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The Role of Environmental Concern and Comfort Expectations in Energy Retrofit Decisions

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ABSTRACT

This study investigates the roles of environmental concern and comfort expectations in the decision to retrofit a dwelling and the implications of these two aspects for the rebound effect. We ex-ante elicit individual preferences for deep thermal energy-saving measures in residential buildings by means of a Discrete Choice Experiment (DCE) among 3161 owner-occupiers and tenants in Germany. Besides room temperature, we include air quality, level of control over the system, noise reduction, and aesthetics of the dwelling as proxies for indoor comfort. Our model also accounts for monthly payments related to the implementation of the measure – and customized based on tenancy status, building type, and size of the dwelling – as well as technical energy cost savings. Econometric estimation provides significant results for most of the parameter coefficients. Findings show that thermal comfort preferences are heterogeneous: 33% of the respondents attach positive values to an increase in indoor temperature that would result from the deep retrofit, providing evidence in favor of a technical rebound effect. While environmental concern explains heterogeneity in most of the attributes, its interaction with thermal comfort is not significant. Thermal comfort turns out to be, however, the least important attribute in the analysis while air quality is the most important one.

1. Introduction

Over the past two decades, household energy consumption and preferences for energy-efficient measures in the residential sector have been the object of intense research, following both the revealed- and stated-preferences approaches. Within the latter field of studies, one of the first conjoint analyses to look into preferences for energy-saving measures at home was conducted by Poortinga et al. (2003). The authors found that the installation of an energy-efficient heating system is more acceptable than any change in heating or ventilation habits. Jaccard and Dennis (2006) elicited Canadian homeowners' preferences for energy-efficient versus non-efficient home renovations and different heating systems. Capital and annual heating costs, purchase subsidy, and comfort level (proxied by air quality) were used to describe the alternatives of a Discrete Choice Experiment (DCE) on home renovations. Banfi et al. (2008) made Swiss home owners and tenants (treated as independent samples) face the decision to either keep their housing at its status-quo or to live in a retrofitted dwelling. Attributes of their DCE were type of windows and façade improvements, ventilation, and price. Environmental benefits and energy savings were not included due to hurdles in assessing them. A study with similar attributes was performed among Korean households by Kwak et al. (2010). More recently, Achtnicht (2011) investigated German homeowners' preferences for a modern heating system versus thermal insulation. Besides acquisition costs, the author also included the annual technical energy-saving potential, the investment payback period, CO_2 emission reduction, the opinion of an independent energy adviser, public and/or private funds, and the period of time during which the contractor is obligated to fix free of charge any deficiency in the retrofit. CO_2 emission reduction resulted as significant only in the choice of heating system, but it did not matter for insulation. The mismatch in preferences for insulation and heating upgrades between landlords and tenants in New Zealand was the core of the work of Phillips (2012). Attributes included ceiling, floor, and wall insulation, window and heating replacements, cost (or increase in rent) as well as the building energy label. Econometric estimations of the model were conducted separately for the two samples. The author found tenants' Willingness To Pay (WTP) to be higher than their energy savings, thus signaling the possible presence of non-monetized benefits in terms of comfort and health conditions. Following Marsh et al. (2011), Phillips set the dwelling in which

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respondents were living at the time of the DCE as the status quo and she formulated attributes in terms of an additional layer of insulation or replacement of the current heating technology. For the first time, thermal comfort was included in an experiment by Alberini et al. (2013) in their study of Swiss homeowners' home renovations. The authors discovered that thermal comfort improvements and climate change considerations both increase the likelihood of respondents to undertake the retrofit project.

With some exceptions, all of these studies have their focus on (i) homeowners as the main research group, (ii) single-family homes as the type of building, (iii) the trade-off among several retrofit measures, most often either insulation of part of the building envelope or installation of a more energy-efficient heating system, and (iv) financial aspects of the retrofit decision rather than comfort-related ones. Indoor comfort, in particular, nowadays triggers the interest of engineers and social scientists alike, being an umbrella concept hard to unequivocally measure and define (Heesen and Madlener, 2014). ASHRAE (2013) (and the European Standard EN 15251, see Cen, 2007) identifies one of the dimensions of indoor comfort as "thermal comfort". The meaning of thermal comfort itself is far from trivial, as this concept encompasses air temperature and radiant heating, levels of air humidity and purity, as well as the presence of air drafts (Galvin, 2015).[1] Although some studies found that thermal considerations are the most dominant factor in the perception of comfort (see e.g. Huebner et al., 2013), also air quality, visual, acoustic, ergonomic, and psychological considerations affect occupants' comfort perception. Given the multidimensionality of comfort, we argue that the implementation of energy-saving measures is not necessarily driven by the desire to increase thermal comfort.

