends Electricity, gas and other fuels	5681.52	1989.06	3316	9347
GAS	Gas consumption	ONS UK consumer trends Gas	2559.81	1070.31	1284	4698
ELEC	Electricity consumption	ONS UK consumer trends Electricity	2792.98	859.97	1768	4167
HW	Housing wealth (£million)	ONS UK national balance sheet Table 10 Housing wealth = dwellings + buildings other than dwellings + other structures + land	3227.54	1302.42	1119.94	5500.49
FW	Financial wealth (£million)	ONS UK flow of funds	2823.30	737.75	1577.38	4770.58
INC	Gross disposable income (£million, SA)	ONS UK economics account HNISH	240416.50	54903.56	149434	336586
CCI	UK consumer confidence index	GfK Consumer Confidence Index downloaded from Bloomberg	91.73	11.57	66	108

Table 2. VECM estimation results

	Total consumption	Goods Consumption	Services Consumption	Total Energy Consumption	Energy Consumption - Gas	Energy Consumption - Electricity
Long-run equilibrium						
Housing wealth	2.1840	2.1768	3.4005***	1.0295**	0.8829**	0.3002*
	(1.395)	(2.548)	(0.584)	(0.491)	(0.364)	(0.166)
Financial wealth	-2.8332	-7.0214	1.4602	-0.6408	-0.2708	-0.3533
	(4.147)	(7.575)	(1.735)	(1.460)	(1.083)	(0.495)
Consumer confidence	0.0030***	0.0048***	0.0014***	0.0006***	0.0005***	0.0002***
	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.6439	0.0081	0.3310	-0.0393	-0.0433	-0.0069
	.	.	.	.	.	.
Short-run adjustment						
Consumption	-0.1249***	-0.0145	-0.2034***	-0.0180	-0.0184	-0.0157
	(0.041)	(0.012)	(0.053)	(0.020)	(0.021)	(0.018)
Housing wealth	-0.0059***	-0.0033***	-0.0131***	-0.0164***	-0.0220***	-0.0479***
	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)	(0.009)
Financial wealth	-0.0004	0.0002	-0.0002	0.0045	0.0059	0.0141
	(0.001)	(0.001)	(0.003)	(0.004)	(0.006)	(0.012)
Consumer confidence	27.6271*	23.5730**	54.2222	136.1536**	191.4897***	389.7726**
	(16.530)	(10.259)	(34.207)	(52.726)	(72.888)	(150.481)
Cointegration Chi-square	65.8079	51.0738	95.5470	21.8989	26.4680	19.8194
AIC	-27.2153	-28.5250	-28.2159	-30.7931	-31.3054	-33.1434
BIC	-26.8970	-28.2067	-27.8976	-30.4747	-30.9871	-32.8251

3. Micro-level analysis using household survey data

3.1: Data Sources

We obtained the data from the Understanding Society Study (USS)[6]. Previously called the UK Household Longitudinal Study, USS is the largest household study in the world, which surveys around 40,000 British households online on an annual basis since 2009. The study covers a wide range of social, economic and behavioural factors on both the household and individual levels. Moreover, the participants of the study come from all ages and across all regions of the UK. The USS database has been widely used by researchers in both the UK and overseas [see, for instance, Booth et al. (2002), Clark and Huang (2003), and Thomas et al. (2005)].

Our dataset was composed by drawing information from several waves of the Innovation Panel (IP) within the USS. A total of 2,760 households were selected from the USS main survey database to participate in the IP study, which serves as a testbed for new ways of collecting data or conducting new researches. The IP questionnaire consists of two groups of questions. The first group of questions are almost identical to those asked in the main survey. Therefore, this set of questions largely remain unchanged over time. The second group of questions, however, are experiments and methodological tests designed to develop and evaluate methodologies and new content for longitudinal survey research. Consequently, this set of questions typically change from year to year. The USS holds annual innovation panel competition to invite ideas from the public. Winners of the competition will have their questions included in the second half of the IP questionnaire, and have their ideas reliably tested with the data collected. The public also benefit from the IP study by having data on cutting-edge research topics for free. For example, in wave 9 (i.e., survey conducted in 2016 and results released in 2017), IP included experiments on opinions towards immigration, education expectations, and 'successful aging', and experiments to explore potential venues to improve survey designs, such as the impact of incentives on response rates, efficiency of fieldwork and costs. Leveraging the versatile survey design of the IP study, we collect data from five IP waves between 2011 and 2015, as shown in Table 3.

3.2: Models and Variables

3.2.1 Life-cycle model

Our first step is to test the basic relationship between housing wealth and energy consumption. After adjusting the effect of household income, the relationship between housing wealth and energy consumption can be captured by the life cycle model as in Ando and Modigliani (1963).

$$\frac{C_{it}}{Y_{it}} = \beta_0 + \beta_1 \frac{W_{it}}{Y_{it}} + \varepsilon_{it} \tag{2}$$

where W_{it} is housing wealth of household i in period t, Y_{it} is household income, and C_{it} is energy consumption. t = 2011, … 2015. We used the reported values of this question *"[What is] the expected property value if the property is sold today?"* as the

---

[6] Website: www.understandingsociety.ac.uk.

measurement of W_{it}. Y_{it} is calculated based on the reported gross income for the month before the interview date. C_{it} is derived based on three variables from the IP survey: *xpelecy* (*how much spent on electricity*), *xpgascy* (*how much spent on gas*) and *xpduely* (*how much spent on gas and electricity combined*). When a household is paying energy expenses in a combined bill, we used the reported value of *xpduely* as the measurement of annual household energy consumption. For households that are paying their energy bills separately, we add up the values of reported electricity bill payment (i.e., *xpelecy*) and gas bill payment (i.e, *xpgascy*) to obtain the value of annual household energy consumption. In summary, variable $energybill$ is constructed by using equation (3) as follows.

$$C_{it} = \begin{cases} xpelecy_{it} + xpgascy_{it}, & \text{if } xpduely_{it} \text{ is missing} \\ xpduely_{it}, & \text{Otherwise} \end{cases} \tag{3}$$

3.2.2 Age effect

Wealth-consumption research also shows that the response of consumption to housing wealth is related to age (Baker et al., 1989; Cashin and Mcgranahan, 2006; Ritchie et al., 1981). Compared with younger people, older people usually save more on energy. However, they may spend more when they feel an increase in housing wealth. Campbell and Cocco (2007) find a large housing wealth effect on consumption for older household, but a small one for younger renters. Younger people's energy consumption behaviour may not be influenced by their perception of housing wealth. Consequently, the housing wealth effect is weaker among younger households than older households (Sierminska and Takhtamanova, 2012). This is often referred to as the direct channel of wealth effect, i.e., that consumptions of older households are more responsive to wealth change than younger households (Gourinchas and Parker, 2002; Juster et al., 2006; Lehnert, 2004). To investigate this age effect, we include a dummy variable *old*, which equals one for those aged 60 or above to Equation (2).

