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SOME LIKE IT HOT: AN EXPERIMENT ON COMFORT EXPECTATIONS AND ENERGY RETROFIT DECISIONS

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Overview

This study investigates the role of comfort expectations in the decision to deeply retrofit a residential dwelling and their implications for the rebound effect. Indoor comfort is an umbrella concept that is hard to define and measure. Huebner et al. [1] found that thermal considerations are the most dominant factors in perceptions of comfort. The implementation of energy-saving measures might, however, also be driven by the need to improve indoor air quality, save on energy bills, or reduce CO_2 emissions (see e.g. [2,3,4]). Individuals' 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" [5]. More in particular, we label this rebound effect as "technical" because it derives from the acceptance of a physical increase in temperature that, cet.par., inevitably occurs whenever an energy-saving measure is implemented [6]. Although there are many studies eliciting preferences for retrofit measures (see e.g. [2,7], and [8]) or attempting to measure rebound effects in residential buildings (e.g. [6]), we find a gap in empirical investigations of the relationship between comfort expectations and rebound effects. Our study aims, therefore, at detecting the presence of direct technical rebound effects (as defined above) resulting from the implementation of comprehensive energy-saving measures in residential buildings. We seek to achieve this through developing a better understanding of the drivers of retrofit decisions. We *ex-ante* explore individual preferences for retrofit measures by means of a Discrete Choice Experiment (DCE) conducted in winter 2015/2016 among 3,161 owner-occupiers and tenants in Germany. Besides room temperature, we included air quality, level of control over the indoor temperature, 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 potential energy cost savings.

Method

In this first-of-its-kind work, we 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. Therefore, we elicited individual preferences for comprehensive refurbishments by means of a DCE. The DCE consisted of presenting to each respondent 6 choice cards described by a set of randomly-varying attribute levels and two holdouts identical for all respondents and between each other. In each choice card respondents were given a scenario describing the hypothetical yet realistic situation in which the subject is living in an old building and considering the option to implement a comprehensive retrofit. For each card respondents had the chance to choose which of two retrofit alternatives best delivered the ideal comfort in their living room on a winter day. If none of the two alternatives matched with their comfort expectations, respondents could instead indicate their preference for not having their dwelling retrofitted. The scenario description and monthly cost options differed by tenancy status, in order to account for the fact that for tenants the investment decision is made by the landlord. The selection of the attributes and levels describing the choice cards stem from a review of studies investigating preferences for retrofit measures, the meaning of comfort, and rebound effects in residential buildings. Semi-structured qualitative interviews were also conducted among occupants of buildings retrofitted to passive house standards. Accounting for monthly payments and potential savings in energy costs related to the implementation of each retrofit measure required computing costs and benefits from the retrofit decision. To this end, we designed a matrix where investment costs were customized based on building type and size of dwelling. The choice data were then analyzed using a Mixed Logit model [9] within the Random Utility Theory (RUT) framework [10]. RUT assumes that respondents are perfectly rational, i.e. they rationally trade-off attribute levels to determine which alternative yields the highest level of utility. This is in line with the Rational Choice Theory, as reviewed in [11]. In this application respondents' utility is described by a linear function of the different proxies for comfort.

Results

Our findings indicate that about 35% of the respondents valued an increase in indoor temperature that would result from the implementation of a deep retrofit. Significant standard deviations of the model coefficients also indicate that attitudes towards comfort are heterogeneous in the sample. When trying to further explain this unobserved heterogeneity, however, the interaction between high room temperature and high potential savings on the energy bill was not significantly different from zero. This result excludes non-linearity in valuing higher thermal comfort. Estimates are robust across different model specifications that, *inter alia*, also include the "none-of-the-previous" constant and allow for correlation across attributes (and therefore also alternatives). When such a constant was introduced, its negative and significant sign captured the presence of heuristic behavior; in fact, respondents seem to associate extra value with the implementation of the comprehensive retrofit measure, value that is not explained by the attribute themselves. We think this could be an artefact of the experiment, as inertia (or status-quo bias) is usually observed in real-life situations. Moreover, we find some evidence of socio-demographics (i.e. gender, age, income, and environmental concern) shaping retrofit preferences. Finally we looked into the estimated relative attribute importance: on average air quality is the most important attribute, followed by technical energy savings (expressed in %) and monthly costs of the refurbishment. Aesthetics, level of control, and noise also seem to matter less that the other attributes. Interestingly, indoor room temperature results to be the least important attribute in the decision to retrofit based on comfort expectations. Unfortunately our model does not provide an explanation for such a finding. We hypothesize that this outcome has to do with Germany being a "fuel-rich" country in which thermal-comfort considerations become secondary in the decision to retrofit.

Conclusions

To the extent that respondents show *ex-ante* expectations for higher room temperatures, we conclude that the choice data gives evidence of a technical rebound effect. The study thus contributes to the debate on rebound effects by pointing out that comfort matters not just because it explains the decision to retrofit, but also since it determines how effective a retrofit measure will be in reducing CO_2 emissions. In a scenario in which the demand for energy services, i.e. room temperature, is expected to rise merely as a consequence of a change in the physics of the building, the potential energy savings brought by the new technology might still be fully realized. This might lead policymakers to draw positive conclusions. To conclude, we believe that policymakers should take into consideration the technical component of the rebound effect when benchmarking policies targeted at improvements in energy-efficiency of buildings. Indeed, this aspect of the rebound effect is less counter–intuitive and as such more predictable than other behavioral components of the rebound effect.

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