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Factors affecting energy-saving behaviours and energy efficiency investments in British households

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ABSTRACT

The objective of this paper is to identify the socio-demographic, dwelling, and environmental factors that have the strongest influence on the daily energy-saving behaviours, the adoption of energy efficient appliances and the energy efficient retrofit investments made by British households. This study uses British household data from the "Survey of Public Attitudes and Behaviours towards the Environment" collected in 2009, and employs nonlinear principal components analysis (NLPCA), ordinary least squares (OLS) regression, and probit models. The results show different household profiles with specific features driving daily energy-saving behaviours and energy efficiency investments. Environmental variables are a good predictor of both energy-saving behaviours and investment in energy efficient appliances but not of energy efficient retrofit measures. Results of income and dwelling type variables with regard to energy-saving behaviours and energy efficient retrofit investments significantly diverge; in addition, interesting patterns emerge with respect to the respondents' age, sex, and marital status. By evaluating and understanding the household and dwelling characteristics that affect energy-saving behaviours and energy efficiency investments, it is possible to obtain a clearer idea of where and how energy and emissions savings can be made, and to propose effective and targeted policies that promote energy-responsible lifestyles.

1. Introduction

The UK government is committed to reducing carbon emissions by at least 80% (from the 1990 baseline) by 2050 and to improving the energy efficiency of the UK's residential building stock (HM Parliament, 2008). Achieving significant improvements in the energy efficiency of the UK's housing stock has the potential to contribute substantially to the three challenges of the energy trilemma. Such improvements not only would decarbonise the energy system but also would ensure that the energy supply is secure and that energy is affordable (World Energy Council, 2016). Moreover, better levels of energy efficiency can improve occupants' health (and thus reduce the burden on the National Health Service), safety, and comfort, in addition to lowering maintenance costs and making homes a nicer place in which to live (IEA, 2014c; Payne et al., 2015). However, the UK's housing stock is amongst the oldest and least energy efficient in Europe. Meeting the UK's long-term carbon emissions target implies that *"one building would need to be retrofitted every minute for the next 40 years at an estimated cost of £85 billion for homes alone"* (Dixon and Eames, 2013). The recent failure of the UK government's flagship energy efficiency policy such as the withdrawal of funding from the Green Deal Home Improvement Fund (GDHIF) has placed a sharp focus on the issue of energy demand reduction in the residential sector.

Studies on energy use at the household level have observed a large degree of variability in energy consumption across identical houses that cannot be entirely explained by infrastructural differences: the role of occupant behaviour is as important as building physics with regard to energy consumption (Santin et al., 2009; Gram-Hanssen, 2011; Morley and Hazas, 2011). Numerous scholars suggest that large reductions in household[1] energy use are unlikely to be achieved from interventions designed to finance building retrofitting alone. There is evidence suggesting the potential for larger energy savings if technical, infrastructural, and energy saving behavioural intervention changes are applied in combination and mutually reinforce each other via the same goal.

Energy behaviours and energy efficiency investment decisions are complex and shaped by many factors, both individual and contextual. Due to this complexity, they are usually studied using fragmented and disciplinary studies from a wide range of thematic areas such as engineering, economics, psychology, and sociology (Lopes et al., 2012).

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[1] The UK government's statistical service defines a household primarily as a bounded physical construction: "as a person living alone, or a group of people (not necessarily related) living at the same address who have the address as their only or main residence, and either share cooking facilities and share a living room or sitting room or dining area" (ONS, 2011).

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Thus, there is an urgent need to develop an integrated approach to domestic energy reduction that simultaneously addresses technical and infrastructural energy efficiency investments as well as occupant energy habits and daily practices, taking into account the heterogeneity of households and dwellings.

Therefore, by employing the household data "Survey of Public Attitudes and Behaviours towards the Environment" (2009) and three different models – nonlinear principal components analysis (NLPCA), ordinary least squares (OLS) regression, and probit – this study uses an interdisciplinary approach to examine the broad spectrum of socio-demographic, environmental, and dwelling factors that drive energy-saving behaviours and energy efficiency investments of British households.

'Energy-saving behaviours' are defined as the daily and habitual practices of households that focus on specific reductions in energy use. Households decide how warm to keep their home in the winter and how cool to keep it in the summer; they decide whether to leave lights and appliances on or turn them off; they select the temperature of the water to wash their clothes; and they decide which dishwasher cycle to use. Either actively or passively, households make decisions regarding how to use their major energy systems.

With regard to 'energy efficiency investments', two types of measures are considered in this study: energy efficient appliances and energy efficient retrofits. 'Investments in energy efficient appliances' are defined as the purchasing of class-A (or more) energy efficient appliances. Home appliances are usually classified as 'large' or 'major' or 'white', such as refrigerators, freezers, refrigerator-freezers, washing machines, dishwashers, and dryers, and 'other' or 'small' appliances which include a wide range of appliances from electronic equipment such as TVs, computers and audio/video equipment to vacuum cleaners, microwave ovens, toasters, kettles, and irons (IEA, 2014a, 2014b).