3.2.3 Energy conservation attitude

Energy conservation attitude is another factor that may affect energy consumption. However, findings on the relationship between energy conservation attitude and energy consumption are mixed. On the one hand, many studies claim that the link between conservative attitudes and energy conservation behaviour is weak (Ritchie et al., 1981; Uutela, 1994; Vringer et al., 2007). Solely changing conservative attitudes receives little energy conservation payoffs. On the other hand, there are empirical evidence in support of this relationship. For example, Brandon and Lewis (1999) find that positive environmental attitudes help households to improve their energy conservation actions. Aydin et al. (2018) find that energy conservative households tend to reduce their energy consumption when receiving consumption feedback. Sapci and Considine (2014) find strong evidence in the US that environmentally concerned households have significantly lower level of energy consumption. Another recent study in Australia find that households with positive environmental conservation attitudes have significantly less water consumption (Willis et al., 2011). In addition, many studies find that even without feedback mechanism, conservative attitudes can independently predict energy conservative behaviour (Sapci and Considine, 2014; Thompson and Barton, 1994). Existing findings seem to be context specific, and there is a lack of empirical evidences from the UK. We consider energy conservation attitude in our models to bridge this gap in the literature.

The innovation panel survey has eleven questions to collect information about participants' environmental habits. These questions are: How often do you (1) leave your TV on standby for the night, (2) keep the tap running while you brush your teeth, (3) Switch off lights in rooms that aren't being used, (4) put more clothes on when you feel cold rather than putting the heating on or turning it up,(5) decide not to buy something because you feel it has too much packaging, (6) buy recycled paper products such as toilet paper or tissues, (7) take your own shopping bag when shopping, (8) use public transport (e.g. bus, train) rather than travel by car, (9) walk or cycle for short journeys less than 2 or 3 miles, (10) car share with others who need to make a similar journey, or (11) take fewer flights when possible? The answers to all questions are coded the same way: 1= Always; 2 = Very often; 3 = Quite often; 4 = Not very often; 5 = Never. As a value of 1, 2, or 3 is an evidence of the corresponding habit, we recoded each variable to be a dummy variable that equals 1 if the original values are less than four, and zero otherwise. An environmental protection attitude score is calculated as follows.

$$Score_i = \sum_{k=3}^{11} habit(k) - \sum_{k=1}^{2} habit(k) \qquad (4)$$

In other words, we use the sum of scores of good habits (i.e., habits [3] through [11]) minus the sum of scores of bad habits (i.e., habits [1] and [2]) to form an environmental habit score for each participant. To obtain a robust measurement, we calculate the environmental protection attitude scores for four waves between 2011 and 2014[7]. The participant is classified as energy conservative (i.e., *Conservative* = 1) if the score is above median level (i.e., 3 in our sample) in all four waves. We include this energy conservative dummy, *conservative*, in Equation (2).

3.2.4 Confidence in financial situation

Psychology research suggests that confidence has significance influence on our decisions (Estes and Hosseini, 1988; Petrusic and Baranski, 2003; Sniezek, 1992), and particularly financial decisions (Carroll et al., 1994; Ludvigson, 2004; Shiller, 2015). Consumer confidence is related to household consumption (Mishkin, 1978). Previous change in confidence has explanatory power for current consumption (Carroll et al., 1994). At the aggregate level, confidence can even moderate the effect of housing wealth and financial wealth on household consumption (Fereidouni and Tajaddini, 2017). However, there has not been any evidences on its effect on energy consumption so far. Our macro-level analysis reveals that market sentiment (i.e., over-confidence or under-confidence) has a significant impact on energy consumption as a whole. Will this relationship hold at the individual level? To answer this question, a reliable measurement of sentiment on the household or individual level is needed. We use the confidence in financial situation as the measurement of confidence, because the important role financial situation plays in spending decisions. We assume that if an individual is less confident in her financial situation, she will save on energy consumption. However, an increase in housing wealth might boost her confidence in future financial situation, and subsequently cause her to spend more on energy.

[7] The questions on environmental conservation attitudes are discontinued after 2014.

The measurement of the confidence in financial situation, *S_fut*, is derived from a question regarding the respondent's assessment of her finance situation[8]. The variable takes the value of 1 if the answer is "*Finding it quite difficult*" or "*Finding it very difficult*", and 0 otherwise if the answer is "*Living comfortably*", "*Doing alright*" or "*Just about getting by*". In other words, *S_fut* equals one if the respondent believes that her future finance situation will be worse off, and 0 otherwise.

3.2.5 Framing effects

We then investigate the framing effect of payment methods on energy consumption. Behavioural economics studies have shown that individuals' decision-making depends on the way options are presented, or 'framed' (Kahneman, 2003; Tversky and Kahneman, 1981, 1986). Framing effect presents when people's response varies when the same information is framed differently. For example, consumer spending is significantly affected by the framing methods of the retailers (Darke and Chung, 2005; DelVecchio et al., 2007; Jia et al., 2018). It is likely that energy consumers are responsive to framing effect as well.

Our IP dataset presents a unique opportunity to study this effect. In the UK, an individual can pay gas and electric bills either separately or as in a combined bill. People who make combined payment may see a bigger number on their bill payment than that when paying separately. They consequently have more energy bill pressure and consume less thereafter. However, as they feel an increase in housing wealth, they will consume more than those using separate payment methods. To verify framing effect, we introduce a dummy variable $combined\_bill$. which equals one if the respondent has her electricity and gas expenses combined in one bill, and zero otherwise.

