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Heating system upgrades: The role of knowledge, socio-demographics, building attributes and energy infrastructure

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ABSTRACT

In the context of moving to a low-carbon economy there is wide interest among policymakers to improve knowledge of decisions surrounding residential heating systems. This research examines four aspects of decision-making with respect to heating system upgrades: home-owner decisions on whether to upgrade, decisions on fuel choice, fuel switching patterns, and an examination of the reasons why home-owners make these decisions. Among the key findings are that proximity to energy infrastructure, e.g. gas network, is an important determinant of residential heating systems upgrades, including fuel choice. With one exception no clear trend emerges on the likelihood of a broad range of socio-demographic variables, including age, income, and working status on home-owner decisions. A cohort of home-owners defined across a few socio-demographic characteristics, including mortgage holders, are predisposed to investing in a heating system upgrade compared to their peers but for reasons unknown do not invest. We also find that environmental concerns, across a number of dimensions, are not an important determining factor in either the decision to upgrade or the subsequent choice of heating system. Information on heating system alternatives is critical for good decision-making but we find that home-owners do not always rely on independent energy consultants for guidance.

1. Introduction

The increasing relevance of environmental problems and concerns for climate change have motivated countries to align their environmental and energy policies to reduce emissions. Through the Climate and Energy Policy Framework, the European Union (EU) has agreed to reduce greenhouse gas emissions for the year 2030 by 40% compared to 1990 levels. A significant amount of current emissions are produced as a consequence of the energy use in different sectors of the economy, especially at household level (European Commission, 2011). Two thirds of this energy consumption is used for space heating, especially in countries such as Ireland, Great Britain (Meier and Rehdanz, 2010), Germany (Braun, 2010; Michelsen and Madlener, 2012), France (Stolyarova et al., 2015) and Finland (Rouvinen and Matero, 2013).

At present the most used heating sources are coal, oil and gas. These sources produce significant negative environmental impacts by the generation of emissions, specifically carbon dioxide, nitrogen dioxide, and fine particulate matter (Greening et al., 2001; Kerkhof et al., 2009). Therefore, households' choices of domestic heating systems and their usage behaviour become a key element affecting overall environmental quality. Hence, understanding households' decision-making process regarding the adoption and replacement of heating systems as well as the factors that determine the choice of these systems are of relevance for climate mitigation policies. Understanding what drives households to make (or not make) such decisions will help policy-makers better design incentives to encourage movement to low carbon heating systems. This paper examines several elements of decisions around home heating systems. First, we consider whether households contemplate upgrading their heating systems. We specifically focus on home-owners, who have agency in this decision and avoid consideration of split incentives associated with rental tenants. The period of consideration for such decisions is 10 years, during which there has been considerable public discussion on the policy response to climate change and specifically in Ireland, where our dataset is located, a State agency has been encouraging households to upgrade their heating systems and improve the energy efficiency of their homes by means of media campaigns and financial incentives. Within that context all home-owners will have some level of awareness of the private (and public) benefits of upgrading their heating system, as well as a grant scheme to encourage action by home-owners. The second area we consider is the heating

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system choice of home-owners that upgrade their heating systems to investigate whether there are systematic differences across home-owners that have upgraded their heating system associated with the type of heating system upgrade. Third, we examine the reasons behind the decisions either not to upgrade, or if upgrading what influenced their decisions. The latter analysis builds on work by Michelsen and Madlener (2013) and Sopha and Klöckner (2011), for example, whereas the earlier analyses follows in the vein of Braun (2010), Laureti and Secondi (2012),Couture et al. (2012), Michelsen and Madlener (2012)

Investments in energy efficiency measures such as improved heating systems are driven not only by financial and economic reasons, but also by behavioural and psychological factors such as attitudes, motivations, expectations and trust (Aravena et al., 2016; Pelenur and Cruickshank, 2014; Stern, 1992), the choice of indoor temperature levels or ventilation rates (Haas et al., 1998), environmental concerns (Lindenberg and Steg, 2007; Oikonomou et al., 2009) and other non-economic elements such as comfort and convenience (e.g. Jakob, 2006; Zundel and Stieß, 2011). There is also extensive literature examining the barriers to energy efficiency in the residential sector. Among the commonly cited barriers are financial or budget constraints, information, inconvenience or disruption, as well as such investments being considered superfluous (Jaffe and Stavins, 1994; Sorrell et al., 2004; Henryson et al., 2000; Clinch and Healy, 2000; Caird et al., 2008; Mills and Schleich, 2012; Achtnicht and Madlener, 2014). These are real considerations for home-owners but not central to this research. Financial or budget constraints, for example, may underpin the choices or outcomes of our analysis pertaining to whether home-owners contemplate heating system upgrades. However, with the exception of information our survey does not contain data on potential barriers facing home-owners and consequently the analysis is intended to identify whether there are systematic observable differences between home-owners that contemplate retrofitting their heating system and those that do not. In the context of the analysis considering choice of heating system upgrade among home-owners that did upgrade we assume barriers to investment as having already been wholly or partially overcome, as home-owners have made an investment.

