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Determinants of energy consumption and exposure to energy price risk: a UK study

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Abstract In this study, we examine the drivers of household energy consumption with a view towards gauging which households are particularly vulnerable to energy price risk. We specifically investigate the relative importance of household socio-economic characteristics versus dwelling characteristics in explaining per capita gas consumption for space heating. The study draws upon a large random sample of households from the English Housing Survey (EHS) to understand the importance of, and interaction between, household and building characteristics. A multivariate OLS regression is used to identify the relative effects of various consumption drivers on gas used for space heating. The use of standardised coefficients allows for a discussion of the marginal contributions of each factor to energy consumption. The results show that variation in gas usage is largely determined by household socio-economic characteristics rather than physical dwelling characteristics. This includes the significant influence of household characteristics such as composition (or type), size, employment status, and income. The main contribution of the study is to underline the relative importance of household socio-economic characteristics over dwelling characteristics in explaining per capita energy consumption. The reported findings challenge the prevailing policy practice, which focusses mostly on dwelling characteristics.

Keywords Energy consumption · Energy price risk · Households · Dwellings · Socio-economic characteristics

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Determinanten des Energieverbrauchs und Energiepreisrisiko: Eine Studie aus Großbritannien

Zusammenfassung Die vorliegende Studie untersucht, welche Faktoren den Energieverbrauch von Haushalten beeinflussen um zu beurteilen, welche Haushalte besonders anfällig für Energiepreisrisiken sind. Insbesondere geht die Analyse der Frage nach, ob sozioökonomische Eigenschaften von Haushalten wichtigere Treiber des Energieverbrauchs sind als Gebäudeeigenschaften. Die Studie stützt sich auf eine große Zufallsstichprobe von Haushalten aus der English Housing Survey (EHS), um die Bedeutung und Wechselwirkung zwischen Haushalts- und Gebäudeeigenschaften zu verstehen. Eine multivariate Regression wird verwendet, um die relativen Auswirkungen verschiedener Verbrauchstreiber für Heizenergie zu identifizieren. Die Verwendung standardisierter Koeffizienten ermöglicht eine Diskussion des marginalen Beitrags jedes Faktors zum Gesamtenergieverbrauch. Die Ergebnisse zeigen, dass die Variation des Gasverbrauchs in hohem Maße von den sozioökonomischen Merkmalen der Haushalte und nicht primär von den physischen Merkmalen der Wohnung bestimmt wird. Ein signifikanter Einfluss geht vor allem von Haushaltsmerkmalen wie Zusammensetzung, Art, Größe, Beschäftigungsstatus und Einkommen aus. Somit stellen die vorliegenden Ergebnisse die vorherrschende Politikpraxis in Frage, die sich hauptsächlich auf physische Wohnungseigenschaften und technische Energieeffizienz konzentriert und die ökonomischen und sozialen Faktoren eines erhöhten Energiepreisrisikos von Haushalten weitgehend vernachlässigt.

1 Introduction

Households, particularly those with lower incomes, are exposed to considerable risks from energy price volatility. The political and academic debates on these risks often refer to the fuel poverty that a growing number of households face (Moore 2012). Although there is disagreement over the definition of fuel poverty, it is acknowledged that a large number of households are forced to spend disproportionate amounts of their incomes on energy. From a policy perspective, the residential built environment has been an important target for energy conservation policies given its immense potential for energy savings through energy efficiency measures. In recent years, this has led to direct government interventions in the form of building standards, mandatory energy labelling, and the promotion of energy efficiency investments. Energy savings estimated by such policies are ex-ante, bottom-up engineering estimations, in which households are assumed to utilise new technologies without necessarily adjusting their usage behaviour (Kavgic et al. 2010; Blumstein and Stoft 1995; Rosenfield et al. 1993; Koomey et al. 1991). Despite their forecasts, such studies are unable to accurately quantify the ex-post energy saving outcome. For example, efficiency gains predicted ex-ante could be offset by a rise in energy demand through behavioural changes—the paradox of the 'rebound effect' (Sorrell 2007; Greening et al. 2000; Aydin et al. 2014). That is, households inhabiting dwellings retrofitted to a high energy efficient standard end up consuming relatively more energy. In their study of OECD countries, Sorrell et al. (2009) conclude that for household heating, the mean value of the long-run direct rebound effect is around 30%. This emphasises the importance of investigating the empirical relationship between household socio-economic characteristics and building characteristics in explaining household energy consumption.