We also included variables to control for key social, economic, and demographic factors. These include *gender* (male or female), *ncars* (number of cars owned by household), *hheat* (whether accommodation is warm enough in winter) and, *hhsize* (number of people in household), *hsbeds* (number of bedrooms), *owner* (whether property owned outright/with mortgage), and *employ* (whether in paid employment). The final model to be estimated is given below[9].

$$\frac{C_{it}}{Y_{it}} = \alpha + \beta\frac{W_{it}}{Y_{it}} + \boldsymbol{\theta}\begin{bmatrix} old_{it} \\ conservative_i \\ S\_fut_{,it} \\ combined\_bill_{it}\end{bmatrix} + \boldsymbol{\gamma}\begin{bmatrix} old_{it} \\ conservative_i \\ S\_fut_{,it} \\ combined\_bill_{it}\end{bmatrix}\cdot\frac{W_{it}}{Y_{it}} + \boldsymbol{\varphi}\begin{bmatrix} gender_{\ i} \\ ncars_{\ it} \\ hheat_{it} \\ hhsize_{it} \\ hsbed_{it} \\ owner_{it} \\ employ_{it}\end{bmatrix} + \varepsilon_{it} \quad (5)$$

In Equation (5), β captures the direct housing wealth effect on energy consumption, $\boldsymbol{\gamma}$ is a row vector of parameters that reflects the medicating effect from

---

[8] We did not include an objective measurement of future financial situation due to the lack of direct observations of the construct. See the discussions in Section 3.? for details.

[9] Note that variable *conservation* is calculated by using data between 2011 and 2014 (i.e., all data available for energy conservation calculations), and therefore, remains the same across the sampling period. This is a reasonable assumption because people's energy consumption attitude should not change significantly over a few years. As a result, variable *conservation* does not have the subscript for time. Similarly, *gender* remains the same across all years.

age, energy consumption attitude, financial situation, and framing on housing wealth effects. Therefore, Equation (5) models both the direct and indirect housing wealth effects on energy consumption. Table 3 gives the definitions and descriptive statistics of the variables used in our final analysis.

3.3: Estimation Strategy

We firstly estimate Equation (5) with OLS method, after adding time and region dummies to control for the variations over time and across geographic regions. We also calculated clustered standard errors on households to take into account the correlation among individuals from the same household. Although the data are from a panel survey database, panel data methods are not suitable for our analysis. Specifically, some personal characteristics in our dataset are time-invariant, such as energy conservation attitude. Such variables will be omitted if a fixed effect panel model is estimated. In addition, the fixed effect model does not allow clustered standard errors within each household.

We then re-estimate Equation (5) by using quantile regression method, for the following two reasons. Firstly, one important variable missing from Equation (5) is the changes in financial wealth. There are related questions included in the 2010 IP survey, yet the high proportion of invalid inputs renders the variables useless. Without controlling for this important confounding factor, our estimation of the housing wealth effect could be biased. For example, if a household's financial and housing wealth increase at the same time, and the financial wealth variable is missing from the equation, it is likely the estimated housing wealth effect will be inflated. To address this issue, we devised an alternative, indirect measurement of financial wealth. We sort respondents into quantiles based on the proportion of spending on energy consumptions, and analysis their energy consumption responses to housing wealth changes within each quartile. The assumption is that people who have more financial assets generally spend a smaller proportion of their income on energy consumption. Hence, the proportion of spending on energy can serve as a proxy of financial wealth. Although this measurement is not ideal, it suffers far less measurement error problems than the original, direct measure of financial wealth. More importantly, this research design also allows us to incorporate an important energy consumption issue in our analysis, that is, fuel poverty.

Fuel poverty has received substantial concerns in the UK. According to the 2016 Annual Fuel Poverty Statistics Report, there are 2.38 million fuel poor households in England, representing around 10.6% of total households. Over the past years, the average fuel poverty gap (i.e., the amount needed to meet the basic fuel requirement) has risen from £231 in 2003 to £371 in 2014. There are dozens of studies that discuss the measurement of fuel poverty (See, for instance, Hills, 2012; Moore, 2012; Thomson and Snell, 2013). Traditionally, households who need to spend more than 10 percent of their income paying energy bills are defined as in fuel poverty. More recently, fuel poverty in the UK is measured using the Low Income High Costs (LIHC) indicator. According to Department of Energy and Climate Change, '*A household is considered to be fuel poor if: they have required fuel costs that are above average (the national median level); were they to spend that amount, they would be left with a residual income* *below the official poverty line*.'[10] In both measures, households who spend a large proportion of their income are directly linked to fuel poverty.

There is a strong association between the 'absolute poverty' and fuel poverty (Healy and Clinch, 2004; Howden-Chapman et al., 2012; Legendre and Ricci, 2015; Palmer et al., 2008). Since the basic requirement of energy consumption does not differ a lot among households, income level directly determines the proportion of energy spending out of total income, thus has a close relationship with fuel poverty (Healy and Clinch, 2004). Many households are fuel 'vulnerable' in the sense that they fall below the fuel poverty line just after deducting energy expenses out of their income. Retired people, households who rent to live, and those with poor house insulation have high likelihood to become fuel vulnerable (Legendre and Ricci, 2015).

Therefore, overlooking the presence of fuel poverty risks a superficial interpretation of any identified housing wealth effect on energy consumption. The fuel vulnerable group should be analysed separately from the rest of the population due to their different energy consumption patterns. They are operating below the 'fuel poverty line', which means housing wealth changes might have a greater impact on their energy consumption. When housing wealth increases, they will be tempted to consume more energy, not to be extravagant, but to meet basic energy needs. The former should be discouraged for energy conservation purposes, whilst the latter should be supported to assure basic social and economic equalities. The findings from such an analysis is particularly important for policymakers, who should strike a balance between social justice and economic efficiency.

Although theories and empirical findings suggest a strong link between the proportion of household income spent on energy and fuel poverty, there is not a hard and fast rule to define fuel poverty line. We opt for a flexible strategy to interrogate the fuel poverty effect. Specifically, we sort respondents into quantiles based on the ratio between energy consumptions and household income, and then analysis energy consumption responses to housing wealth changes within each quantile. Compared to the dummy variable approach (i.e., arbitrarily determine a fuel poverty line), this method can reveal the gradual changes of housing wealth effects as the ratio of energy consumption to household income increases. This approach allows us to examine the relation between housing wealth and energy consumption in each quantile of energy spending, and identify the quantile with the highest and the lowest housing wealth effect.