As noted above, information/knowledge, or lack thereof, is a well recognised barrier to energy-efficiency investments. Specifically related to investment in heating systems, Michelsen and Madlener (2016) argue that knowledge of energy efficiency is a key driver in the decisions of home-owners to switch from fossil fuel based heating systems to low carbon alternatives. But few papers have examined the behaviour of pro-environmental home-owners, as distinct from home-owners that possess pertinent information with respect to energy efficiency investments. Relevant knowledge is accumulated over time by the provision of information and education, including information that is not necessarily specific to heating system technologies. Pro-environmental home-owners reveal themselves in terms of environmental behaviours such as recycling activities or installation of energy efficiency measures. Ramos et al. (2016) examine whether pro-environmental households are more likely to invest in energy efficiency with two divergent findings. First, environmental concerns are generally less important for high-cost investments with less frequent replacement, where economic considerations predominate. Stated environmental attitudes do not show any effect on energy efficiency investments. Second, home-owners engaging in pro-environmental practices, such as recycling or participating in environmental policy activism, are more likely than others to invest energy efficiency. The authors attribute the divergence to 'compliance bias' and conclude that environmental attitudes are not necessarily translated into real actions. These findings are mirrored elsewhere in the context of space heating energy use, as opposed to capital investment (Lange et al., 2014; Brounen et al., 2013). This paper expands the empirical analysis on this issue considering home-owners' pro-environmental behaviours, as well as, knowledge of energy and environmental matters. We hypothesize that such home-owners may be more likely to invest in upgraded heating systems that others with lower knowledge levels or fewer pro-environmental behaviours

The evidence in relation to the determinants of choice of energy systems and fuel switching patterns in the literature is both wide ranging and mixed. Local availability and proximity of fuels is found to be a significant variable (Braun, 2010; Laureti and Secondi, 2012; Fu et al., 2014; McCoy and Curtis, 2018) with access to natural gas networks playing an important role in fuel choice decisions in the US, France and Ireland (Mansur et al., 2008; Couture et al., 2012; Fu et al., 2014). Socio-demographic characteristics are also important drivers but the findings are often case or country specific. High emission fuels such as oil and coal are often associated with lower income home-owners (e.g. Fu et al., 2014; Laureti and Secondi, 2012; Özcan and Gülay et al., 2013) though other studies find only negligible income effects or none (e.g. Braun, 2010; Lillemo et al., 2013; Couture et al., 2012). The effects of higher education and economic status on fuel choice are generally similar to those associated with income. In the case of occupant age, Özcan and Gülay et al. (2013) find that household heads aged 50 and above are more likely to choose gas, oil and electricity compared to coal and other solid fuels for reasons of ease of use and for health concerns, whereas Decker and Menrad (2015) find that neither age, education nor income are important variables in explaining choice of residential heating systems. Property age is an important influencing factor in some situations (Laureti and Secondi, 2012; Michelsen and Madlener, 2012) whereas property size and type are more relevant in others (Michelsen and Madlener, 2016).

The literature on determinants of heating systems using microdata includes a large number of empirical studies that are focused on the determinants of households' expenditure on space heating in different countries, such as Germany Schuler et al. (2000); Rehdanz (2007), Great Britain (Meier and Rehdanz, 2010), Norway (Vaage, 2000), Austria (Haas et al., 1998; Hecher et al., 2017), the US (Mansur et al., 2008) among others. A methodology used in several of these papers is the discrete-continuous method originally developed by Dubin and McFadden (1984) where the decision about demand for space heating is divided into two stages. In the first stage the household chooses the technology or heating system and in the second stage, given the available technology, the household decides how much energy it consumes. Therefore, there is a clear differentiation between the demand for heating systems and the demand for energy itself caused by the use of the system. An alternative methodology is the conditional demand approach, which focuses on the demand for energy as a function of a given technology, (e.g. Leth-Petersen and Togeby, 2001; Rehdanz, 2007; Meier and Rehdanz, 2010). There is a small but growing literature using choice experiments to study the attributes that explain the choice of different heating systems by households (e.g. Rouvinen and Matero, 2013). A more recent approach focuses on the use of multinomial logit models in which the choice of heating systems is the dependent variable and is explained by a number of covariates such as building and household's characteristics (Braun, 2010; Couture et al., 2012; Laureti and Secondi, 2012; Michelsen and Madlener, 2012). It is within this latter literature that this paper is positioned, adding some new dimensions. We closely follow the approach of Braun (2010) considering first the broader decision process contemplating an investment in a heating system upgrade, and subsequently the more focused decision of heating system choice among home-owners that actually upgrade. We find that home-owners' knowledge or actions on energy or the environment are not significant determinants of decisions either regarding heating system upgrades or choice of heating system/fuel type. Even among home-owners who are actively making decisions about home heating, knowledge, past environmental behaviours, socio-economic and dwelling characteristics have little explanatory power in determining heating system and fuel choice. Proximity to a networked fuel, specifically natural gas, is a key determinant of home-owners home heating choices.

The rest of the paper is organized as follows. In Section 2 we describe the methodology. Section 3 presents into detail the survey design and implementation. Section 4 describes the data used in the