In the European Union, the Directive concerning the Energy Performance of Buildings, which came into effect in the UK in 2007, requires member states to introduce Energy Performance Certificates (EPCs) for buildings. The objective of the Directive is to increase information provision for market participants, and promote improvements in the energy performance of buildings within the Community, taking into consideration outdoor climatic and local conditions as well as indoor climate requirements and cost-effectiveness. Therefore, it is important to highlight that EPCs are an environmental rating scheme to indicate the energy performance of a building in order to aid the decision-making process in the real estate market. As such, EPCs do not strictly indicate the energy consumption of a building, but instead reflect the energy efficiency of a building.

In this context, this study conducts an empirical investigation into the main factors driving energy consumption in dwellings in England. In particular, it examines the relative importance of household socio-economic characteristics and dwelling characteristics in explaining the variance in gas used for space heating. The study draws upon a large sample of micro-data on households and dwellings from the English Housing Survey (EHS), a continuous cross-sectional survey administrated by the Department for Communities and Local Government (DCLG). We use multivariate OLS regression to explore the interaction of household socio-economic and dwelling characteristics on energy consumption. Our findings highlight the significance of socio-economic characteristics to household energy consumption behaviour. In contrast to many studies across several countries that report that the dwelling characteristics affect domestic energy consumption significantly more, our results reveal that households' characteristics and consumption behaviour substantially impact domestic energy consumption.

2 Background on residential energy consumption

According to National Statistics (2017), the domestic sector accounted for 29% of total energy consumption between 2015–2016, final domestic energy consumption increased by 3.1% without a simultaneous increase in average temperature levels. The majority of this increase related to gas consumption (4.6% higher), reflecting higher heating requirements. Average electricity consumption dropped by 0.8% during the same period. Moreover, 80% of domestic final energy consumption relates to space and water (provided primarily by gas) heating. In addition to this, consumption per household increased by 2.1% between 2015–2016, while per capita energy consumption also increased by 2.3%. Finally, in addition to weather factors, several household characteristics (i.e., number of households, disposable income, and energy prices), efficiency measures, the number and usage of appliances along with appliance efficiencies all affect fuel and electricity consumption (National Statistics 2017).

At a theoretical level, Hitchcock (1993) proposes an integrated framework for household energy use and behaviour. A household operates as a 'system' that can be defined both as a physical household and as a social household. The physical household includes the materials and devices operating in a dwelling, while the social household constitutes the occupants that live in the dwelling. The combination of these two subsystems and the way they interact with each other in addition to the household's environment determine the energy consumption of that dwelling. This basic system is then extended to include a number of detailed system components such as static characteristics, dwelling size, materials, heating system, stock of appliances, etc. (as physical parameters); household income, social status, number of occupants, etc. (as human/social parameters); and climatic, economic and cultural system (as environmental parameters). With regards to empirical studies, the determinants of household energy consumption remain understudied. In the case of the UK, the scarcity of data has contributed to indefinite conclusions on these determinants. Several studies have examined occupants' behaviour in order to identify the effects on building energy use and/or energy performance and form any relevant policies (Allcott and Mullainathan 2010; Andersen et al. 2009; Fabi 2012; Santin 2011; Shogren and Taylor 2008; Yohanis 2012).

In one of the first micro-econometric studies, Baker et al. (1989) adopt a conditional demand approach, accounting for socio-economic characteristics of households to model energy demand in English dwellings. By using a random sample of 50,000 households pooled from 12 consecutive years of the UK's Family Expenditure Survey, they conclude that households' characteristics and energy prices have a significant bearing on the forecasting of electricity and gas consumption in English dwellings. Drawing on these findings, Druckman and Jackson (2008) cite dwelling type, tenure, household composition and rural/urban location to be important determinants of household energy consumption. Interestingly, they also examine specific neighbourhoods with contrasting levels of deprivation (based on the Index of Multiple Deprivation in England), and they report differential patterns of consumption to the different segments.

Similarly, Alberini et al. (2011) used a mixed panel/multi-year cross-sections of dwelling/households in the 50 largest metropolitan areas in the United States in order to study the residential demand for electricity and gas over the period 1997–2007. Among their findings, there is strong household response to energy prices, both in the short and long term. While they identify no evidence of significantly different elasticities across households with electric and gas heat, they find that the price elasticity of electricity demand drops with income, though the magnitude of this effect is not large.