[10] https://www.gov.uk/government/collections/fuel-poverty-statistics

Table 3. Variable definition and descriptive statistics

Variable	Definition	Obs	Mean	Std. Dev.	Min	Max
C	Energy consumption (gas and electricity)	4293	1270.347	545.377	0	7000
W	Housing wealth	3979	242937.700	138936.700	76	2000000
Y	Gross household income	5433	3598.873	2475.861	0	20000
old	Whether individual is older than 60	5485	0.366	0.482	0	1
S_fut	Whether subjective future financial situation is worse off	5485	0.196	0.397	0	1
combined_bill	Whether energy bills are paid as a combined one or separate ones	4824	0.545	0.498	0	1
conservative	Whether individuals have conservative environmental habits	5485	0.541	0.498	0	1
gender	Male or not	5485	0.446	0.497	0	1
ncars	Number of cars	5420	1.534	0.959	0	6
hheat	Whether household is able to keep property warm enough	5418	1.060	0.240	1	3
hhsize	Number of people in household	5435	2.630	1.312	1	10
hsbeds	Number of bedrooms	5428	3.045	0.963	0	7
owner	Whether household own property outright/with mortgage or not	5485	0.799	0.401	0	1
employ	Whether individual is in paid employment	5350	0.551	0.497	0	1

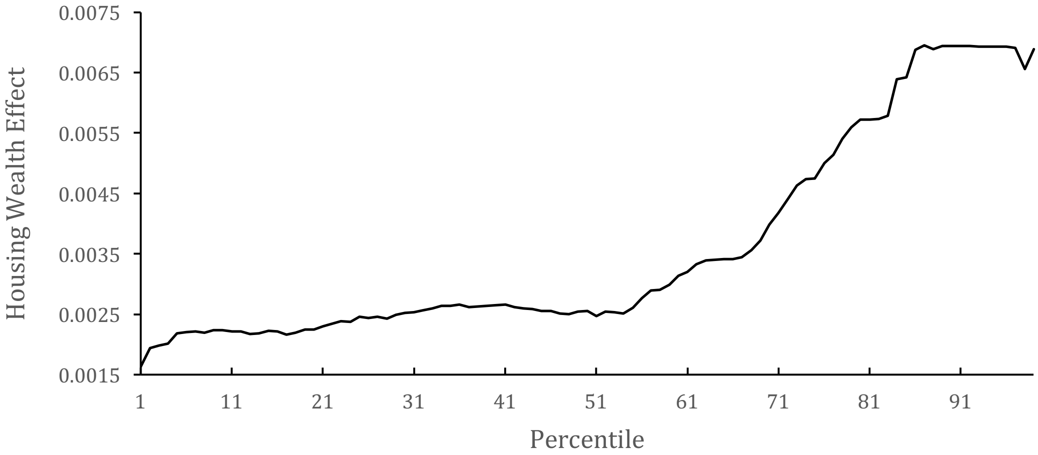
Notes: This table shows definitions and descriptive statistics of main variables in this paper. The first column shows the variable name (in italic font). The second column shows the definition of each variable. The third to seventh column presents the total number of observations, mean, standard deviation, minimum value and maximum value, respectively.

3.4. Empirical findings and Discussions

Table 4 presents the OLS regression outputs of five models with energy consumption to income ratio (i.e., $\frac{C}{Y}$) as the dependent variable. Model (1) is the baseline model that includes housing wealth to income ratio (i.e., $\frac{W}{Y}$), and the wave and region dummies only. Model (2) adds all variables included in Equation (5). Model (5) is the same as model (2) except that it uses clustered standard error. Model (3) and (4) are intermediate calculations without either the wave and region dummies or the control variables to check the robustness of the findings in Model (5). Overall Model (5) is the best one in terms of coefficient estimates and model fitting statistics. We then use Model (5)'s specification in the quantile regression analysis. A total of five more models are estimated for the 10^{th}, 25^{th}, 50^{th}, 75^{th}, and 90^{th} percentile respectively, and the results are given in Table 5. The outputs of Model (5) in Table 4 is also included in the last column of Table 5 for comparison purposes.

The quantile regression outputs show the gradual changes of housing wealth effect across groups with different energy consumption to income ratios. Although the overall housing wealth effect is identified to be around 0.002 in all models included in Table 4, the quantile models in Table 5 suggested a substantial disparity between the 10^{th} and the 90^{th} percentiles of the sample. For example, the housing wealth effect for the most worth-off group (i.e., the 90^{th} percentile) is 0.0069, which is more than three times of that for the most well-off group (i.e., the 10^{th} percentile). The estimates of these coefficients across the five percentiles considered show a consistent increasing trend as the proportion of energy consumption in income increases. To further explore this pattern, we also run 99 quantile regressions from the 1^{st} to the 99^{th} percentile with a 1% step value. The estimated housing wealth effect in these regressions are plotted in Figure 2. The housing wealth effect remains stable until around the 50^{th} percentile, where it starts to increase steadily and rapidly. It once again stabilized at around the 85^{th} percentile. These evidences are consistent with the definition of fuel poverty by the Department of Energy and Climate Change (i.e., fuel cost is above the national average), and with the statistics reported in the Annual Fuel Poverty Statistics Report (i.e., 10.6% of the UK households are fuel poor). We conclude that fuel poverty affects housing wealth's effect on energy consumption significantly. Energy-poor households are much more responsive to the changes of housing wealth when it comes to energy consumption. When energy poor households perceive an increase in their housing wealth, their energy consumption level will go up considerably more than other households.

Figure 2. Quantile regression estimation of housing wealth effect on energy consumption (1^{st} to 99^{th} percentile)



The quantile regression approach reliably separates the direct housing wealth effects from other energy consumption determinants, as evident in the first row in Table 5. Moreover, it also improved the estimation of the indirect effect of housing wealth on energy consumption, as discussed below.