Cole and Lorch (2008) and Shove (2003) clarified that comfort is also about individual and cultural attitudes. It might result from anything that is perceived as "natural". Comfort, or acceptance of the indoor climate, also seems to depend on external weather and one's belief in the ability to make oneself comfortable; for this reason, higher degrees of system control are thought to lead to higher tolerability of discomfort. According to the adaptive comfort theory (de Dear and Brager, 2001; de Dear et al., 2013), the mere impression of being able to control the indoor temperature already improves the thermal comfort perception, as a field study has recently revealed (Luo et al., 2016). Automated versus manual control was also the object of the analyses by D'Oca et al. (2014), who concluded that passive interaction, i.e. occupants' practice of letting the system adjust the indoor environment by minimizing the manipulation of control devices such as windows and radiator valves, is negatively correlated with the achievement of personal comfort. Moreover, Hauge et al. (2011) believe that, besides perceived personal control and operability of the system, what makes an energy-efficient building more desirable are its architecture and aesthetics. Together with thermal comfort, aesthetics was one of the most important drivers of the implementation of energy retrofit measures, according to results from a survey among German single- and two-family houses (Novikova et al., 2011). Jakob (2006) stresses how the benefits of retrofit come among others from "operating ease, protection against external noise, additional safety". Based on results from a principal component analysis, Michelsen and Madlener (2012) also found "improved ease of use" of the heating system as a proxy for comfort to be a significant decisional factor. Finally, Wilson et al. (2015) summarized that energy savings, increase in thermal comfort, reduction in drafts, as well as air condensation and increase in property values are the main reasons for homeowners to invest in energy-efficient measures.

Insofar as implementing comprehensive building retrofit measures carries the potential to deeply alter (hopefully for the better!) indoor comfort conditions, it is important to include comfort in any analysis. Recent studies point out that the decision to retrofit should go beyond mere cost-benefit considerations and include less quantifiable aspects, e.g. increase in comfort (Knight et al., 2006). Lutzenhiser et al. (2001) found that the wish to improve indoor comfort is the most highly rated motivational factor in home retrofit decisions in California. We believe that studies including comfort aspects in relation to the decision to retrofit have so far only focused on one or two comfort dimensions at a time. To the best of our knowledge, however, no study has explicitly attempted to account for comfort in all its dimensions with the purpose of ex-ante identifying what type of expectations drive the decision to retrofit, which is the aim of this work. In this first-of-its-kind work, we moreover hypothesize that expectations about thermal comfort in the aftermath of the retrofit are – among other factors – responsible for an increase in the demand for energy services. Against the background of rational choice theory, the ex-ante detection of thermal comfort expectations in favor of an increase in indoor temperatures can help to disentangle technical sources of rebound effects from more behavioral ones. It is well known that the implementation of energy-saving measures in residential buildings (e.g. wall insulation) leads to higher indoor temperatures ceteris paribus. Coupled with the installation of a more energy-efficient heating system, the desire to live in a warmer dwelling might be real especially among fuel-poor households (see e.g. Milne and Boardman, 2000). Individuals' habits (Maréchal, 2010) and expectations about thermal comfort in the aftermath of retrofitting affect the final demand for energy services. When occupants come to expect higher room temperatures as a result of the retrofit measures – i.e. expectations about thermal comfort are changed – or when the retrofit is conducted with the purpose of achieving higher room temperatures, we witness an increase in the demand for energy services known as "direct rebound effect" (Sorrell and Dimitropoulos, 2008). More in particular, we label this rebound effect as "technical" or "comfort-taking" because it derives from the acceptance of a physically-induced increase in the indoor temperature of a dwelling (Galvin, 2015); on the contrary, the "behavioral" part of the rebound effect finds its roots in both planned and unplanned changes in occupants' lifestyles, i.e. changes in heating, ventilation, and occupancy habits. To the extent that the achievement of indoor comfort affects a household's final demand for energy, comfort can be used as a proxy for energy services. The most recent works on this topic have gone a long way in explaining the different components of rebound effects from retrofit in buildings and in disentangling its multiple sources. Although there are many studies eliciting preferences for retrofit measures or attempting to measure rebound effects from heating in residential buildings (see e.g. Haas and Biermayr, 2000; Madlener and Hauertmann, 2011; Chitnis et al., 2014; Aydin et al., 2015), we find a gap in the empirical investigation of the relationship between comfort expectations and rebound effects. We choose to conduct a Discrete Choice Experiment (DCE) to explore our research hypotheses with data gathered from an extensive sample of German households. Our reasoning for preferring this methodology is as follows: firstly, we look at the motivations (and thus barriers to adoption) of deep thermal retrofits whose implementation – at least in Germany – is lagging behind policy expectations (Galvin, 2014; Achtnicht and Madlener, 2014; Novikova et al., 2011); secondly, by enabling respondents to trade off attributes of the DCE, preferences are elicited without the need to recall information about past retrofits in order to evaluate the alternatives. Thirdly, our sample also includes tenants, a category whose involvement in the investment decision is often small or non-existent but worth being investigated given the high tenancy rate in Germany (ca. 43% of all households).

[1] For an exhaustive review of all factors affecting thermal comfort, we refer to Rupp et al. (2015).