A more recent study by Brounen et al. (2012) on energy consumption of Dutch dwellings suggests that physical building features and socio-economic characteristics of households are crucial determinants of domestic energy consumption. Specifically, age, sex, number of children, marital status and income profiles influence per capita gas and electricity consumption. In a separate specification, dwelling characteristics, such as dwelling type, vintage class, number of rooms and size are also found to be significant determinants of households' per capita gas and electricity consumption. However, unlike Druckman and Jackson (2008), gas and electricity prices are not accounted for. For the Dutch residential stock in particular, Santin et al. (2009) look at the effects of occupant behaviour on energy consumption for space heating, and find that occupant characteristics and behaviour significantly affect energy use (about 4.2%). However, they find a greater significance of dwelling characteristics (42%) while the actual effect of occupancy characteristics might be biased by, and related to, the type of dwellings. Similarly, Estiri (2014), using microdata from the 2009 Residential Energy Consumption Survey (RECS) in the United States, found that the direct effect of household socio-economic characteristics on domestic energy consumption is significantly lower than the corresponding effect coming from the dwelling characteristics.

More relevant to our study, Rehdanz (2007) uses cross-sectional data to examine the determinants of energy used for space heating and hot water supply for a sample of households in Germany. Socio-economic characteristics of households, building characteristics and energy prices are found to be important, despite the lack of controls on variation in weather conditions. Meier and Rehdanz (2010), who also adopt a conditional demand approach to incorporate socio-economic and building characteristics into the energy demand analysis, complement this study. A panel study of households in England involving more than 64,000 observations over multiple years is used to show the significant influences of socio-economic characteristics in determining residential energy consumption. It is also suggested that in order to design target-oriented policy measures, a clear understanding of the impact of differences between types of household is required. Furthermore, this is the first study to account for the variation in weather conditions and price variation over time on energy expenditure for space heating. In particular, energy expenditures are found to vary positively with the number of heating degree days per year.

In addition, Huebner et al. (2015) use a dataset including 924 English households (collected in 2011/2012) to study the comparative contribution of building factors, socio-economic characteristics, behaviours and attitudes. Their findings suggest that, *inter alia*, it is the physical dwelling attributes that determine household energy consumption. Another study of relevance to our paper is Wyatt (2013), who examines the drivers of domestic energy consumption in England, looking at both physical dwelling characteristics and a set of socio-economic characteristics of occupants. The data is sourced from electricity and gas consumption metrics provided by energy suppliers and the information company, Experian. From his results, both the size (floor area) and the different dwelling types are significant drivers of domestic energy consumption, while dwelling age appears as a non-associated factor. On the other hand, the socio-economic factors included in his empirical analysis, such as households' income, number of resident adults, and tenure status are all very significant but highly correlated with dwelling size.

More broadly, there have been a number of studies on occupants' behaviour and energy use. Fabi (2012) conduct a literature review on occupants' interactions with building controls aimed at maintaining preferred indoor environmental conditions, specifically examining the case of window opening behaviour. Occupants are found to have a large influence on the variation in energy consumption in different building types. The estimates suggest that residential energy use differs by a factor of up to two, even when equipment/appliances between households are identical. In this study, the driving forces of occupants' behaviour are a combination of physical environmental, contextual, psychological, physiological, and social factors. To give an example, window operation in residential buildings is driven by occupants' physiological factors such as age and gender, but also by psychological factors such as perceived illumination, in addition to social factors such as presence at home. Similarly, in their study of occupant control of the indoor environment in Danish dwellings (using repeated surveys of 933 respondents), Andersen et al. (2009) confirm that window opening behaviour is linked to, *inter alia*, the 'perception' of environmental variables. A number of studies are also looking at the domestic usage of the household appliances and their relation to the occupants' energy consumption behaviour (such as the Dubin and McFadden 1984).