<u>*Age Effect*</u>

Elderly residents generally spend less on energy, as indicated by the coefficient estimates of variable *Old* in Model (5). However, this mostly comes from the 25th and 50th percentile groups, according to the quantile regression outputs of Models (7) and (8). It seems that both the most well-off group and the fuel poor groups consumer more if they are aged 60 or above. All else being equal, elderly people needs to consume more energy because they tend to spend more time in their houses and requires more heating and cooling than younger people. Meanwhile, they also want to save on energy (among many other things), as indicated by the significant coefficient estimate of *Old* in Model (5). However, the elderlies in the most well-off group have the means to spend as much as they want on energy, whilst the elderlies in the worst off groups have to spend a substantial proportion of their income on energy even if they want to save. The only groups who both want and can save on energy is the 25th and the 50th percentile groups, of which the coefficient estimates of *Old* is positive.

Age moderates housing wealth effect in a similar way. Although as a whole, the elderlies are likely to spend more on energy in face of an increase of housing wealth, the housing wealth effect is smaller for the worth-off groups (i.e. the 75th and 90th percentiles) because they have a relatively smaller budget to manoeuvre and more financial issues to deal with. When the energy consumption to income ratio goes below the median level, elderly people tend to spend even more of the perceived housing wealth on energy, as suggested by the positive coefficient loadings on variable Old in Models (6) through (8).

<u>*Energy Conservation Attitude*</u>

The overall effect of energy conservation attitude on energy consumption is insignificant in Model (5). However, when we analyse this relationship by quantile, the results make more sense. The better-off groups (i.e., the 10th to 50th percentile) tend to save more on energy consumption if they are classified as energy conservative (i.e., *conservative*=1). This is in the same vein as the findings regarding the age effect. For the fuel poor groups (i.e., the 75^{th} and the 90^{th} percentile), even if they are very environmentally conscious, they are unlikely to have the financial means to act upon such a good intention. Consequently, the coefficient estimates in Models (9) and (10) are statistically insignificant, which means energy conservation attitude does not have a significant effect on energy consumption for these groups.

However, energy conservative people will be less affected by the housing wealth effect on energy consumption, and this tendency is stronger among the worse-off groups. The coefficient estimates of the interaction term between *conservative* and the housing wealth variable is negative in all the quantile regression models in Table 5, and the largest coefficient loading (in absolute term) is in the 90^{th} percentile model. Intention is easier to be translated to actions even if one's housing wealth level is only perceived to be improved.

Confidence in Financial Situation

we identify an influence of financial constraints on energy consumption behaviour, in terms of both energy spending out of total income, and the housing wealth effect on energy spending. First of all, the confidence in one's future financial conditions affects energy consumption behaviour directly. Financial constrained people generally spend less on energy consumption due to their poor finance prospect. As shown in Model (5), people who believe they would have finance difficulty in the future save an average of more than 6% on energy out of income. This effect is stronger among more financially disadvantaged groups (i.e., the higher percentile groups). For example, the coefficient estimates of *S_fut* in the 90^{th} percentile model is -0.0244, which more than ten times greater than that in the 10^{th} percentile model.

Understandably, when there is a perceived increase in housing wealth, less confident groups (i.e., when *S_fut* =1) may experience a boost in their confidence, and subsequently spend more on energy. Once again, this pattern is much stronger among the worse-off groups. The increase in housing wealth effect for the 90^{th} percentile group is more than ten times greater than that for the 10^{th} percentile group. This suggests that the confidence in future financial situation has great impact on energy consumption behaviours for the worse-off groups.

Framing effect

Compared with those pay bills separately, people who pay combined bills spend 0.5% less on energy out of income. The framing effect believes that the way options are presented can influence people's decision-making. When people use combined bill payment, the aggregated cost figure might look bigger than each of the separated gas and electricity costs. Consequently, people may perceive a large energy consumption level, and consequently lower their consumption thereafter.

The frame effect is a type of 'nudge' that affect people's behaviours without changing economic incentives or forbidding the exercise of freewill. In the context of combined energy bill payment, it is essentially a psychological pressure that works on a subconsciously level to induce people to spend less on energy. Our empirical evidence show that this nudge works like a double-edged sword. For better-off groups (i.e. the 10^{th} to 50^{th} percentile groups), the nudge effect works as expected when housing wealth increase. However, for the worse-off groups (i.e., the 75^{th} and the 90^{th} percentile), the long-experience pressure on energy spending actually will boost the housing wealth effect. In other words, the positive relationship between housing wealth and energy consumption is stronger for worse-off groups who use combined bill payment method.

Table 4. Housing wealth and energy consumption

	(1)	(2)	(3)	(4)	(5)
$\frac{W}{Y}$	0.0030***	0.0021***	0.0021***	0.0021***	0.0021***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
old		-0.0166***	-0.0163***	-0.0136***	-0.0166***
		(0.003)	(0.002)	(0.005)	(0.002)
old*$\frac{W}{Y}$		0.0020***	0.0020***	0.0020***	0.0020***
		(0.000)	(0.000)	(0.000)	(0.000)
S_fut		-0.0635***	-0.0643***	-0.0624***	-0.0635***
		(0.003)	(0.011)	(0.013)	(0.011)
S_fut *$\frac{W}{Y}$		0.0087***	0.0087***	0.0085***	0.0087***
		(0.000)	(0.001)	(0.002)	(0.001)
combined_bill		-0.0055**	-0.0043**	-0.0060***	-0.0055***
		(0.002)	(0.002)	(0.002)	(0.002)
combined_bill *$\frac{W}{Y}$		0.0003***	0.0003***	0.0003***	0.0003***
		(0.000)	(0.000)	(0.000)	(0.000)
conservative		0.0062*	0.0067	0.0032	0.0062
		(0.003)	(0.004)	(0.006)	(0.005)
conservative*$\frac{W}{Y}$		-0.0033***	-0.0035***	-0.0024*	-0.0033***
		(0.000)	(0.001)	(0.002)	(0.001)
gender		-0.0004	-0.0005		-0.0004
		(0.002)	(0.002)		(0.002)
ncars		-0.0027*	-0.0030**		-0.0027**
		(0.002)	(0.001)		(0.001)
hheat		-0.0043	-0.0015		-0.0043
		(0.007)	(0.007)		(0.007)
hhsize		0.0001	0.0003		0.0001
		(0.001)	(0.002)		(0.002)
hsbeds		-0.0047***	-0.0048***		-0.0047***
		(0.002)	(0.001)		(0.001)
owner		-0.0037	0.0007		-0.0037
		(0.011)	(0.004)		(0.005)
employ		-0.0058*	-0.0058*		-0.0058
		(0.003)	(0.004)		(0.004)
_cons	0.0158*	0.0635***	0.0614***	0.0307***	0.0635***
	(0.009)	(0.014)	(0.011)	(0.004)	(0.010)
wave dummies	yes	yes	no	yes	yes
region dummies	yes	yes	no	yes	yes
clustered SE	no	no	yes	yes	yes
N	3292	3184	3184	3292	3184
R2	0.7531	0.9275	0.9268	0.9200	0.9275
Adj-R2	0.7520	0.9268	0.9264	0.9194	0.9268
F-stat	666.17***	1345.09***	2496.59***	1579.72***	2060.03***

