**THE DETERMINANTS OF *Fuel poverty and its impact on health wellbeing: a case study of social housing tenants in the southwest of England***

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## Overview

Fuel poverty is a growing problem in European countries. It affects around 44.5 million people in the EU in 2016 (Thomson & Bouzarovski, 2018) and 2.53 million UK households were unable to keep warm in 2017 (Department of Energy and Climate Change, 2019). It was first defined as the inability to afford adequate warmth in their homes (Lewis, 1982). It involves both affordability and accessibility in developing countries, whereas it mainly involves issues of affordability in developed economies. Although a common European definition is still lacking, fuel poverty is often be considered as the inability to keep the home adequately warm due to the unaffordability of energy and poor energy efficiency of the house (Antanasiu et al., 2014). In the UK, fuel poverty has always been dominated by concerns about the affordability of heating specifically (Hills, 2012). Studies on EU countries have mostly focused on citizen’s ability to properly warming their homes (Liddell and Morris, 2010; Bouzarovski and Tirado Herrero, 2017).

Fuel poverty is commonly measured applying an expenditures-based approach. A household is considered to be fuel poor if it needs to spend more than10% of its income on fuel to heat its home to an acceptable level, as proposed by Boardman (1991). A disadvantage of this approach is that the self-report expenditure often refers to actual expenses of households for purchasing electricity and fuel, rather than the necessary cost ensuring adequate thermal comfort conditions inside dwellings. As a result, adequate energy expenditures are often underestimated and many fuel poor household is not recorded (Legendre and Ricci, 2015). An alternative approach is to measure fuel poverty according to the household indoor temperature during the winter. The UK’s adequate standard of warmth is defined as 21ºC for the main living area and 18 ºC for other occupied rooms (DBEIS, 2019). But so far, studies use self-reported temperature which is not accurate. To report an accurate overnight temperature of the bedroom, one must have a thermostat in the bedroom and living room. The procession rate of a thermostat (in the bedroom) low in the UK. So far, there is no study has accurately measured the fuel poverty and therefore the estimation of determinants of fuel poverty may be biased. Furthermore, recent studies have estimated the effect of fuel poverty on health wellbeing using self-reported fuel poverty which may not be accurate (Howden-Chapman et al., 2007; Liddell and Morris, 2010; Gilbertson et al., 2012; Hernandez et al., 2016).

Our study estimates the determinants of fuel poverty and its effect on the health wellbeing of social housing tenants in the south-west of the UK. This paper estimates the socio-demographic and behavioral determinants of fuel poverty among social housing tenants. We further estimate the impact of fuel poverty on the mental and physical health wellbeing of tenants of social housing. Our study contributes to the literature on smart home device adoption in several ways:

1. We estimate the determinants of fuel poverty among tenants of social housing because tenants of social housing are more vulnerable to fuel poverty since social housing generally support older and lower-income households. So far, there are only a few studies that focus on social housing tenants. (Anderson et al., 2012; Sharpe et al., 2015).
2. Unlike previous studies that rely on a survey, we have installed smart sensors in 283 social tenants and we measure the revealed (observed) fuel poverty according to the observed overnight indoor temperature. To compare with previous studies, we have also collected participants’ self-reported fuel poverty. We are able to provide more detailed and consistent results on the determinants of fuel poverty.
3. We have estimated the effect of fuel poverty on the health well-being of tenants of social housing. Although the UK’s standard is 18 ºC for occupied rooms (DBEIS, 2019), other studies argue that the 18 °C standard is less important for healthy adults (e.g. Wookey et al., 2014). By estimating the effect of fuel poverty on health wellbeing, our study aims to find out the more adequate standard of warmth between the actual standard fixed at 18 ºC and a flexible standard with a lower temperature for healthy adults.

## Methods

We use sensor data to measure the revealed fuel poverty according to the mean of the overnight bedroom temperature of the main bedroom. If the temperature is higher than 18 ºC, the coldness equals zero and if the temperature is lower than 18 °C, the coldness equals the difference between the observed temperature and 18 °C. To measure the self-reported fuel poverty, we use a three-item fuel poverty scale in our survey which is adapted from Sharpe et al. (2015). Participant’s health wellbeing is measured using SF-12™ version 2 functional health and well-being survey (SF-12v2) which is a validated and reliable survey item for measuring health status (Ware et al., 1996) that has been commonly used in health economics.

A face-to-face survey was carried out to collect information on socio-demographic characteristics, indoor/outdoor activities, and answers to the survey items for measuring fuel poverty and health status. The housing data is provided by the housing association who manage social housing. We use structural equation modeling to estimate the determinants of fuel poverty and its effect on health wellbeing. In addition, we run an OLS regression to find the determinant of indoor temperature.

## Results

## Among tenants of social housing, older respondents are less likely to report fuel poverty or having a cold bedroom. If a participant’s household size is larger, the bedroom temperature is higher and the participant is less likely to report fuel poverty. Respondents living in flats are less likely to be fuel poor. The bedroom temperature and the probability of being fuel poor are not affected by the energy efficiency rating of the house which confirms a previous study who argue that tenants of social housing are more vulnerable to fuel poverty even many of them live in an energy-efficient house (Bramley et al., 2017). We also found that fuel poor household is the ones who spend more time at home during the weekend.

## The determinants of self-reported fuel poor are different compare to revealed fuel poverty. Although the indoor coldness is not affected by being retired and having chronic diseases, the retired participants are less likely to report being fuel poor and participants with chronic diseases are more likely to report fuel poor. The main bedroom temperature is lower in a larger house, but living in a larger house has no significant effect on self-reported fuel poverty. The houses that have mold are warmer, but the participants who live in a house with mold have the same probability of reporting fuel poor.

## In the short run, both self-reported and revealed fuel poverty has a negative effect on mental health, but fuel poverty doesn’t have a significant effect on physical health.

## We compare the UK’s fixed standard at 18 ºC and a flexible standard in which the standard for a healthy adult is 17 ºC. We found that living in a bedroom under the fixed standard has no significant effect on mental health. But the mental health wellbeing reduces if the bedroom temperature is lower than the flexible standard. It implies for a healthy adult, their adequate warmth standard can be 1 ºC lower than the UK’s actual standard which supports the suggestion of Wookey et al. (2014).

## Conclusions

## This paper estimates the determinants of fuel poverty among social housing tenants and the impact of fuel poverty on their health wellbeing. The results show that being fuel poor depends on socio-demographic characteristics(age, household size), housing characteristics (size, type of property), and we found that the fuel poor participant also spends more time at home during the weekend. Providing low-income households energy-efficient house doesn’t reduce their chance of living in fuel poverty. We also find that revealed fuel poverty and self-report fuel poverty have different determinants. For policymakers, these results can be used to identify fuel poor households among social housing and making their policy accordingly. Our results show that fuel poverty has a negative effect on mental wellbeing and no impact on physical wellbeing in the short term. We should collect more data to do dynamic analysis to estimate the health impact of fuel poverty in the long run. We have also provided evidence that the 18 ºC standard is less important for healthy adults who live in social housing which may help improve the fuel poverty policy.