In addition, Yohanis (2012) studies energy use behaviour among a sample of 240 households. By using a questionnaire methodology, the study investigates the key drivers that affect domestic energy use, including ascertaining the role of occupants' energy behaviour (including attitudes to saving energy and households' awareness levels). The study suggests that information provision is not adequate by itself to change households' behaviour; the adoption of 'good' energy behaviour requires a combination of strategies that disseminate information on energy issues using a variety of platforms (for e.g., newspapers, TV programmes, etc.). Significant improvements in energy behaviour can only be achieved by significantly boosting levels of awareness. Research by Santin (2011) reinforces the importance of specific behavioural patterns as drivers of energy consumption. In a survey study of energy consumption for space and water heating among 313 Dutch households, Santin (2011) investigates the influence of building characteristics (for e.g., dwelling type, size, etc.), household characteristics (i.e., socio-demographic variables and lifestyle), and occupant behaviour (for e.g., use of heating systems, frequency of household behaviours, etc.). In turn, by using these factors to determine behavioural patterns and user profiles, the study proposes that more accurate predictions of energy consumption can be achieved by linking dwelling type with user profiles, which in turn can be linked to behavioural patterns.

3 Econometric method and estimation strategy

Firstly, in order to estimate the gas used for space heating for the dwellings in the sample, a multivariate ordinary least squares (OLS) regression with log transformation is applied:

$$G_i = X_i\beta + Y_i\delta + \epsilon_i \tag{1}$$

Equation 1 relates gas used for space heating per capita in dwelling i (G_i) to a vector of explanatory variables representing household socio-economic characteristics (X_i) and dwelling characteristics (Y_i). The variables representing household socio-economic include household composition (type), household size, gross household annual income. The variables representing dwelling characteristics include number of bedrooms, age, and dwelling type. ϵ_i is a stochastic composite disturbance term taking the form of a normal distribution with a mean of zero and variance of σ^2.

4 Data and descriptive statistics

The standard methodology for investigating the determinants of energy consumption is a conditional demand analysis. The underlying premise of conditional demand analysis is to use a multivariate regression technique, which combines energy billing data with weather information and household survey data to produce robust end-use energy consumption estimates. The dataset applied to construct the regression analysis presented in this study is the English Housing Survey (EHS). The EHS is a continuous cross-sectional survey administrated by the Department for Communities and Local Government (DCLG), and it compiles information on households' housing conditions and energy efficiency in English dwellings. The EHS consists of two components: a household interview conducted with a sample of 13,300 households per year and a physical inspection by qualified surveyors of a subsample of 6200 dwellings per year.

For the purpose of this study, a sample of households drawn from the EHS 2012 series compiling various socio-economic characteristics is used. Information for a total sample size of 10,437 households was collected between April 2011 and March 2013. After the data cleaning, and for the purposes of our specifications, 9,116 household observations were regressed. Tables 1 and 2 present descriptive statistics of the refined sample.

As can be seen from Table 1, the sample includes an adequate number of households for each household type or composition given that it is representative of the population. More specifically, 12% of the sample are single person households under the age of 60, 30% are couples without children of all ages, 23% are couples with at least one dependent child, 11% are lone parents with child(ren), 8% are constituted of any other multi-person household, and the remaining 16% are single person households over the age of 60. The sample could be similarly described if we instead look at household type—the main difference being that the latter focuses on the gender of single person households, not their age. Taking the case of household size, the average number of people in a household is between 2–3. In terms of households' annual gross income, the average household earns about £30,000 per annum.

Furthermore, Table 2 presents the employment status of: (i) the primary household reference person (HRP)[1]; and (ii) the employment status of the primary HRP and their partner combined. In the first case, 41.71% of the sample are in full-time employment, 11.07% are in part-time employment, 28.92% are retired, 5.21% are unemployed, less than 1% are in full-time education, while the remaining 12.35%

[1] In the private rented sector, the HRP is the 'householder' in whose name the accommodation is rented. Where a joint tenancy agreement is place, the HRP is the person with the highest income.

Table 1 Descriptive statistics of selected household socio-economic characteristics ($n = 9116$)

Variable	Categories	Mean	St. Dev
Household composition	One person under 60 (reference)	0.12	0.32
	Couple, no dependent child(ren) under 60	0.14	0.35
	Couple, no dependent child(ren) aged 60 and over	0.16	0.37
	Couple with dependent child(ren)	0.23	0.42
	Lone parent with dependent child(ren)	0.11	0.31
	Other multi-person households	0.08	0.28
	One person aged 60 or over	0.16	0.36
Household type	Couple, no dependent child(ren) (reference)	0.30	0.46
	Couple with dependent child(ren)	0.23	0.42
	Lone parent with dependent child(ren)	0.11	0.31
	Other multi-person households	0.08	0.28
	One male	0.12	0.33
	One female	0.15	0.36
Household size	Continuous variable	2.46	1.37
Gross HH annual income (£1000)	Continuous variable	30.09	22.32

report 'other' inactive/non-specified employment status[2]. Regarding the combined household employment status, the sample is fairly representative as 45.20% of respondents are households in which at least one person is in full employment, 10.87% are households in which at least one or more members are working part-time, 28.07% are households in which no member is working (while being retired), while to the remaining 15.86% of households are those in which no one is working or retired (without any other specification on their earnings).