Notes: This table shows results from OLS regression. *, **, and *** denote significance level of 10%, 5%, and 1%, respectively. The dependent variable is energy consumption divided by total income. *hw_income* is the housing wealth to income ratio. Clustered SE is the clustered standard error on each household. Model (1) only include *hw_income* as the explanatory variables. Model (2) also include an array of mediators and control variables. Model (5) use clustered standard error on each household. To verify the robustness of the results, model (3) drops wave and region dummies, and model (4) drops control variables.

Table 5. Quantile regression results: housing wealth effect on energy consumption

	(1)	(2)	(3)	(4)	(5)	(6)
percentile	0.10	0.25	0.50	0.75	0.90	OLS
$\frac{W}{Y}$	0.0022***	0.0025***	0.0025***	0.0047***	0.0069***	0.0021***
old	0.0018*	-0.0015*	-0.0074***	0.0024	0.0143***	-0.0166***
old*$\frac{W}{Y}$	0.0001***	0.0006***	0.0016***	-0.0006***	-0.0028***	0.0020***
S_fut	-0.0017*	-0.0023***	-0.0078***	-0.0114***	-0.0244***	-0.0635***
S_fut *$\frac{W}{Y}$	0.0004***	0.0006***	0.0018***	0.0026***	0.0055***	0.0087***
combined_bill	-0.0028***	-0.0022***	-0.0038***	-0.0081***	-0.0110***	-0.0055***
combined_bill *$\frac{W}{Y}$	-0.0000	-0.0002***	-0.0003***	0.0003***	0.0003***	0.0003***
conservative	-0.0019**	-0.0028***	-0.0025*	-0.0025	0.0000	0.0062
conservative*$\frac{W}{Y}$	-0.0002***	-0.0003***	-0.0005***	-0.0007***	-0.0011***	-0.0033***
gender	-0.0002	-0.0004	-0.0004	-0.0003	0.0000	-0.0004
ncars	-0.0005	-0.0006	-0.0012*	-0.0019*	-0.0022**	-0.0027**
hheat	-0.0043**	-0.0015	0.0012	0.0048	0.006	-0.0043
hhsize	0.0017***	0.0010***	0.0012**	0.0019**	0.0029***	0.0001
hsbeds	-0.0021***	-0.0023***	-0.0028***	-0.0038***	-0.0056***	-0.0047***
owner	-0.0042	-0.0004	-0.0007	0.0018	-0.0078	-0.0037
employ	-0.0019**	-0.0011	-0.0022*	-0.0055**	-0.0084***	-0.0058
_cons	0.0198***	0.0194***	0.0251***	0.0237**	0.0393***	0.0635***

Notes: This table shows results from quantile regression. *, **, and *** denote significance level of 10%, 5%, and 1%, respectively. The dependent variable is energy consumption divided by total income. hw_income is the housing wealth to income ratio. There are six interaction terms that are product of certain independent variable and hw_income: old*hw, findifffut*hw, findiffnow*hw, billbehind*hw, combined*hw, and conservative*hw. Model (1) predicts the dependent variable in the 10th percentile. Model (2) predicts the dependent variable in the 25th percentile. Model (3) predicts the dependent variable in the 50th percentile. Model (4) predicts the dependent variable in the 75th percentile. Model (5) predicts the dependent variable in the 90th percentile. Model (6) is the OLS model (5) in Table 4.

4. Conclusions

This paper investigates the housing wealth effect on energy consumption in the UK. Using macroeconomics data, our long-run investigation reveals a positive relation between housing wealth and residential energy consumption between 1995 and 2016 in the UK. We further explore this relation using data at the household level. Leveraging a large nationwide household survey data across five waves, we confirm the significant association between housing wealth and energy consumption at the micro-level as well. As the perception of housing value increases, people tend to increase their energy consumption. This effect varies according to respondents' age, financial situation, and environmental awareness. We also investigate the role of framing in moderating housing wealth effect on residential energy consumption. Framing effect, as represented by whether households make combined bill payment or separate bill payment, does affect energy consumption. Combined bill payers save more on energy since they are more likely to feel 'pressure' of the big amount on their bill. However, such people have stronger housing wealth effect; they increase greater marginal energy spending than others facing same amount of housing wealth increase.

Our household-level analysis also shed lights on the intriguing relation among housing wealth, residential energy consumption, and fuel poverty. By looking into different quantiles of the energy consumption distribution. We run the quantile regression on the 5th, 25th, 50th, 75th and 95th percentile, and identify an interesting pattern of the varying housing wealth effect. Overall, the effect becomes stronger as the energy to income ratio increases. When energy-poor households perceive an increase in their housing wealth, their energy consumption level will go up considerably more than other households. However, this is mainly due to their needs to bring their energy consumption level to the normal level, as many of them might have been operating below the 'fuel poverty line'. Such increase in energy consumption should not be discouraged; but policy makers do need to be wary about the externality of such an effect. Cashing out housing wealth appreciation is not straightforward, sometimes is not even possible. This is particularly true for financially constrained households, such as the energy-poor group. If they act upon the 'feeling rich' psychological effect resulted from housing wealth appreciation, their financial and energy consumption situations could be worsened in future, with a larger energy bill down the road. On the other hand, during financial downturns, local governments and support groups should also take into account the additional psychological pressure from housing wealth depreciation on energy consumptions among these households. In summary, the relation between housing wealth and residential energy consumption varies according to building and household characteristics, and psychological factors play a significant role in moderating such a relation. This analysis provides empirical evidence from the UK that shed light on the connection between housing wealth and residential energy consumption. The findings are helpful in the design and delivery of energy consumption policies that can be both economically beneficial and socially fair.