The term 'energy efficient retrofit investments' is used here to denote major structural improvements to a house or 'substantive physical changes to a building' (Dixon and Eames, 2013). They typically involve changes or upgrades to the building envelope, such as the installation of solid/cavity/loft insulation or the replacement of single glazing with double glazing, or changes to the heating and hot water systems, such as the installation of ground source heat pumps, condensing boilers, and solar water heating (Gardner and Stern, 2008; Dietz et al., 2009).

By jointly investigating the factors driving energy efficient retrofit investments, the adoption of energy efficient appliances and the habitual energy-saving behaviours of British households, this study captures the underlying determinants of these different types of energy behaviours. Previous empirical studies have not considered the synergies among daily and one-off energy behaviours. In addition, with regard to energy efficiency investments, this study provides a clear theoretical and empirical distinction between energy efficient appliances and energy efficient retrofits.

The results have implications for energy conservation policies. Influencing policy makers to develop strategies that promote more energy-responsible lifestyles in light of significant emission reductions requires a thorough understanding of the drivers that affect households' energy behaviours and energy investment decisions. Therefore, to maximise their impact, energy conservation interventions need to reflect the heterogeneity of households and dwelling characteristics and remain sensitive to context-specific factors.

The remainder of the paper is organised as follows. Section 2 illustrates the main literature findings in the energy behaviour and energy efficiency fields; Section 3 describes the data and methodologies used in the study; Section 4 shows the results of the econometric estimations, in which energy-saving behaviours, energy efficient appliances, and energy efficient retrofits are distinguished and compared; and Section 5 presents the paper's conclusion and provides relevant implications for energy policy.

2. Literature review

Household energy demand is not a direct demand for energy, but rather a derived demand for the production of energy services – such as lighting, water heating, cooking, space heating, and air cooling – that is embedded in a complex system involving technology adoption, behavioural economics, and psycho-social origin elements (Hunt and Ryan, 2015; Pothitou et al., 2016a; Blasch et al., 2017b; Fell, 2017). Understanding the factors that govern household energy consumption and conservation to determine how these behaviours can usefully be altered by policy initiatives, awareness campaigns and technological solutions, has thus been the subject of abundant literature for more than 30 years (e.g., Olsen, 1981; Black et al., 1985; Stern, 1992; Sardianou, 2007; Steg, 2008; Abrahamse and Steg, 2009; Martinsson et al., 2011; Kang et al., 2012; Ameli and Brandt, 2014; Steg et al., 2015).

Households can reduce their energy consumption and related emissions by investing in energy efficiency solutions and/or by adopting energy-saving behaviours. In recent years, several studies have examined the differences between these two concepts. Oikonomou et al. (2009), indicate that whereas energy efficiency refers to the adoption of specific technologies that reduce overall energy consumption without changing the relevant behaviours and achieving the maximum services obtainable, energy saving is merely a change in consumer behaviour that leads to energy savings without investing in new technologies. Barr et al. (2005), assessing studies on the categorisation of energy behaviours at the household level, suggested that two main fundamental groups of energy behaviour exist. The first group consists of 'habitual' and 'daily' actions or 'curtailment' behaviours (Black et al., 1985), which are all focused on everyday and specific reductions in energy use that require either no or minimal structural adjustment. Energy-saving behaviours such as switching off the lights in unoccupied rooms, turning off the heating when leaving the house for few hours, and filling the kettle full before boiling, are evidently related to the everyday habitual element of individuals' lifestyles as they undertake daily activities. These habitual actions vary both in their frequency and in the size of their impact on energy consumption. In addition, even within a single household, different members can behave in counteracting ways, and their behaviours thus can have opposing effects on energy consumption (Palmer and Cooper, 2013). The second type of energy behaviour focuses on 'purchasing activities' and 'energy efficiency choices' (Barr et al., 2005; Black et al., 1985). This group is more disparate than the first in the sense that the amount of financial resources can vary greatly, for example, from installing wall insulation to purchasing energy efficient appliances. Similarly, many other authors (Gardner and Stern, 2002; Jansson et al., 2009; Laitner et al., 2009; Urban and Ščasný, 2012) have distinguished between energy efficiency as one-off/one-shot behaviours that require a monetary investment and daily energy-saving behaviours that involve repetitive efforts to reduce energy use but do not require any monetary investment.

While acknowledging these differences, this article also emphasises a distinction between two types of energy efficiency investments: the purchasing of energy efficient appliances and the energy efficient retrofit measures (see Introduction for definitions). Although both of these types can be considered as one-off/one-shot behaviours and refer to monetary investments aimed at reducing energy consumption, they deserve to be differentiated for several reasons. First, energy efficient retrofit investments have high cost, time, and skill requirements and are typically performed by professional contractors with appropriate technical expertise (Maller and Horne, 2011). Conversely, the adoption of energy efficient appliances is considered a do-it-yourself (DIY) activity; compared to energy efficient retrofit measures, it requires much lower investment costs, thus implying a lower temporal discounting.

Second, energy efficient retrofits are fixed to house infrastructure, whereas the majority of appliances are not. Hence, if a household is planning to move in the near future, energy efficient retrofit