In continuation, Table 3 presents descriptive statistics of the dwelling characteristics of the 9116 dwelling in the dataset. As noted, the sample contains dwellings that have, on average, between 2 and 3 bedrooms. In addition, the dataset includes relatively new dwellings, as the average age of dwellings is just less than six years old. Finally, regarding the property types represented in the sample, the dataset includes a diverse group of eight different dwelling types, out of which 18% are mid-terrace, 10% are end-terrace, 24% are semi-detached, 11% are detached, 9% are bungalows, 3% are converted flats, and the remaining 23% are purpose built high/low rise flats.

In order to look into the per capita gas consumption of the dwellings and the households available in our dataset the following figures present the relationship of the mean per capita gas consumption with several subcategories such as each different dwelling type, the number of household members and their household composition. Fig. 1 below illustrates the variance in mean per capita gas consumption categorised by dwelling type. There is little standard deviation in mean per capita gas

[2] Potential biases may exist form the days/time that the survey took place, i.e. if the time/date of the survey was a weekday between 9am and 5pm, the 'full-time work' status group is disadvantaged as fewer people from this group are likely to have responded to the survey.

Table 2 Descriptive statistics of households' employment status ($n=9116$)

Variable	Frequency	Percent
Employment status of primary household reference person (HRP)		
Full time work	3802	41.71
Part-time work	1009	11.07
Retired	2636	28.92
Unemployed	475	5.21
Full time education	68	0.75
Other inactive	1126	12.35
Employment status of primary HRP and partner combined		
1 or more work full time	4120	45.20
1 or more work part time	991	10.87
None working, one or more retired	2559	28.07
None working and none retired	1446	15.86

consumption across most dwelling types, although households residing in bungalows have a noticeably higher per capita gas consumption. Finally, the purpose built flat type with high rise seems to have relative lower per capita gas consumption compared to the rest of the dwelling types.

Fig. 2, illustrates the mean per capita gas consumption in relation to the household size. From this figure, it is evident that the bigger households make substantially more efficient use of their gas consumption. In particular, the single person households consume 3–6 times more gas compared to the other multi-family/person households.

Looking at the composition of these households, we observe that the single person households that consume the most gas per capita for space heating are the aged people (related with the time that they spent at home). The second highest consumption comes from the single person households under 60 which is 1.5–2 times higher than the per capita gas consumption of the couples without dependent children (below or above the age of 60). Finally, the household composition of families with

Table 3 Descriptive statistics for selected dwelling characteristics ($n=9116$)

Variable	Categories	Mean	St. Dev
No. of bedrooms	Continuous variable	2.69	0.97
Age	Continuous variable	5.59	2.04
Dwelling type	Mid terrace (reference)	0.18	0.39
	End terrace	0.10	0.30
	Semi detached	0.24	0.43
	Detached	0.11	0.32
	Bungalow	0.09	0.29
	Converted flat	0.03	0.18
	Purpose built flat (high rise)	0.03	0.18
	Purpose built flat (low rise)	0.20	0.40

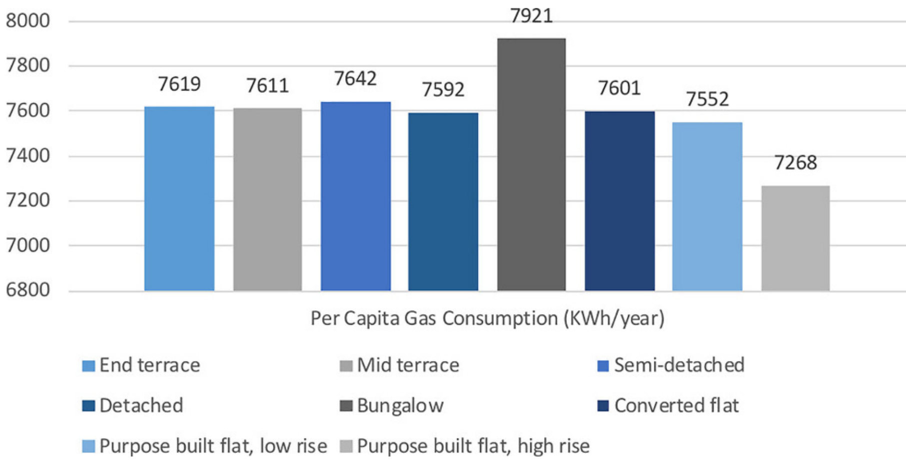

Fig. 1 Mean per capita gas consumption (for space heating) categorised by dwelling type

dependent children or any other type of multi-person household seem to consume less per capita gas consumption compared to the rest of the groups.