Acknowledgement:

We are grateful for financial support from the Senior Members' Research Grant from Newnham College, University of Cambridge.

Reference

1. Aladangady A. Housing Wealth and Consumption: Evidence from Geographically Linked Microdata. Am Econ Rev 2017;107; 3415-3446.
2. Ando A, Modigliani F. The Life-Cycle Hypothesis of Saving - Aggregate Implications and Tests. Am Econ Rev 1963;53; 55-84.
3. Attanasio OP, Blow L, Hamiltonww R, Leicester A. Booms and Busts: Consumption, House Prices and Expectations. Economica 2009;76; 20-50.
4. Aydin E, Brounen D, Kok N. Information provision and energy consumption: Evidence from a field experiment. Energ Econ 2018;71; 403-410.
5. Baker P, Blundell R, Micklewright J. Modeling Household Energy Expenditures Using Micro-Data. Econ J 1989;99; 720-738.
6. Barrell R, Costantini M, Meco I. Housing wealth, financial wealth, and consumption: New evidence for Italy and the UK. Int Rev Financ Anal 2015;42; 316-323.
7. Booth AL, Francesconi M, Frank J. Temporary jobs: Stepping stones or dead ends? Econ J 2002;112; F189-F213.
8. Bostic R, Gabriel S, Painter G. Housing wealth, financial wealth, and consumption: New evidence from micro data. Regional Science and Urban Economics 2009;39; 79-89.
9. Brandon G, Lewis A. REDUCING HOUSEHOLD ENERGY CONSUMPTION: A QUALITATIVE AND QUANTITATIVE FIELD STUDY. Journal of Environmental Psychology 1999;19; 75-85.
10. Brounen D, Kok N, Quigley JM. Residential energy use and conservation: Economics and demographics. European Economic Review 2012;56; 931-945.
11. Campbell JY, Cocco JF. How do house prices affect consumption? Evidence from micro data. Journal of Monetary Economics 2007;54; 591-621.
12. Carroll CD. The Buffer-Stock Theory of Saving - Some Macroeconomic Evidence. Brookings Pap Eco Ac 1992; 61-135.
13. Carroll CD, Fuhrer JC, Wilcox DW. Does Consumer Sentiment Forecast Household Spending - If So, Why. Am Econ Rev 1994;84; 1397-1408.
14. Carroll CD, Otsuka M, Slacalek J. How Large Are Housing and Financial Wealth Effects? A New Approach. J Money Credit Bank 2011;43; 55-79.
15. Cashin DB, Mcgranahan L. Household energy expenditures, 1982-2005. Chic. Fed Lett.: Fed. Reserve Bank Chic 2006;227; 1-5.
16. Chen J. Re-evaluating the association between housing wealth and aggregate consumption: New evidence from Sweden. J Hous Econ 2006;15; 321-348.
17. Clark WAV, Huang YQ. The life course and residential mobility in British housing markets. Environ Plann A 2003;35; 323-339.
18. Darke PR, Chung CMY. Effects of pricing and promotion on consumer perceptions: it depends on how you frame it. J Retailing 2005;81; 35-47.
19. Deaton A. Understanding consumption / Angus Deaton. Clarendon Press ; Oxford University Press: Oxford [England] : New York; 1992.
20. DelVecchio D, Krishnan HS, Smith DC. Cents or percent? The effects of promotion framing on price expectations and choice. J Marketing 2007;71; 158-170.
21. Dolmas J. A note on the potential pitfalls in estimating a 'wealth effect' on consumption from aggregate data. Econ Lett 2003;78; 437-441.

22. Druckman A, Jackson T. Household energy consumption in the UK: A highly geographically and socio-economically disaggregated model. Energ Policy 2008;36; 3177-3192.
23. Estes R, Hosseini J. The Gender Gap on Wall Street - an Empirical-Analysis of Confidence in Investment Decision-Making. J Psychol 1988;122; 577-590.
24. Estiri H. Building and household X-factors and energy consumption at the residential sector A structural equation analysis of the effects of household and building characteristics on the annual energy consumption of US residential buildings. Energ Econ 2014;43; 178-184.
25. Fereidouni HG, Tajaddini R. Housing Wealth, Financial Wealth and Consumption Expenditure: The Role of Consumer Confidence. J Real Estate Financ 2017;54; 216-236.
26. Gan J. Housing Wealth and Consumption Growth: Evidence from a Large Panel of Households. Rev Financ Stud 2010;23; 2229-2267.
27. Gatersleben B, Steg L, Vlek C. Measurement and determinants of environmentally significant consumer behavior. Environ Behav 2002;34; 335-362.
28. Gourinchas PO, Parker JA. Consumption over the life cycle. Econometrica 2002;70; 47-89.
29. Healy JD, Clinch JP. Quantifying the severity of fuel poverty, its relationship with poor housing and reasons for non-investment in energy-saving measures in Ireland. Energ Policy 2004;32; 207-220.
30. Hills J, 2012. Getting the measure of fuel poverty, Final Report of the Fuel Poverty Review.
31. Howden-Chapman P, Viggers H, Chapman R, O'Sullivan K, Barnard LT, Lloyd B. Tackling cold housing and fuel poverty in New Zealand: A review of policies, research, and health impacts. Energ Policy 2012;49; 134-142.
32. Huang WH. The determinants of household electricity consumption in Taiwan: Evidence from quantile regression. Energy 2015;87; 120-133.
33. Iacoviello M. Housing Wealth and Consumption Board of Governors of the Federal Reserve System International Finance Discussion Papers 1027 2011;August 2011.
34. Iyke BN. Electricity consumption and economic growth in Nigeria: A revisit of the energy-growth debate. Energ Econ 2015;51; 166-176.
35. Jackson T, Papathanasopoulou E, Bradley P, Druckman A, 2007. Attributing UK Carbon Emissions to Functional Consumer Needs: methodology and pilot results, RESOLVE Working Paper 01-07, University of Surrey.
36. Jia H, Yang S, Lu XH, Park CW. Do Consumers Always Spend More When Coupon Face Value is Larger? The Inverted U-Shaped Effect of Coupon Face Value on Consumer Spending Level. J Marketing 2018;82; 70-85.
37. Juster FT, Lupton JP, Smith JP, Stafford F. The decline in household saving and the wealth effect. Rev Econ Stat 2006;88; 20-27.
38. Kahneman D. Maps of bounded rationality: Psychology for behavioral economics. Am Econ Rev 2003;93; 1449-1475.
39. Khandker SR, Barnes DF, Samad HA. Are the energy poor also income poor? Evidence from India. Energ Policy 2012;47; 1-12.
40. Kishor NK. Does consumption respond more to housing wealth than to financial market wealth? if so, why? J Real Estate Financ 2007;35; 427-448.
41. Legendre B, Ricci O. Measuring fuel poverty in France: Which households are the most fuel vulnerable? Energ Econ 2015;49; 620-628.

42. Lehnert A, 2004. Housing, consumption, and credit constraints. Board of Governors of the Federal Reserve System (U.S.).
43. Ludvigson SC. Consumer confidence and consumer spending. J Econ Perspect 2004;18; 29-50.
44. Ludwig A, Sløk T. The Impact of Changes in Stock Prices and House Prices on Consumption in OECD Countries. IMF Working Paper No. 02/1 2002;January 2002.
45. Lynham J, Nitta K, Saijo T, Tarui N. Why does real-time information reduce energy consumption? Energ Econ 2016;54; 173-181.
46. Miller JI, Ratti RA. Crude oil and stock markets: Stability, instability, and bubbles. Energ Econ 2009;31; 559-568.
47. Mishkin FS. Consumer Sentiment and Spending on Durable Goods. Brookings Pap Eco Ac 1978; 217-231.
48. Moore R. Definitions of fuel poverty: Implications for policy. Energ Policy 2012;49; 19-26.
49. Ndiaye D, Gabriel K. Principal component analysis of the electricity consumption in residential dwellings. Energy and Buildings 2011;43; 446-453.
50. Nguyen-Van P. Energy consumption and income: A semiparametric panel data analysis. Energ Econ 2010;32; 557-563.
51. Nye M, Whitmarsh L, Foxon T. Sociopsychological perspectives on the active roles of domestic actors in transition to a lower carbon electricity economy. Environ Plann A 2010;42; 697-714.
52. Odusami BO. To consume or not: How oil prices affect the comovement of consumption and aggregate wealth. Energ Econ 2010;32; 857-867.
53. Paiella M. Does wealth affect consumption? Evidence for Italy. J Macroecon 2007;29; 189-205.
54. Palmer G, MacInnes T, Kenway P. Cold and Poor: An Analysis of the Link Between Fuel Poverty and Low Income. Report New Policy Institute 2008.
55. Petrusic WM, Baranski JV. Judging confidence influences decision processing in comparative judgments. Psychon B Rev 2003;10; 177-183.
56. Rahut DB, Behera B, Ali A, Marenya P. A ladder within a ladder: Understanding the factors influencing a household's domestic use of electricity in four African countries. Energ Econ 2017;66; 167-181.
57. Rao MN, Reddy BS. Variations in energy use by Indian households: An analysis of micro level data. Energy 2007;32; 143-153.
58. Ritchie JRB, Mcdougall GHG, Claxton JD. Complexities of Household Energy-Consumption and Conservation. J Consum Res 1981;8; 233-242.
59. Sapci O, Considine T. The link between environmental attitudes and energy consumption behavior. J Behav Exp Econ 2014;52; 29-34.
60. Shahbaz M, Solarin SA, Hammoudeh S, Shahzad SJH. Bounds testing approach to analyzing the environment Kuznets curve hypothesis with structural beaks: The role of biomass energy consumption in the United States. Energ Econ 2017;68; 548-565.
61. Shiller RJ. Irrational Exuberance, STU - Student edition, 3 ed. Princeton University Press; 2015.
62. Sierminska E, Takhtamanova Y. Financial and Housing Wealth and Consumption Spending: Cross-Country and Age Group Comparisons. Housing Studies 2012;27; 685-719.
63. Sniezek JA. Groups under Uncertainty - an Examination of Confidence in Group Decision-Making. Organ Behav Hum Dec 1992;52; 124-155.

64. Sonje AA, Casni AC, Vizek M. Does housing wealth affect private consumption in European post-transition countries? Evidence from linear and threshold models. Post-Communist Econ 2012;24; 73-85.
65. Swan LG, Ugursal VI. Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. Renew Sust Energ Rev 2009;13; 1819-1835.
66. Takama T, Tsephel S, Johnson FX. Evaluating the relative strength of product-specific factors in fuel switching and stove choice decisions in Ethiopia. A discrete choice model of household preferences for clean cooking alternatives. Energ Econ 2012;34; 1763-1773.
67. Thomas C, Benzeval M, Stansfeld SA. Employment transitions and mental health: an analysis from the British household panel survey. J Epidemiol Commun H 2005;59; 243-249.
68. Thompson SCG, Barton MA. Ecocentric and Anthropocentric Attitudes toward the Environment. Journal of Environmental Psychology 1994;14; 149-157.
69. Thomson H, Snell C. Quantifying the prevalence of fuel poverty across the European Union. Energ Policy 2013;52; 563-572.
70. Tso GKF, Guan J. A multilevel regression approach to understand effects of environment indicators and household features on residential energy consumption. Energy 2014;66; 722-731.
71. Tversky A, Kahneman D. The Framing of Decisions and the Psychology of Choice. Science 1981;211; 453-458.
72. Tversky A, Kahneman D. Rational Choice and the Framing of Decisions. J Bus 1986;59; S251-S278.
73. Uutela HM, 1994. The everyday energy use and lifestyles of families in single family households, In: Arvola A, Rautavaara E, Uutela A (Eds), Energy and the Consumer, Helsinki: Ministry of Trade and Industry, Energy Department; 1994.
74. Valenzuela C, Valencia A, White S, Jordan JA, Cano S, Keating J, Nagorski J, Potter LB. An analysis of monthly household energy consumption among single-family residences in Texas, 2010. Energ Policy 2014;69; 263-272.
75. Vringer K, Aalbers T, Blok K. Household energy requirement and value patterns. Energ Policy 2007;35; 553-566.
76. Willis RM, Stewart RA, Panuwatwanich K, Williams PR, Hollingsworth AL. Quantifying the influence of environmental and water conservation attitudes on household end use water consumption. J Environ Manage 2011;92; 1996-2009.