5 Regression results and discussion

Table 4 presents the multivariate OLS regression results of our model examining the relationship between various household and dwelling characteristics, and per capita gas used for space heating for the cross-section of English dwellings. Model 1 estimates the impact of the dwelling characteristics on per capita gas used for space heating. Model 2 appends this analysis by including the variables representing household socio-economic characteristics. Finally, Model 3 is a test for robustness, as the variable 'household composition' is replaced with 'household

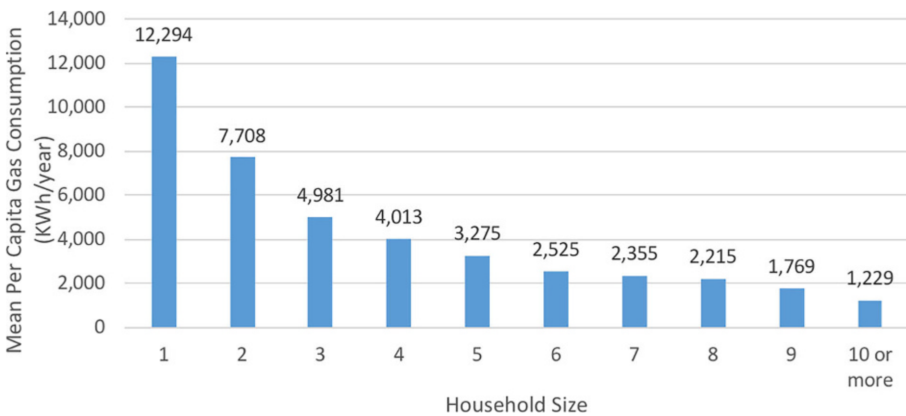

Fig. 2 Mean per capita gas consumption categorised by household size

type', which is a slightly different categorical dummy (with a different reference value). Importantly, the models make use of standardised coefficients, which allows for a discussion of the marginal contributions of each factor to energy consumption.

Importantly, numerous statistical diagnostics were conducted to produce stable coefficients and robust standard errors. First, the regression results were tested for multicollinearity using the Variance Inflation Factor (VIF). This led to the exclusion of the control variable, 'number of children in the household', as it was found to have a VIF significantly greater than 10. Second, given the presence of heteroscedasticity, robust regression was applied to weight the observations differently. Third, a logarithmic transformation of the dependent variable is applied in order to interpret marginal changes in the explanatory variables in terms of percentage changes. This transformation was favoured since the dependent variable (per capita gas consumption) and some of the independent variables were highly skewed to the right (i.e., in the positive direction). Applying log transformations worked to make the data distribution more symmetrical and the relationships between variables more linear. Finally, we test whether the non-linear combinations of the fitted values help explain the dependent variable (i.e., per capita gas consumption for space heating) using the Ramsey Regression Equation Specification Error Test (RESET).

Table 4 illustrates that, with the exception of a few variables, most coefficients are statistically significant at an acceptable confidence level (taking the case of Models 2 and 3). Together, the variables in the model explain approximately 55.70% of the variation in per capita gas used for space heating. This is an improvement over Meier and Rehdanz's (2010) model, which explains less than 30% of gas expenditure for a panel of English dwellings. In interpreting the estimated coefficients, the sign and size of the coefficients of the variables are in and of themselves important. It is important to mention at this point that we regressed a number of different combinations of household socio-economic characteristics and dwelling characteristics—the results presented here are the most consistent and robust across all considered formulations. The main finding of our paper is that household socio-economic characteristics, including household size, annual gross household income, primary employment status, and household composition (or type) are the main drivers of the per capital gas consumption (for space heating). In fact, in contrast the majority of the existing literature, dwelling type and age seem to be consistently insignificant for England.

Taking the case of dwelling characteristics, the regression results confirm that dwelling size (measured in terms of the number of bedrooms) positively effects the per capita gas consumption. With reference to the results from Model 3 (which reports standardised coefficients), a one standard deviation increase in the number of additional bedrooms has a significant, positive marginal contribution to per capita gas consumption (for space heating). The age of the dwelling (i.e., the depreciation rate of the dwelling) seems to be consistently unrelated to the per capita gas consumption for heating purposes (confirmed also by Wyatt 2013). Given that the dataset mainly includes relatively 'new dwellings' (as can be seen from Table 3), this result is not surprising, especially when considering the widespread prevalence of gas central heating in modern dwellings. Finally, after testing for the different dwelling types (also by taking different reference values), the results appear consis-

Table 4 OLS multivariate regression

Dependent variable: Gas consumption for space heating per capita (log)	Coef. (t-stat) Model 1	Coef. (t-stat) Model 2	Coef. (t-stat) Model 3
Dwelling characteristics			
No. of beds (Standardised)	0.060*** (7.72)	0.295*** (47.45)	0.297*** (47.57)
Dwelling age (Standardised)	–0.009 (–1.04)	–0.008 (–1.38)	–0.008 (–1.37)
Dwelling type (reference: Mid terrace)			
End terrace	–0.019 (–0.62)	–0.008 (–0.38)	–0.008 (–0.40)
Semi-detached	0.006 (0.26)	0.010 (0.61)	0.010 (0.60)
Detached	0.006 (0.20)	–0.003 (–0.15)	–0.003 (–0.14)
Bungalow	0.042 (1.31)	0.019 (0.88)	0.0187 (0.88)
Converted flat	–0.037 (–0.78)	0.000 (0.00)	0.000 (0.01)
Purpose built flat, high rise	0.009 (0.33)	0.015 (0.87)	0.015 (0.87)
Purpose built flat, low rise	–0.062 (–1.30)	–0.025 (–0.77)	–0.024 (–0.75)
Household characteristics			
Household size (Standardised)	–	–0.456*** (–47.46)	–0.458*** (–47.75)
Household composition (reference: One person under 60)			
Couple, no dependent child(ren) under 60	–	–0.352*** (–14.93)	–
Couple, no dependent child(ren) aged 60 or over	–	–0.292*** (–11.11)	–
Couple with dependent child(ren)	–	–0.398*** (–13.76)	–
Lone parent with dependent child(ren)	–	–0.471*** (18.30)	–
Other multi-person households	–	–0.382*** (–14.04)	–
One person aged 60 or over	–	0.016 (0.62)	–
Household type (reference: Couple, no dependent child(ren))			
Couple with dependent child(ren)	–	–	–0.065*** (–3.29)
Lone parent with dependent child(ren)	–	–	–0.142*** (–6.77)
Other multi-person households	–	–	–0.059*** (–2.81)
One male	–	–	0.330*** (16.37)
One female	–	–	0.320*** (16.78)
Household employment status (reference: FT work)			
PT work	–	0.039** (2.09)	0.046** (2.44)
Retired	–	0.109*** (5.17)	0.136*** (9.01)
Unemployed	–	–0.010 (–0.40)	–0.007 (–0.29)

Table 4 (Continued)

Dependent variable: Gas consumption for space heating per capita (log)	Coef. (t-stat) Model 1	Coef. (t-stat) Model 2	Coef. (t-stat) Model 3
FT education	–	–0.045 (–0.74)	–0.044 (–0.71)
Other inactive	–	0.012 (0.61)	0.015 (0.78)
Gross household income (all members) (£) (log) (Standardised)	–	0.052*** (7.19)	0.050*** (7.05)
Constant	8.677*** (472.36)	8.906*** (396.79)	8.574*** (501.66)
R^2	0.007	0.5584	0.5581
Adjusted R^2	0.006	0.5573	0.5571
Observations	9116	9116	9116

Significance at the 5, 1 and the 0.1% levels are marked *, **, and *** respectively

tently insignificant, confirming that the dwelling type is unrelated to the per capita gas consumption for space heating.

With regards to households' socio-economic characteristics, starting with household size, larger households are more 'efficient' in their gas consumption, as per capita gas consumption significantly drops as the number of household members' increases. The standardised coefficients used in Model 3 (as shown in Table 4) illustrate the effect of a one standard deviation change in the household size on per capita gas consumption. The results obtained are supported by: (i) the household composition results, in which the per capita gas consumption of couples and families (or other multi-person households) is lower compared to single-person households (see Fig. 2 below); (ii) the household type results, in which, using as a reference

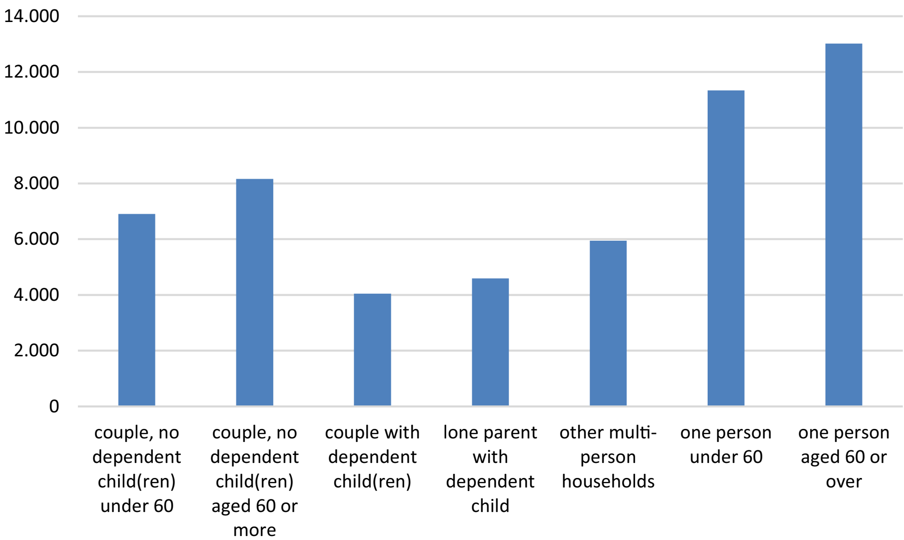

Fig. 3 Mean per capita gas consumption categorised by household composition

value, 'couples without dependent child(ren), all other forms of families or other multi-person households consume less per capita while single family households consume more gas for space heating; and (iii) the household size variable, which is found to be negative and significant, suggesting that the larger the household, the lower the per capita gas consumption (also visible by Fig. 3).

The regression model includes the employment status of the primary HRP in order to identify whether their professional activity influences their per capita consumption. The results suggest that part time workers and retired individuals have higher levels of per capita gas consumption as compared to full time workers (while the other employment status values are insignificant). We argue that this is likely to be the case because, *ceteris paribus*, part time and retired individuals are more likely to spend time at home (i.e., in their dwelling) as compared to full time employees. Finally, annual gross household income is consistently found to be positively associated with per capita gas consumption. This is in line with intuition, which suggests that the wealthiest households consume more per capita gas for heating than poorer households. Although this finding is to be expected, considering that the model controls for dwelling size and type, there is evidence for a behavioural pattern among high-income households who are found to spend more for space heating.

6 Conclusions and policy implications

This study set out to investigate the drivers of energy consumption (focusing on gas consumption) for domestic space heating to establish which households are particularly exposed to risks associated with changes in energy prices and fuel poverty. In contract to the literature that identifies the dwelling characteristics as significant factors of the domestic energy consumption, our results revealed that the socio-economic characteristics of the people living in the houses affect their per capita consumption. To this end, a sample drawn from the English Housing Survey is used to incorporate socio-economic characteristics at the household level into the analysis, along with physical building characteristics of the dwellings in the sample. The regression results revealed that household socio-economic characteristics (such as household size, annual gross household income, primary employment status, and household composition/type) are more important predictors of gas consumption (for space heating) than simple dwelling characteristics (such as dwelling type and age—which appeared consistently insignificant). It also seems that occupants' economic, professional and family status seems to affect their energy consumption behaviour (controlling at the same time for the dwelling and household size).

Notwithstanding our findings, several caveats remain. With respect to the EHS data used in this study, greater information on households' day-to-day activities and occupancy behaviour would be useful. Information on households' awareness of their energy consumption behaviour, as well as on their knowledge of potential energy saving measures would provide further avenues for research. Furthermore, the lack of detailed information on households' income significantly constrains our analysis of occupants' energy consumption behaviour. The dataset also includes mainly 'new' dwellings that are likely to be equipped with modern heating systems, which in turn are likely to be more energy efficiency in their consumption of energy for space heating. Despite these limitations, our results suggest that the provision of adequate energy-efficient housing to low-income households may be an important step in alleviating the risk of fuel poverty and energy price risk.

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